Oral History of Frank Talke

Interviewed by:
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Yamashita: This oral history records Professor Talke's contribution in the following areas. In the field of tribology and head disk interface mechanics while at IBM, the establishment of a very successful center of magnetic recording research, now it's called..

Talke: Center for Memory.

Yamashita: ...Center for Memory Research--Memory and Recording Research. A joint university research center at the University of California San Diego, UCSD, and his research on HDD-related topics, especially in the area of Tribology, head dynamics simulations and various important measurement techniques related to head disk interface at UCSD. Now, he's also credited with advancing the technology in tape drives and also conducting some pioneering work on inkjet printing, I understand, while at IBM. Professor Talke educated many, many students that went on to make contributions in HDD industry and many other fields. So my name is Tom Yamashita. I will be conducting the interview and I have had the privilege of working with Professor Talke over many years while I was at Komag Inc. So with that, I'd like to start with the first question. Tell us about your family background, where you were born, grew up and received your early education.

Talke: Thank you, Tom. Yes. I was born in Germany in a city called Dresden. Dresden is in the area that was formerly East Germany. It is south of Berlin. It's a very beautiful city that was bombed at the end of the Second World War. And I was born there and went to school in Dresden. I went to high school in Dresden and after finishing high school I went to become an apprentice in mechanical-- in mechanics, in fact,as a mechanic and a tool and die maker. And then after about two and a half years, I started to study at the University of Dresden and left Dresden on August 6, 1961 through Berlin. That was one week before the wall was built.

Yamashita: So this is a period in Germany right after the war, when things were-- must have been terrible.

Talke: Yes, yes. I do remember a few things. I was very small. I was born in 1939 and I do remember some of the difficulties that my parents had to get food on the table, and I remember when the Russian soldiers came in May and I do remember when Dresden was bombed. That's, in fact, my first memory of my childhood. My parents took me out to the second floor, and looking north, one could see the whole city burning kind of like Hiroshima.

Yamashita: I see. So, during this time, so you-- this is East Germany, but you were able to go into the West Germany?

Talke: Well, that's what I said. At that time, until the 13th of August of 1961, people could go to Berlin and go from East Berlin to West Berlin and then fly out to Hannover. On the 13th of August, they [the communists] built that wall, [and] closed that escape route. So I'm lucky that I left one week before the wall was built on the 6th of August. Exactly the Sunday before the wall was built.

Yamashita: Did you go with the rest of your family?

Talke: No. My family stayed there and it was actually really lucky. I also had plans originally to go a week later or two weeks later because I always wanted to go to the Alps and do some mountaineering there. My dad had told me that it would be better to go earlier in August because the weather could get bad. So it was very fortunate that I was leaving one week before the end of the possibilities when the wall was built, that one could not leave anymore.

Yamashita: You weren't able to meet your parents and so on after that?

Talke: No. I never went back to East Germany until 1990, until the wall fell and I did see my parents maybe twice. One could-- in that time, one could go to, say, Czechoslovakia from West Germany. They could go to Czechoslovakia and there you could meet.

Yamashita: Oh, I see. I see.

Talke: So, I met them maybe twice. And once, actually two times, my parents came to California when we lived in Los Gatos and in Morgan Hill and the first time, when they could come was when they both were in retirement. And so they could fly from or they could take a train, go to Stuttgart, and I had an uncle in Stuttgart. He was the brother of my father and he helped them to get a passport, a German passport and then I paid the flight and they flew back or they flew to San Jose.

Yamashita: So for your college work, you were an apprentice, but what made you decide to go into education?

Talke: It's a kind of-- somewhat long story, but I-- my dad was a mechanic. He had a small business in making equipment, testing equipment for the concrete industry. And I had an uncle, like I said, in Stuttgart, who was a professor and I had always [an] interest in studying and maybe even becoming associated with the University later on in life. But when you were in East Germany, not everybody could go to the university unless you were on the side of the communists, and so I was not allowed, initially, to go to the university. And so I said, "I'll become a mechanic and tool and die maker." And after that, they let me [attend] the university.

Yamashita: So there, basically you were by yourself and you had your uncle, I suppose?

Talke: Well, my uncle didn't help me financially but he helped me with advice and when I was in Stuttgart, I very soon got a fellowship since I had good grades and did really well [in school]. And so as a student you also don't need all that much money. When I think how little money one had in today's dollars, you know, in today's market, that currency at that time, I think our demands were much less than the demands of today's people, young people.

Yamashita: So what did you major in?

Talke: I majored in mechanical and aerospace engineering.

Yamashita: I see.

Talke: And in Stuttgart, the university had also been bombed in the war and it had just expanded and moved to a suburb from Stuttgart in 1961 and then in 1962 or 1963, the first classes were held in an area that is called “Pfaffenwald”, and so I was a student there from 1961 to 1965.

Yamashita: I see. And then you decided to pursue a graduate degree, so how did that come about?

Talke: Essentially, what you get in Germany is a five-year degree. It's kind of like a master's degree here in the United States, and since I had learned Russian, or had to learn Russian in school and didn't know much English, I wanted to go to the United States to study for a year and learn English. And I had this fellowship from the German Studienstiftung, which is kind of like a national science scholarship. And so I had the opportunity to come to the US and I chose to go to UC-Berkeley.

Yamashita: Initially it was to learn English.

Talke: What?

Yamashita: Initially the objective was to learn English?

Talke: Yes. Well, and study. You know, study. And after one year I got in Berkeley the masters. A master’s degree and I had, actually a position in Stuttgart at a professor's department to do my PhD thesis there. And in Berkeley, one of the professors, or several of the professors said to me after that year, 1966, "Frank, why don't you do your PhD here in Berkeley?" And I had this girlfriend in Berkeley who is [now] my wife and it was not that hard a decision to say, "Yeah, I'll stay in Berkeley."

Yamashita: So you met your girlfriend, your wife-to-be, at Berkeley?

Talke: She was a student in Berkeley and she studied English and German and so it was a fairly great match and we later, after I finished, we got married and lived in [Los Gatos]..

Yamashita: So she taught you some English, too, I imagine.

Talke: What?

Yamashita: She taught you English.

Talke: Well, I keep telling her she taught me quite well how to write English, but she never taught me how to speak without an accent. And then she keeps saying, "Well, Frank, if you are an engineer and have a German accent, then that's okay." <laughter>

Yamashita: It helps. I see. And who-- so when you started your PhD program, this was in the mechanical engineering department also?

Talke: Yes, it was in the ME Department.

Yamashita: And who did you work for?

Talke: I worked for Professor Berger. He was a professor, a young Assistant Professor in fluid mechanics, really dynamic and very well-trained, very mathematically-oriented and he taught fluid mechanics. So I really liked what he was doing and teaching, and from Germany I had a more applied background. And so I studied in Berkeley and the ME Department in fluid mechanics.

Yamashita: So what sort of thesis work did you do at Berkeley?

Talke: Okay, so as thesis work, I had a problem, like the flow along a flat plate, viscous flow along a flat plate, and you can see that a boundary layer develops along the flat plate. And where the flat plate ends, there's all of a sudden no boundary layer anymore on the flat plate. And so there is an area, a very small area where the flow is not boundary layer flow, but [where] it has the same velocities in the X and the Y direction and that is called the Navier-Stokes [region] at the trailing edge of a flat plate. So that's what I worked on and did, actually, a mainly numerical and mathematical solution to that problem.

Yamashita: So it was highly theoretical work?

Talke: That was quite applied mechanics, you would say, or kind of theoretical. It turned out that the solution was to come up with a numerical solution of a set of coupled, ordinary, non-linear differential equations and I had to do that numerically going always to the computer center.

Yamashita: I see. So back then, it was probably punch-cards and..

Talke: Yes, yes. You had to use punch-cards, Tom, and the computer in Berkeley was on a four-hour turnaround, meaning you submit a deck and..

Yamashita: You've got to wait.

Talke: Wait four hours. And so in the last year, when I was working there, you essentially came every four hours. Every four hours at the computer center, and turned in a new deck and corrected whatever mistakes there were and put it back in. And I remember at one time, close to the end, I knew I had run out of computer time. We got hours on that computer. I think it was a Univac 6700 or something like that. At that time, I put all my programs that I had, put [them] in [the computer] and watched them even more than normally, and they [the computer operators] didn't have the cutoff right there and then. It took them 24 or 48 hours to figure out when you were out of computer time. And so I got all my work done before they found out I had no more computer time.

Yamashita: I see. I see. Interesting. It was much harder back then to do this type of work, obviously.

Talke: Yes, yes.

Yamashita: So you must have met many interesting people at your graduate work, made good friends and so on.

Talke: Yes, I made really a lot of friends in Berkeley and that's why I also liked to be a student in Berkeley. I lived in the I House. That's the International House and so besides Professor Berger, some of the professors there were Professor Corcos, Professor Sherman, and Professor Holt. And one of the students with whom I was in the same year was Ray Tseng. You know Ray.

Yamashita: Mm-hmm.

Talke: And then Ulf Bossel, Harvey Segur, Herm Greenberg. And Harvey Segur went on to become a professor in mathematics, and he is at the University of Colorado in Boulder. Next week, he has a symposium in honor of his 75^{th} birthday in Seattle and I will be going there and give a talk at his symposium. And so it's interesting, the students from that time, even [though] I was only three years in Berkeley, they really, at that time, made a very strong impression in my life and I have quite a few friends from that time. Another friend I have is a person by the name of Paul Wishinski who lives in-- on the East coast, I think in Vermont. And he comes even now visiting me once every other year and we talk to each other and have gone rock climbing together.

Yamashita: Rock climbing?

Talke: And hiking, yes.

Yamashita: You still do rock climbing?

Talke: Not anymore now, but when I was younger, you know.

Yamashita: I see.

Talke: So we used to hike in the Sierra on the John Muir Trail.

Yamashita: Wonderful.

Talke: ...and in Yosemite. And with him I hiked there, and then maybe 20 years ago, he was visiting Nepal, because he had been in the Peace Corps in Nepal and so he had asked me, "Why don't you come with me to Nepal and we go hiking around the Annapurna, and so I met him in Nepal and we hiked almost halfway around the Annapurna."

Yamashita: Wow, so 50 years ago you still have these friendships from..

Talke: Yes

Yamashita: ...Cal. So you say you were there for three years. You finished everything in three years?

Talke: In three years. I mean, I started in September of ‘65 and got my degree or turned in my thesis in November of ‘68.

Yamashita: So this is including your masters and PhD?

Talke: Yes.

Yamashita: In three years?

Talke: And sometimes, Tom, I say I should have stayed longer and enjoyed life as a student, maybe.

Yamashita: I see. And then you went directly to work at IBM.

Talke: Yes. I started IBM in February 1969, and so in the time [after] I turned in my thesis in November, 68, i.e., in December 68 and January, 69, I interviewed in a number of places and I got an offer from, I think it was Purdue University, to teach and I got an offer as a post-doc and I got an offer in General Electric and an offer in Shell Oil Company and another oil company. And I think I got an offer in the Xerox Company and then I had gotten initially also an invitation at IBM in San Jose, and that was in research in San Jose, and so I went there. [Earlier] I had talked about the computer in Berkeley for my thesis, and it turned out that the computer system often failed at that time and it failed because people said the “flying heads were broken” and I didn't know what a flying head was, you know?

Yamashita: I see.

Talke: But then when I visited IBM and they showed me big disks and said there is a head that flies half a micron above the disk or a micron, I realized that was [the part that] caused the failure in the disk drives in the university. And so I thought, well, that was an interesting problem that I didn't quite know and understood, but in [IBM] research at that time, they had a task force where the general product division had made the demand or the request that [IBM] research would go into the area of supporting the work in magnetic recording in San Jose. And so that was the reason for them [for] creating my opening and then several other openings. And so we started a group that was called “Device Mechanics Group” in the Research Division in San Jose. And that was at a time when the research building, which was later Building 28, (that was the triangular building, may be you know that), wasn’t even built. So I started in Building 25, which was kind of a-- how would you call [it, just] a temporary type of building, and that was in February, 1969, and IBM was a really interesting company at that time. You know, they were expanding. They were hiring many different people and for the first or second-- for the first two months, I was essentially left alone in Building 25. I had a manager who said, "Well, we want to get into the area of magnetic recording," and they had this interface and just tried to study what is around. And in IBM, five or six years earlier, maybe even ten years earlier, there was that famous person, Bill Gross, and he had worked on the first head disk interfaces for the Ramac [IBM's first commercial disk drive product] and he had later on also written a book on gas dynamics, air bearings. Or it was called maybe—[gas bearings], I forget now what the exact name was, but he had left and had gone to Ampex. And so the people who had worked on magnetic recording and research had all gone away, and so that was the reason for hiring me as an engineer. And when I came down to IBM and said, "Well, I have studied fluid mechanics and I'm an engineer, I got my first degree in Germany" they made me an offer. I didn't really know if they were serious, you know, because I said, well, at the very beginning I didn't really know what a disk is and what the recording process is. So I went a second time [to visit IBM], and then I thought, "Well, I don't know much about it [the disk technology], but it seems very interesting."

Yamashita: So they had a mind to hire a specialist in fluid mechanics. That was their interest?

Talke: Yes, I think so. I think they knew that the heads were flying and that it had something to do with viscous flow and that it needed to be looked upon first from that point of view. And so that's, I think, when I got this offer and then I started to work [at IBM] in February 1969.

Yamashita: Could you comment on some of the people that you work with at the time? You know, your manager, people like that?

Talke: Yeah, I think [I can]. Initially, my manager's name was Durbeck. And we talked to the people in the product division. Ken Haughton was one of the people running the-- the product division. After two or three years, we got [deeply] into—[the head disk] interface and the understanding of what happens during start/stop in contact. That was the time when the Winchester technology was being developed. That was the [so-called] start/stop in contact [technology] and I got involved in that and in understanding how one could minimize wear during start/stop and we looked at all these effects during start/stop. So, we worked with the General Product Division. Ray AbuZayyad had a group in-- SDD, I think that is how it was called. And that group was similarly involved in looking at start/stop, flying height and wear between the slider and the disk and so we worked quite cooperatively together.

Yamashita: So it's a very active field back then?

Talke: Oh yes, it was tremendous, because the demand for disks was just outstripping all the supply. I do not know exactly the numbers, but IBM made a lot of money on these disk drives, and they were at that time, I think in 1969, pretty much the only big company that made disk drives. They had, more or less, a monopoly.

Yamashita: I see. And did you just continue work on your theoretical work or did you start getting into <overlapping conversation>.

Talke: Oh, in IBM, I mean, the first thing was to look at what happens between the slider and the disk during start/stop. And we know that there is wear. And one of the things we looked at initially was, you know, measuring the friction and wear on these oxide-coated disks that one had in 1969, 1970 and until the mid-80s. There was γ-Fe_2O_3 and abrasive particles in that coating. So there was abrasive wear between the slider and the disk. And one of the investigations I remember, I did, was what is called autoradiography. We irradiated the ferrite slider, made it radioactive, and then when the disk and the slider were in contact during start/stop, the small, worn-off particles would be deposited in the track. And then you put a photographic film on top of this track and expose it to the radioactive radiation. And that is a way where you could see very small, minor wear particles and you could see where they get distributed. And so you could see that as a function of the number of start/stop cycles, there was more or less transfer of material from the slider to the disk. And one of the things that we got very soon involved was how could we prevent the wear of the head disk interface during start/stop, and that led, automatically, to the studying of lubricants. And when you look or talk to anybody now in the area of lubricants, it has become a highly-specialized and complicated field. At that time, no one really knew anything about lubricants. So what we did in my group, we looked for oil suppliers and looked at silicon oils and we looked at organic oils, hydrocarbon oils, and there was one oil available which was used a few years earlier for the space [program], [when] satellites were put in space, They [the sattelites] needed sometimes (lubricating) oil, and these were perfluorinated polyethers. And they are lubricants that, instead of a C in the backbone, have F, fluorine. And they actually lubricated quite well. And the reason for that was two-fold. They had a very low vapor pressure, and, in addition, they did not deteriorate. And because of the low vapor pressure, they stayed on the disk. Initially, we found many lubricants that would work and would reduce the friction and wear of the head disk interface and you had many thousand start/stop cycles. After a while, after maybe one week, all of a sudden, overnight, it [the head disk interface] would fail. And that was when you have a hydrocarbon or an oil that has a high vapor pressure, all of a sudden, nothing is left on the disk. And so that was one of the most important things in my first and second year at IBM that I worked on and got involved with. And actually, I got one of those outstanding contribution awards from IBM for my work in-- they called it friction, wear, and lubrication. At that time, the name of tribology was very new to the field of engineering. It had been created in 1966 by Peter Jost in England and that was 1969 or 1970. We started to call this field tribology but no one on this 8,000 or 10,000 or 12,000 people plant site knew anything about what is called ‘tribology’. And so that was one of the really important areas that became very big for the start/stop technology of the Winchester drives. And then we also did one more thing, and you are very familiar with that. You have a lubricant but you want to still improve on this lubricant and put additives in the lubricant. And so we looked at various antifriction phosphate lubricant additives and really discovered that one can improve the reliability of the head disk interface substantially by selecting the right lubricant and selecting the right additive.

Yamashita: So you worked with a team on this, obviously?

Talke: Say again?

Yamashita: You worked with a team?

Talke: Oh, yes. Yes.

Yamashita: To develop these things?

Talke: And so the team that I worked with initially consisted of Ray Tseng. I hired Ray Tseng from Berkeley. After about a year and a half, they made me a manager and had some openings. So I hired Ray. I knew him, as I said, from Berkeley and then I hired Herm Greenberg He was also from Berkeley. He was in the ME Department, but in the area of solid mechanics and computer modeling. And then there were a couple of technicians that we had. One technician was George Nelson, who was an outstanding technician. We also had the machine shop in research and there was a German model maker. His name is Horst Mossbrugger.

Yamashita: What? Horst?

Talke: Horst Mossbrugger. B-R-U-G-G-E-R. And first Moss, M-O-S-S, B-R-U-G-G-E-R. And he was just outstanding. You know, when I had something to be built, I did not make a drawing, a careful drawing of it. I just went to his place in the machine shop. We talked, we made some little sketches, and if I had made a good drawing, like with SolidWorks today, he would have probably been really unhappy, because he wanted to implement the ideas that we had, and he did that. And one of the first things that I built was a test stand for 14-inch disks. And that test stand, we figured, needed to have an air-bearing spindle, so that we would not get the non-repeatable radial runout. And so I designed an air-bearing spindle and Horst built it and it looked just like a museum's piece. It was all wonderfully configured and the surface was beautiful and he used-- wherever he had to use brass, say, for a slide, it would be polished. It was just amazing and wonderful what he could do.

Yamashita: Of course, you know, you have a background in tooling, those kind of fields, too.

Talke: Yes, and that actually, you know, initially when I went to become a mechanic, because I was not allowed to go to the university in East Germany, I thought that may not help me ever. And I never had to use a machine, a shaping machine or milling machine, in IBM. But because I knew what one can do and how it's being done, the machinists, they took me seriously and we were a really good-- a good team. And so we built this, and at that time you needed always a big lab because all these big granite stands with 14-inch disks and all the other equipment, so that was an exciting and really interesting time.

Yamashita: So you won the contributor award, you know, your first year, so you were off to a really good start.

Talke: Yes, I think I was off to a good start, and it may have been the second year. And then, let's say, in addition to working also on hard disks, I had also work going on with some other people on linear tapes, and in my first couple of months, as I said, in IBM, no one really told me what to do, which is unheard of in today's world, you know? And so one of the problems that I had heard about was [related to] tape drive. Tape drives had vacuum columns in the tape drive where the tape got buffered. They experienced tape edge wear on the tapes, and there was the question “how does tape edge wear occur? How is it-- how can one reduce it? How can one improve on it? And that is something I worked, also, on. And one of my first papers in IBM is on tape edge wear work. And the reason for that is not that it was my first work, but IBM would not let us, for confidentiality reasons, publish anything about start/stop in contact or [about] the wear of the head disk interface.

Yamashita: Oh, I see. So you were making great contributions, but you couldn't publish at all?

Talke: Yes, yes. I could not publish, and what I did, often, is I wrote IBM research reports.

Yamashita: I see.

Talke: And I wrote them in a way that they could later on, two or three years later, be submitted to a journal, and so I always knew that if you ever want to go into academia, you need to have record, proof of what you have done, because when you invent or discover [for instance] PFPE lubricants and additives and how to improve on this start/stop [performance], you cannot tell a university that's what you did. They don't understand it, and it's not published. And so that was one of the things that I, in general, did. I wrote up these topics and investigations for internal confidential research reports. And then two or three years later, I asked my management often, "Can we publish this now?" And then sometimes they said, "No! It needs to be waiting. We need to wait five years." And some of the papers, I actually published four or five years afterwards. And they were not outdated, because at that time, no one was allowed, or no one worked in that area and published. And then I worked on a couple of other projects, if you don't mind.

Yamashita: Sure.

Talke: We worked on a 12-inch floppy disk. And that was a project that had originated in Poughkeepsie with Jim Weidenhammer, and Jim Weidenhammer was a really solid good mechanical engineer and IBM Fellow. And at that time--

Yamashita: He was IBM Fellow already ?

Talke: He was an IBM Fellow, yes. He was older than me. He was probably at the time when I was 35, he may have been 60 or 65, and so here, the idea was then when a new computer system was shipped, was built and shipped, they needed to have all the programs [operating system] to get them started to run. And at that time, we didn't have an internet, we didn't have any items or any ways to send those files to start the system, to load the system. And he came up-- or he worked on this 12-inch floppy disk, which had maybe a couple of megabyte at the most of storage, to be used as a disk with all the information when the new system was shipped. And along that time, he had started a project where he put a hundred floppy disks on one spindle. And they were all separated by a spacer. And [air] was flowing out [between the disks], and [if one wanted to write one had] to open the disk pack So that was a technology that he had more or less invented, and I visited him once, and we cooperated, and I said, "Well, we could maybe have a knife, an air knife from the outside that would split the pack open so that you could insert the read/write head. And actually we did that, and we called that the stack of floppy disks. I don't exactly know whether it was '73 or '74, maybe even '75, and that was in a way tremendous, because you would say, rather than having one disk, like the hard disks, [where]you had to have a spacing on the order of half-an-inch, you had a hundred disks per inch. And so the idea was that you would say you [have] much higher volume density than the hard disk drive assembly.

Yamashita: Was this ever built?

Talke: There was one shortcoming with that idea, and that is, on a floppy disk you can store as high a linear density maybe as on a hard disk, but you cannot store as high a track density than in a hard disk. And here's the deal when you have an areal density on tape, that is one-hundredth of that on a hard disk, the advantage of having a hundred disks in the space of two hard disks turns out to not be an effective improvement in the storage density. And so that was a project that had, I believe, become a product program in Boulder, Colorado. IBM had a big tape lab in Boulder Colorado, and then all of a sudden, from one day to the next, this product program and all work with this floppy stack of disks got canceled and no one followed it up.

Yamashita: Oh, I see.

Talke: And then I also worked on (in that time in IBM), I worked on helical scan tape drives, and we had a two-inch, or two-and-a-half inch wide tape that is wound around a rotor and on that rotor you have a head that reads and writes. And since the tape is [positioned at] an angle, it reads and writes on an angle when you stretch it out. The tape rides on the certain angle it tracks. And that head tape interface was also configured that it would be a flying head tape interface. That there would be some spacing, no contact, and based on this and based on what I had seen and started and learned earlier, I really concluded that magnetic recording in heads and tapes will only work when you have an air bearing. And there were always, even at that time, and many times later, people who would say, "We want to have contact recording." And even though it would be nice to have contact recording where the head and the disk [are in contact], i.e., where the magnetic material has no spacing, as an engineer, I told myself, and convinced myself, "It will never work." You have always wear. And even if the head disk interface is loaded very, very lightly, you know, with 20 milli-Newton, maybe with micro-Newtons, you still will, after a number of millions of revolutions, have wear, and such a contact recording interface will not work.

Yamashita: So this-- but yet IBM developed this contact start/stop as a-- so how did you feel about that?

Talke: Well, see, we-- I don't exactly remember the numbers whether we said, "It needs 50,000 start/stops or 100 thousand start/stops," but that is limited, Tom. There, you know, are maybe two three revolutions in contact, and then the slider starts flying. And that's why we needed the lubricant to reduce the wear, and the wear coefficient. But it was limited, because these hard 14-inch disks would not be started and stopped ten times a day. You know, you had maybe once a week a service, or once a month. And even if you were to say [the drive] is [started and stopped] every day or that [the drive] would be shut down at night, it would only be 300/400 [cycles] a year. And if you wanted to design [the disk drive] for five years, it would be 1,500 start/stops. And so given a factor of 10 or 20 [more that] was something one could try to design. And that indeed was designed and it was made successful for many years.

Yamashita: I see.

Talke: And then maybe one more thing about IBM's involvement, or my involvement in IBM was in 1976, I had gone to a conference in mechanics, fluid mechanics, and I heard some person give a talk about fluid jets, where you have a high-pressure reservoir somewhere, and you drive a jet of fluid out of a nozzle. And they have a piezo electric driver that causes perturbations on that jet and the jet breaks up into drops. And then I studied, after I came back, I studied the literature, and there were some patents. One was by a person from Sweden called Stemme (Erik Stemme, Chalmers University)], on creating drop on demand inkjets. And so I had a summer student, his name was Jorge Escobar. He later worked for 30 years at IBM. He was in the local San Jose State University as student. And I had him as a summer student. And so we took that patent and read it carefully and said, "Let's try to build one of those drop on demand drivers." And there I learned how difficult it is to do something that is described in a patent. Because it said there, "You have this [circular] PCT transducer, and by conventional means you fix it on [a surface], and you actuate it, and the drop comes out." And it took us three months to get the first drop to come out, and after a while, it was actually interesting and you could get a drop out at a certain frequency. Drop on demand means [that] when you don't want a drop, you don't drive the piezo electric driver, and you don't get to drop out. And in IBM they worked at that time on continuous inkjet printing. They had a big product program where they had 200 heads that would go across the paper [with a] one inch high head, and they would print a one-inch swab on paper. And this continuous inkjet technology means that all the drops that you do not want to use for printing on the paper, they have to be electrostatically deflected in a sump. And recirculated, because ink is expensive. And it turned out that due to the paper and the general contamination and the recycling of the ink, there was always clogging of nozzles. And you could almost be sure that if you leave one of those inkjet devices on Friday in the lab, on Monday, algae had grown and nothing would work anymore. And drop on demand is then an alternative, because you don't need to recirculate the ink. And that became a really successful project in

IBM, or in research. We built a color inkjet printer which had piezo electric tubes as piezo electric drivers. Maybe, I don't remember how many we had. Maybe on the order of ten for each color, we used black, cyan, magenta and yellow. And you could then move that print head across the paper, incrementally. Move it again and make color prints. And since for color print, you need these four colors, black, cyan, magenta and yellow, the data rate with which these drops came out was too high for whatever computers were available at that time. And that was maybe in '81 or '82 or '83. The first PCs had just been invented and came on the market. One needed to have graphic accelerators to get all these bit maps printed. And we actually exhibited this drop on demand color inkjet printer in Japan, and IBM also exhibited it in Monaco, South of France.

Yamashita: Monaco, why?

Talke: Because IBM had so much money and they wanted to show they built the new technology.

Yamashita: I see.

Talke: And Siemens in Germany had also been developing a color printer, or a drop on demand black-and-white inkjet printer, I think it was called the P- or PT-80, and so IBM wanted to show off this color printer, and I don't remember when it was. It was maybe '83/'84 in Monaco. And so, I spent two weeks there in these big hotels, and some of the people who had worked in my group with me were also there. And Neil Armstrong came by--

Yamashita: Wow.

Talke: -- looking at IBM's newest things. I think IBM had invited him, and it was a memorable event to have someone like Neil, who was the first to walk on the moon, come by and look at what we had been doing. Today it would impress me even more than at that time. You know, it seemed like at that time, "Well, it was naturally that we would get something new to work, and that was this color inkjet."

Yamashita: So this is in common use today, so you have done some really pioneering new work on this.

<overlapping conversation>

Talke: Yeah, and it really is true that what I mentioned earlier with a student, it took three months to get the first drop out. You would never, at that time, have believed-- or let me say it differently. It took a big leap of faith to say, "We can make an array of nozzles, we can use it for black and white printing. We can use it for color printing." And it took some real imagination. But that one can use it for 3D printing as today, you know, that you don't only print fluids that are viscous, you print heated-up [liquid] plastics, you print with metals, you print with various types [of materials]. One would never, never have thought [this possible] at that time.

Yamashita: Were you able to get some patents at the time?

Talke: Yeah, I have a couple of patents on the inkjet printing, and on this, I think, stack of floppy disks, and the flexible disks. And today, one uses still two technologies for inkjet printing. One is with piezo electric drivers, and I think Canon works on that. And then there is another type which is called the thermal inkjet, and there you have a cavity where the liquid is and the nozzle where the liquid can go out. And in the back-end of the cavity, you have a tiny little resistance heater. And that heater can be energized, so it heats up a very tiny little area, and the fluid evaporates and the evaporation of the fluid increases the volume and it drives the drop-out. And so that is the thermal inkjet and that is maybe more than half the technology behind it, and then the piezo electric inkjet. But since that was on the order of 1980, all these patents have run out and would not be of use anymore. But I got another of those outstanding contributions awards for that. In fact, I had three altogether, yeah.

Yamashita: That was at IBM?

Talke: Yeah.

Yamashita: So this-- I remember back in, I think it was in '70s, IBM used to have this commercial, TV commercial showing the inkjet printing. I believe that was a continuous model.

Talke: That's what I said, IBM was initially on this--

Yamashita: Was really pioneering this kind of work.

Talke: Yes. And so [we were] at that time in Building 28, and there was, it was called OPD, I think, Office Product Division. And they worked on this continuous inkjet and having read and heard about this drop on demand inkjet got me to think that would be the way to do it. And I actually did not tell my management that I would do that. You know, I had this summer student, and after the end of the summer when it was starting to look good, or that I could get some drops out, then I showed it to the management and then they got excited.

Yamashita: I see. I want to go back to discussion about perfluoro lubricants. You probably had gotten some early basic patents for using these compounds on disk drives, no?

Talke: Yeah, when we discovered these PFPE lubricants, we filed a patent disclosure within IBM, and IBM had this very stringent review. And then the review came back that something like that would not ever be a patent, but they wanted to treat it as trade secret.

Yamashita: Trade secret.

Talke: So on the day when I got that review back that it would not be a patent, I think a patent on similar lubricants had just become available from Ball Brothers.

Yamashita: Ball Brothers (Research Corporation). Oh, okay.

Talke: So they had similar lubricants discovered, and as an upshot of all of that, IBM treated this totally [as] trade secret. And I know that they purchased some of these PFPEs in drums on the East Coast, and they shipped these drums-- I'm not sure whether I can say all these things, but it's a long time ago.

Yamashita: It is a long time ago, yes.

Talke: They were afraid that somebody would see where those drums would go. And so they shipped them to Colorado to IBM Boulder, and from there to San Jose.

Yamashita: To hide the fact.

Talke: Yes, exactly! You know, and you can see, in a way that was quite a substantial progress. It was also quite important to hide it, because if it became published or known then anybody could copy it, and so anyway, that was the approach that IBM did. And--

Yamashita: It just shows how important this was to IBM to have gone through these kinds of procedures.

Talke: I think so, and on this lubricant work, I would have to check it, but I don't think I ever was allowed to publish anything. And you know, then when it became quite apparent that there was also a lot of chemistry involved, then research hired chemists who would work also on these lubricants and we also did often meet, or a few times we met with lubricant companies, all companies. Shell Oil, for instance, and we often-- I remember meeting, and discussions that went the following way. You know, these people came and we said, "That's about what we want to have, this type of lubricant, maybe this type of additive." "No problem! This type of additive, no problem. We can do that." "Can you do that?" "No problem." "How many hundred thousands of pounds can we plan on?" And you said, "Well, it's about a hundred pounds a year." "No, we cannot do that." That's really what happened, because you really can calculate, even if it's one nanometer on a 14-inch disk, and there were not that many hundred million disks made. It just comes out to a very small amount of lubricant. And so the oil companies were not interested. And IBM then put some serious effort into this, and all the knowledge that exists now, one would never have expected that this is needed to make this head disk interface working well. In fact, I remember in the early '70s, when I went back to Berkeley sometimes and talked to people, and they said, "What are you doing?" I say, "I work on hard disks." "What's a hard disk?" And later on in the '80s or so, or early '90s, even my little young six-year-old, he had the little hard disk to play with, or a floppy disk, at least. And so it has changed so much in those 45 years.

Yamashita: Well, some of the lubricant they played an incredibly important part in the hard disk drive success.

Talke: Yes, yes, yes.

Yamashita: I remember when I got involved, there were companies in Italy. Montedison was it?

Talke: Yes, that is right! I don't remember anymore who it was, but that is--

Yamashita: Were you involved with them at all?

Talke: I don't think while I was at IBM, but I do remember there was one company in Italy, and I don't-- as I say, I don't remember that.

Yamashita: Montedison or some name like that.

Talke: Yes, yes. And I think some of the work that we did when I was in UCSD were you-- Komag supported us. We also did some lubricant work and some wear and friction of the then being developing thin film disk technology.

Yamashita: Were you involved in creating instrumentation or sensors to measure contact start/stop? I remember IBM possessed a lot of interesting technology back then, just to measure friction, friction coefficients and those kinds of things.

Talke: Yes, yes, that was along the main thrust of our work in those first years to see how we could measure the coefficient of friction, how we could measure the vertical force, the friction and the force, what the coefficient of friction was, how we could measure stiction. Because stiction was one of the important points. The high friction peak during startup. And later on, there were some companies that developed friction testers and it became then, I think, more efficient, almost to use those rather than build them. But as I said, in the first few years, I think, in the big plant in IBM, San Jose we had the first and only tester that was dealing with friction and wear and when I talked to people [who knew that I] worked for IBM, they asked me to say a little bit more [about my work], I said, "Yes, we work on-- friction between the slider and the disk." They wondered how that would fit into a computer.

Yamashita: Right. But the IBM was obviously a leader in taking these kinds of measurements. It's only company that I was aware that had instrumentations like that for quite a while.

Talke: Yes, yes, yes, yes.

Yamashita: So you had a lot to do with developing some early instrumentation to do those type of work.

Talke: Yes, yes, yes. You know, and then also when the chemists got involved, they used infrared IR-spectroscopy to measure the thickness of the lubricant, that was another important parameter. And then measuring how lubricant would spread on the disk surface, or how it would evaporate, and those were really challenging questions. And in today's world, we all know that this is important and we have lots of papers in the literature, but you have to say at that time, there was nothing in the literature, and everything that we did or worked on and built was new, and was difficult. In measuring flying height, say at 500 nanometers or then at 300 and 200 nanometers, that seems today as something no one would want to do. But it was difficult and we used white light interferometry to look at the fringes and color fringes and there is a first blue fringe, and a second blue fringe, and a third blue fringe, and then the green and red and yellow fringes. And so you could, by eyeballing, and by starting the disk spin-up, you could first see what the flying height was of the head disk interface. We used glass disks for that. You know, ferrite sliders and glass disks. And that was interesting and challenging. And in that situation one would use optics and instrumentation and mechanics [also on] tapes. We also did tape flying height measurements, and there were materials problems, and very soon one realized that these problems in the head tape and head disk interface area were very interdisciplinary, that they were challenging because of the fact that it was not just fluid mechanics or solid mechanics, or electrical engineering. It was bringing all these things together, physical science and chemical science, or chemistry, physics, engineering, electrical engineering. And in IBM, people were always quite helpful when we had questions with chemistry or physics or magnetic recording. And so that was the real good thing in IBM that there were all these experts in these various disciplines.

Yamashita: I see. During the late-- it's not on the list-- but during the late '70s, maybe, or early '80s, you know, IBM had tremendous difficulty with the 3360 [drive], was it?

Talke: 3380.

Yamashita: 3380 drives, just kind of brought production to a standstill, and were you involved in the projects to solve that, as well?

Talke: I mean, almost anybody--

Yamashita: Everybody was involved.

Talke: -- in IBM was involved in that. And what really happened is that the disk shipment date was delayed for the 3380, and that is a drive where there were nine disks with two heads on each disk surface, and it had an "enormous storage capacity" of [one or two] gigabytes. In CMRR, we have an old 3380 in the hallway, and when you look at that, these 14-inch disks, nine next to each other, the disks is-- each disk was probably five millimeter thick that looks really like mechanical engineering, you know, a big shaft and [disks] just spinning. And then there were the air supplies to pump air. And so there were problems that IBM could not ship this device. And almost everyone in IBM San Jose, including anyone in research who had ever seen a disk drive, would look and work on task forces and on issues related to contamination, and so IBM really did not leave any stone, I would say, unturned to make sure that they would find out what the reason [for the failure] was. And eventually, they shipped it and it worked. But no one could claim he or she was the one who found the problem.

Yamashita: Solved the problem.

Talke: It was not one problem. It was many. But again I think for sure it was the head disk interface problem, it was a tribology problem, and one can really say that (and my magnetics friends would probably even agree) that no disk drive [program] has ever failed for magnetic reasons. They have always failed for tribological reasons.

Yamashita: I imagine that that event made the issue of tribology in the forefront--

Talke: Stuck out. Yeah, yes and no.

Yamashita: I mean, is that--

Talke: Essentially what happens in 1975, '76, '77 [is that] the interest in research on magnetics and magnetic recording had waned somewhat, because the Product Division made all those devices, you know. And no one really ever is interested in people who are doing failure analysis for potentially *future* problems. And so what I've kind of always said is you have to study today what the problems could be in three or four years, put it in your desk, and when these problems really occur, then you pull them out and say, "That's how we can solve the problem." But you know, it is true that IBM realized more and more that the interface (materials, mechanics, electronics interface) and tribology was really one of the key problems in the field.

Yamashita: Right. So I think this covers my questions while you were at IBM. One interesting question I thought I might ask is you've met some very-- people that-- who were very interesting, and went on to do all kinds of different work afterwards. Do you have some people that comes to mind that you met that, thinking back over it now that would be interesting to talk about?

Talke: Yeah, let me say the following. I worked for a number of years off and on with Al Hoagland. And Al Hoagland was really interested in the magnetic signal, and working with him, I learned a lot about the magnetics aspects of the head disk interface, and we had at one time the goal to achieve ten to the eight bits per square inch on flexible media. That was called the benchmark problem. And then I also met on the stiction problem crisis, I met Denis Mee, in SDD in the Product Division. And Carl Shelton, who was in IBM Research, was in the office, next to me, and he went later on to form this hard disk drive company, Quantum. And I knew Ray Abu-Zayyad quite well.

Yamashita: He became a director at San Jose, eventually.

Talke: Yeah. And we talked to each other quite a lot when he was still a first-line manager and I was a first-line manager. And I remember a few of our discussions, you know, what will be the ultimate flying height, and I was maybe very cautious and I said one could reduce the flying height a lot but you need to improve the surface roughness and understand the head disk interface. And he pushed that idea in the product division and he became the general director of the product division. And I know when shortly before I left IBM in 1986, he called me to his office, and so I visited him and I know it as if it had been yesterday. He said, "So, what do you plan to do when you go to the university?" and I said, "Well, I will work on the head disk interface and try to put additional science behind that." And he said, "Well, I'll give you $50,000. You can start your project."

Yamashita: Oh, that's great.

Talke: Yeah. No one would do that today anymore.

Yamashita: A good endorsement.

Talke: Yeah, and $50,000 was..

Yamashita: Back then was a..

Talke: ... a lot more, and so there were no strings attached. You know, he said, "You get this shipped or transferred to San Diego," and that's what he did. I also met Rich Balanson, if you know.

Yamashita: I remember him, mostly.

Talke: ...of him. He was in San Jose at some time, a higher-up manager, and then he came on a sabbatical to San Diego. And so we have a couple of papers together. He was in the chemical-- on the chemical side and he had, with my students and me, worked on some of the carbon overcoat wear and understanding the crystalline and amorphous areas. And then I worked also with Jim Lemke. And Jim lives, still, in San Diego. He is a real inventive person. He has always invented new things and maybe we will talk later on about that he also came up with a liquid lubricant technology for hard disk drives, but he and Denis, and Art Anderson [Arthur G. Anderson, former IBM VP], who had been also the director of all the product storage divisions, they talked to me and told me-- well, they didn't tell me, but they said, "You know it would be really nice if you were to go to San Diego where we built this new center." And so Jim Lemke talked to me and at one time in 1985 it looked like I was going to say no, because you know I lived in Morgan Hill. We had a nice place. We had built a house. My wife was a teacher in Morgan Hill. Everybody was happy, and so Jim called me, and I don't remember how he called me or got my home phone number, because we didn't have cell phones. And he said, "Frank, how are you doing?" I said, "Fine." And he says, "I'm coming this afternoon in my plane to Morgan Hill. You remember, there's this little airport." And he said, "Can we meet maybe.."

Yamashita: This is Jim Lemke you're talking about, right?

Talke: Yes, Jim Lemke. "...maybe at two or three o'clock," and so I met him and I said, "Let's fly somewhere," and I don't remember. I think we flew over to the coast and back and my wife was with us, and then we went for dinner and all of a sudden he said, "Frank, it would be good for you if you come to San Diego."

Yamashita: I see.

Talke: And so I “blame” or “credit” Jim, actually, for quite a bit that we ended up in San Diego. Also, Denis Mee was very supportive. And the reason why I was interested, actually, in going, say, to a university, was two or three fold. I'd been a student in Berkeley. I told you that. And in my second or third year in IBM, when I had just become manager, I had this summer position for faculty. And so I talked to my former professor, Professor Berger [Stanley A. Berger, Professor Mechanical Engineering UC Berkeley], whether he knew of someone who would be interested in looking in that area or whether he would have time. And he told me he didn't have time. He was involved with something, but there was a new assistant professor in Berkeley, and that was Professor Bogy. And he said, "Why don't you talk to him?" And so I talked to Professor Bogy and he spent the summer with my group in San Jose, and I had then been lucky to hire him for almost ten years afterwards, always, as a consultant to our work in San Jose. And when we had started this inkjet work, we measured the motion of the inkjet PCT with a laser Doppler interferometer. And I had said at that time, "Why don't we use that laser interferometer to measure the dynamics of the head in our disk drive." For some reason, I was involved with the inkjet at that time. No one picked it up or it didn't work, and I had gone for a year to Berkeley on a sabbatical.

Yamashita: So this was 1984.

Talke: Four, yes. And so I had been teaching in Berkeley and I had helped Professor Bogy to build up his laboratory and we got him some equipment from IBM and I worked with him and his students. And so I enjoyed my time in Berkeley and when this Center for Magnetic Recording, now Memory and Recording Research, was founded.

Yamashita: This was in UCSD?

Talke: In UCSD.

Yamashita: Who founded that, by the way?

Talke: That was founded by Art Anderson.

Yamashita: Oh, I see.

Talke: And Jim Lemke. They were the prime movers behind it initially.

Yamashita: Those two people started it?

Talke: Yes. And so, making a long story short, since I had enjoyed my year at Berkeley and there were so many interesting problems, when they asked me to apply at UCSD, I said, "All right, I'll apply." And I go down and you apply for becoming a faculty. You have to give a talk and you have to talk to the people in the department. And I gave a talk that was probably at the end of 1984, beginning of 1985, and I talked about mechanics and materials problems, and design problems in magnetic recording and inkjet technology. And for the faculty at that time, that was really fairly new. And so they were excited and they said, "Yeah, we think even though he comes from industry, we'll make him an offer." And I had a bunch of papers, you know, maybe 30, 40 papers by that time, which was just enough to become-- to be eligible, say, for a professorship at a university. And so that's when Jim Lemke and also Art Anderson and then Denis Mee had talked to me, and then they told me that they would have four chairs in San Diego. One was in magnetic recording. That was Neal Bertram. One was in signal processing. That was Jack Wolf, One was supposed to be in physics of magnetic materials. At that time, they didn't know who would be hired. That was later on, Ami Berkowitz and they wanted this chair in tribology and mechanics. And so I actually visited Neal Bertram, who worked at the Bay area at Ampex.

Yamashita: He wasn’t at the UCSD yet?

Talke: He was later, then. That was when these positions were going to be filled, and he had accepted the position. So I talked with him and I went down and talked with Jack Wolf and I realized that UCSD was an up-and-coming place. They were really having an outstanding chancellor who wanted to have this center in UCSD, and in any case, it was challenging and I thought I would like to try it. On the other hand, when you look at the university, Tom, it is really difficult to create the infrastructure that one had at IBM. You know, at IBM, we had all the chemists, the physicists and the machine shop and the electronics shop. And all the technician support. At the university, you really don't have that. You know, you have to use your smarts, so to speak, to overcome some of those shortcomings. But making things short, I felt I wanted to try it and I decided if I go there and don't like it, I can always come back to the Bay area and would find a job here. Even so, at that time, leaving IBM was the end of the road in IBM. They would never hire you back.

Yamashita: Oh, they had a policy like that?

Talke: Oh yes, there was this policy. And in fact, it may sound funny in today's world, but when I had decided to leave IBM, there were some people who wouldn't talk to me anymore. You know, it was such a great paternalistic company that leaving was not what one would expect. And I mean, people, when you told them at that time you worked at IBM, that was a real big thing, because they knew it's not easy to get into IBM, but if you are in IBM and you have a good job, so a realtor who shows you a house at that time, he would easily spend all his time, if you said you worked at IBM.

Yamashita: Those were the days.

Talke: Yes, yes.

Yamashita: For sure. So you had interest in academia throughout, I take it?

Talke: Yes. In fact, I should say when I worked in IBM, I was teaching one course a year, sometimes two courses at Santa Clara University. And I was teaching there air bearing theory and lubrication theory, and that was in the “Early morning program”. And that, I do not really remember, that was probably in the late 70s, early 80s, and they had this program where students could get their master's degree who worked in industry, and so you had to be there at seven-- from seven o'clock to nine o'clock and even so it was, at that time, perhaps unusual that someone would come to work at 9:30, I worked it out with my manager that I could go that one time a week and teach at Santa Clara University. And so I enjoyed always interaction with younger students. At that time, I was fairly young myself. And that was, in a way, exciting, and I had interest in teaching.

Yamashita: Were they all students or were there some competitors from other companies?

Talke: Well, that is interesting. Some of them were student and some of them were, later on, so to speak, competitors. But since I did not say anything about an IBM product that was acceptable.

Yamashita: But those were not your typical, you know, class, taught in a university, certainly.

Talke: That is true, you know, because..

Yamashita: They are very specialized topics.

Talke: Yes. It's a specialized, really specialized topic, because the flow between the slider and the disk is governed by what is called the Reynolds equation, and that is a partial differential equation, non-linear, and has to be solved numerically. And you have some limiting cases, and I talked about that, but things that were known in the literature. And also, about what causes friction and wear, and I interacted with a professor from MIT, professor Rabinowicz [Ernest Rabinowicz, MIT Professor in Tribology].

Yamashita: Rabinowicz, yes.

Talke: Yes, and so we became really good colleagues and friends, and he was from MIT. And then when I became professor in San Diego, the industry had so much need to learn about tribology. We organized for ten years in the 90s classes at UC-San Diego, or outside of UC-San Diego, but in San Diego between Ernie Rabinowicz and Professor Bogy and me, and had a three-day class, say, on introduction to tribology of magnetic recording. And we had many people also at that time from Komag, and from ReadRite and from Quantum and from all the companies that were in the field at that time.

Yamashita: That's a great resource, I remember.

Talke: Pardon me?

Yamashita: It was a great resource..

Talke: Yes, yes.

Yamashita: ...to provide such classes. So did you have to convince your wife to move to San Diego or was she-- she came along without much convincing? That must have been hard.

Talke: She was supportive, really, of that. And when I had-- at one time, I had told the dean "I'm not going to come," and then I was having second thoughts and she said, "Well, Frank, if you really want to do that, don't worry about it. We'll make it. We'll go down to San Diego." So she was very supportive. And one of the things that made it a little bit easier, we had this farm in Morgan Hill. You know Morgan Hill, right?

Yamashita: Yes, of course.

Talke: And there's El Toro, and we had 80 acres on the north side of El Toro and had built a house. And we actually kept that land and I said, "If I come back, we can always go back there."

Yamashita: Oh, that's great. It's worth quite a bit, I'm sure, now.

Talke: Yes.

Yamashita: So that's 30 years ago now?

Talke: Yes. I left in 1986, and so it's 31 years ago.

Yamashita: So already a long career in academia.

Talke: Yes, because I was 17 years in IBM, and from ‘69 to ‘86, and now it is my 32nd year at UCSD. And I always said-- you can strike it from the records if you want, but I always said, when I worked in IBM, "I'll probably retire when I'm 55 and go to help professor Bogy in Berkeley or go to a university and help some other professors." And then when you are at a university, you don't have this retirement limit, you know? And one can say as long as a professor is active and contributes, the students like it and the university likes it, and so in fact they do something that is totally unheard of in industry. They call us a senior professor, which is with some recognition that while when you are in industry and are 60 or 70, the idea is to always try to get younger people and get rid of the old people, you know?

Yamashita: So what were some of the challenges, you know, when you started your academic career? You say you had lack of instrumentation..

Talke: Yeah.

Yamashita: ...probably the computing power that you had was totally inadequate compared to what you had at IBM.

Talke: Yes, all of the above is true. You know, at the university, I came to CMRR. I think you may have been in CMRR.

Yamashita: A few times, yes.

Talke: Yes. I had two labs that were as large as, say, two times, maybe, this lab. And when I got there, there was nothing in the lab. No floor, the walls were just painted. That was all. And so there was not a single piece of equipment in the lab. I had a little bit of experience from having been in Berkeley how a university works, and I knew something about the university from my former advisor, Professor Berger, and also from David Bogy. In fact, I can say most of the things that I knew or know about the university comes from him and from that time. But so I was there and I remember from the first day I was in my office and I had-- actually didn't have a telephone connected, and I thought after the-- at the end of the day, "Wow, that is quite lonely." And then I got the phone connected the next day and pretty soon I used the phone to talk to people and order this and that and then I got some students and got some additional students and some visitors and pretty soon I was as busy or busier than at IBM. And so it was exciting, you know, to figure out what to build and I had bought, initially, a 5,000 pound granite slab to put an air-bearing spindle in to measure non-repeatable flutter of the disk. And then I built or built together with the students that I got, we built some start/stop testers and we looked at-- is it-- yes, we looked at various wear testers in flow shrouds for the disks to see how the air flow influences the flutter of the disks, and so after a half a year or after a year, I had several students and had also a post-doc, and then the work was going well and I worked, also, with the people from IBM at that time. And they supported some of our research and they had this whole big warehouse where they had old equipment and I went often there and looked and found good equipment and materials and slides and designs and testers that could be rejuvenated or improved and that all helped. And so after maybe two or three years, we had a fairly good laboratory looking at interferometry, having helical scan tape drives, having hard disk drives, having microscopes and pretty soon we got one of the first optical instruments, the-- what later on became Wyko, the Topo 3-D, and I think in 1989 I got one of the first scanning tunneling microscopes.

Yamashita: Were these working with the vendors..

Talke: Yes.

Yamashita: ... to develop the tools for them?

Talke: Yes. But what really happened, often, is that these vendors would have come maybe or sent one or two of their guys to these workshops that we had, to teach tribology, and then they saw what we were working on. For instance, with Jim Wyant, who is the WY in Wyko. He said, when I asked him about the instrument, he said, "Yeah, we can donate one of our instruments to you because you have so many people from industry, coming and seeing what you have there." And so we actually wrote some-- one of the students wrote some software to look for crown-- yeah, for curvature of the slider in two directions for the crown. He developed some biquadratic surface fits and Wyko liked it and they gave us the Topo 3-D and we had similar equipment from, later on, digital instruments and got through these cooperative efforts a lot of our instruments. The problem is, with these expensive instruments, that's worse for the university that you have to keep them up. You have to keep them calibrated and you need to improve them, and all those instruments, in today's world, they cost 150 to 250,000 dollars, and so that is a lot of money. And that makes the university research, at that time, more difficult. Now, at UCSD, we have a nano-lab, Nano-3, and there's all this analytical equipment available and you can use it for a fee and you get all these optical instruments and all the contact instruments and all the equipment there. And that makes it easier now to use these complicated instruments.

Yamashita: How did you get your initial funding for the work and supporting grad students? How did that work?

Talke: That's interesting, too. Initially, when I debated about coming to San Diego, they said, "Well, each of the endowed professors will get $150,000 a year endowment-- no, funding, plus some endowment. And it turned out, at that time, Tom, if I wrote a proposal, it always looks good when you get matching funds. And so I talked to four or five companies and said, "I want to propose this and that to, maybe, INSIC [Information Storage Industry Consortium]" or to various agencies, and I said, "I need some matching funds." It was easy to get $200,000 matching funds.

Yamashita: I see.

Talke: And so at that time, money was not really that much of an..

Yamashita: That much of an issue, okay.

Talke: ...issue, because the industry was developing, you know? It was growing and they needed people.

Yamashita: They needed the help.

Talke: ...and they needed the help. They needed also people with good education in that area, and so they..

Yamashita: They needed your graduate students.

Talke: Yeah, that's exactly true. And so, they often didn't even [require anything] at that time [like Ray AbuZayyad] , they said, "Okay, we'll support your research." And I said, "Why don't you send it to me as an unrestricted gift? Then I can save overhead and it works better for the research and for me." And I got a lot of these unrestricted grants and people knew that what we promised we would do and, I mean, you remember that probably, too. And so that's what we did. And [research] money in the late 80s was not a problem.

Yamashita: I see. And how about the grad students? Or did you hire undergraduates as well?

Talke: Yes. So initially I hired some undergraduate students and a few graduate students, and that was not totally easy to get students who knew me because I had not been teaching. You know, and like last quarter I was teaching a graduate class. It was called Computer-Aided Analysis and Design and there were 35 or 40 students, and I had many coming to me and saying, "I would like to work in your research group, and can I do that?" But initially, 30 years ago, you know, I had to establish myself, and so it was not totally easy to do that, but with enough energy and getting the lab built and then starting to teach, some students knew about it and they wanted to work, and then I had some really good students initially who-- one of them is Chris Lacey, who is the founder of MicroPhysics, if you remember that instrumentation company, but he worked at one of the tape companies and wrote to me that he wanted to do a PhD. And then I had a couple of other students who came, actually, not from UCSD. They had known about the Center of Magnetic Recording Research and they contacted me, and so, after, I'd say, a year or two it was-- I had a group of six, seven grad students and some visitors. And at that time, as I said, money was not that difficult, and I supported the grad students, actually, after the first year, and, generally, as research assistants. And today, it's much more difficult. You know, you don't have that much money, and so the students often in their second and third year work still as teaching assistants. But that is not that bad, because teaching and learning how to teach or help the professor is also good for their education. And so let me say when I think, sometimes, back, I say, "How could I have done all of that?" Because I had a growing family, three kids. We built a house in Rancho Santa Fe and I was the general contractor and I had these students, and I worked with the students in building this lab. And there was lots and lots of work, but it worked out well.

Yamashita: I see. So it was a good decision?

Talke: Yeah.

Yamashita: To go to USCD.

Talke: So I have to say, for sure afterwards, even after a few years, I said it was a really great decision because, as you know, in industry, you are somewhat limited to choosing your own projects. There's always the management that tells you what to do, that I was lucky in IBM to choose the inkjet printing, for instance. And some of the other projects was because they had seen that the group was doing good work. But yes, it was a really good decision and I'm happy that I did it. And I worked with all the people in the industry.

Yamashita: Right. That's one thing that is different, when you have to go do lots of selling and..

Talke: Yes.

Yamashita: ...visiting companies..

Talke: Yes.

Yamashita: ...raising money, whatever.

Talke: Yes. And of course, we could then, also, do this teaching and with Neal Bertram and Jack Wolf, we went to many companies and had a three-day course where Jack talked about signal processing..

Yamashita: Oh, right.

Talke: ...the second day, Neal talked about the magnetic recording aspects, and I talked about the tribology. And so that way we actually met even more people than I could meet at IBM, because IBM..

Yamashita: Was so contained, right.

Talke: ...made this cocoon around us. We'd not be able to talk to people from Komag or to people from HP or any of the other companies, and not being at the university, we could [not] do that. And so CMRR became, in terms of having information, really a center. People came for our conferences in tribology and signal processing and in magnetic recording and could first-- the first time talk to other people from other companies, and that was really, really great. And because Jack was a real leader in the field of signal processing and Neal was a leader in the magnetic field and I worked in this tribology area, that was really a drawing point, and so we had a lot of these people come and the industry supported us. They said, "Indeed, that is what we need." That was also the main thing for having the center started, because Art Anderson and also Jim Lemke, they said "This technology is very important for America." And they extrapolated from how the companies from making photographs, you know, the photographic industry and other electronic industry, how it had moved from the US to Japan. They said "We cannot let this happen and that's why we founded the center." And when people in industry then saw that there was more than the individuals at the center, they supported the center, and so at that time, if I had known how much more difficult it is to get money, I would have enjoyed the time maybe even more, because as I said, there was plenty of money. And then in the 90s, after the fall of the wall, there was money from-- I'm not sure whether it was NSF or DARPA money, and so it was really very easily possible to make a little request and get equipment for the lab.

Yamashita: I see. What do you think some of the key work that you think you've done during your time at the CMRR, with respect to the HDD technology?

Talke: Yes. I think in CMRR I started to continue on the work that I did in IBM. I continued on the wear of the head disk interface. I worked on various studies of non-repeatable axial and radial spindle runout. We looked at load/unload. That became, later in the late 80s, early 90s, one of the really important things. We worked on interferometry, and when the spacing became less than about 160 nanometers, then you had difficulties to see good fringes. And when the spacing became down to maybe 80 nanometers, color interferometry would not work anymore. And there we developed on the tape, initially, an approach where we used three or five discrete wavelengths in the blue/red/green area, and used these wavelengths to get an interference pattern and looked by interpolating the intensity profile what the spacing could be and by using more than one color, like three or five, one could uniquely determine what the flying height was. And so that was something that we did and actually one of the students who worked with me on that was this student, Chris Lacey, and he went on a summer job to Phase Metrics, where Art Cormier was the owner and manager, and there they applied this technology to the head disk interface. And that was, you remember, Phase Metrics the company, when they made flying height testers that allowed to measure flying height down to maybe 20, 30 nanometers, and I remember that Art and I worked quite closely together. He invited me once to go to Japan because he wanted to demonstrate his flying height tester up there, and he told me at that time he had maybe 5 or 10 people in his company and he said, "Frank, if we were to build 16 of those testers in the next 2 or 3 years, we will be all set," and it turned out that this was such a commercial success that they expanded and that the industry went down (toward lower) flying heights. They needed to measure these flying heights, and he expanded his company. You may remember that. It...

Yamashita: Very successful, yes.

Talke: ...became so successful that you could compare it to a shooting star because within one year-- and I don't remember anymore exactly when the time was. That was probably in the early '90s. He expanded to 50 people, and then he took money from Wall Street and developed-- and increased to 200 people and then he bought some other companies in the servo and servo writing area and moved to San Jose and had a company at one time of 800 people and it grew so fast that it fizzled away. They just didn't have enough control of inventory and how to manage those many people within the span of a year, and then it was eventually bought by Tencor, KLA-Tencor.

Yamashita: I don't remember exactly.

Talke: It went all the way, and they already saw very closely actually how a successful idea from the university gets transferred to the industry, can make it really successfully in the industry but how difficult it also is if it is not managed correctly, and at one time Art had to leave or left the company if I recall right, and you see that in many of the startups in the industry. We see it from Apple and all these original inventors and founders did not-- were not able to keep it all together.

Yamashita: But he had a lot to do with the concept and the instrumentation so...

Talke: Yeah, sure. We built on that.

Yamashita: ...key to the success of the company, some maturity.

Talke: Yes, yes, and so that was one of the really exciting things. We also worked continuously on lubricants, and I made contact with some people from Dow Corning and they had some lubricants that were called phosphazene lubricants and I worked with them and they supported our research and again, that was not writing a proposal where you would have to commit what you do each week. They gave the money and said, "Here, do some work," and so we worked on these phosphazenes and we used them also as additives with the PFPEs and worked with the industry looking at contact start/stop at that time and add friction and where, and then in one of the companies-- and I've-- my memory is a little unclear about that because I was not physically involved, but they had used PFPE lubricant and then they wanted to use this phosphazene lubricants and they had this trough where the phophazene had been in, and they put PFPE in and all of the sudden that lubricant worked really well and it was not Komag. It was one of the other companies.

Yamashita: This is the X1P?

Talke: Yes, the X1P, and what happened to him was-- that's how I'm-- was told-- there was X1P left when they put the PFPE in, and they had not followed what we had suggested, but they had done their studies with phosphazenes and with PFPEs and with phosphazenes and then took the phosphazenes out and put the PFPE in and had enough phosphazenes left to make it work as a small additive.

Yamashita: It was a contaminant left over from the experiment, and that's...

Talke: Yes, it's left over, and they even wrote patents on it and they had patents for it and my intention at that time was not-- I was not looking for patents anymore. At the university it's different now, but 30- 20 years ago, the university, when they evaluate a professor they look at his or her publications and his or her research and if you said, "I have five really important patents," they would have said, "We don't care about that," and so that really happened. Phosphazenes that we started-- Ming Yang. I don't know whether you remember.

Yamashita: I do remember that, right.

Talke: Yeah. Ming Yang, she worked as a Ph.D. student on that, and that became then for many years, I think, the really important additive in the disk lubrication field, and as I said, I had worked in IBM in my first two years on additives that were different additives but some of them were also phosphazenes, phosphorus related. So I knew that they would potentially be important. That was then a big, great success, and I'm happy that it worked out like that.

Yamashita: Well, these people made lots of money, but... <laughs>

Talke: Yes, and that is probably true and-- but again, as a professor I had a good salary. We enjoyed our life, and it was nice to say, help the industry, and I didn't care whether anybody said, "Well, we got that from UCSD." The main thing was that it would work and that the industry actually could capitalize and make better disks with lower flying heights and all those things that in a way contribute to flying height measurements and the dynamics with the laser Doppler interferometers. That's what I worked with, my students, and the students, many do the work, and so I want to give a lot of credit to any of the things that perhaps have helped the industry. I want to give the credit to the students.

Yamashita: The laser Doppler method you say was-- originally you used it on the inkjet?

Talke: Yeah, and the...

Yamashita: That was how it got started?

Talke: Yeah, that's how it really happened, and that was available and known that there is this laser Doppler, and when we had these piezo electric cylinders in our inkjet head. That was in the 1982-83 timeframe. I had a summer student from Berkeley from Professor Bogy. I don't remember who that was. He measured or worked with these PZTs, and we measured the frequency with which they would get pulsed and at that time I said, "I really want to" or "That would be useful for the head-disk interface," and I know Professor Bogy in Berkeley had some laser Doppler instrumentation and he had measured wave propagation on certain flat surfaces with an LDV, and when I came to Berkeley we worked together on implementing this for the measurement.

Yamashita: This was 1984 when you took...

Talke: Yeah, that was 1984.

Yamashita: ...a sabbatical. That's what you worked on.

Talke: Yes, yes, and that became an invited paper for the IEEE Intermag Conference, I think, in 1985, and that was really great from the viewpoint that an academician, Dave Bogy, and I, a professional in industry had cooperated and shown that and that technology, I think, has been...

Yamashita: It became just fundamentally...

Talke: Fundamentally, yeah.

Yamashita: ...the most critical instrument.

Talke: Yeah, and all the-- initially you're saying, "Okay, this [is] fairly easy," so we measure it. Then you say, "Yeah, the spot needs to be centered at the right place," and then you have the laser beam that reflects from the surface that you measure and you have a reference beam and then with one of my first students, we said, "The reference beam we take next to the slider on the disk and the beam on the slider so we could measure the relative flying height change between the slider and the disk." That was Tim Riener.

Yamashita: Tim Riener.

Talke: I think Tim must still be working in that-- in this...

Yamashita: Tim Riener was your graduate student over there?

Talke: Yes, yes. He was my grad student, and it happened that he had applied [for graduate school] in Berkeley, and Professor Bogy told him, "Why don't you go to Frank Talke at UCSD? He is starting off this new area," and so Tim came down [to San Diego] and he did a really wonderful job as a Master's student on implementing this two-beam laser Doppler interferometry. Do you know Tim?

Talke: Yes, professionally. He was at Quantum, then, and then he moved on to Western Digital. I met him again.

Talke: Yes, and I wished-- I have to follow up sometime and call him up because...

Yamashita: Have your reunion of the rest of this.

Talke: Yes. Yes, and it sometimes has happened in my working career that someone comes to me in a conference and says, "Professor Talke,"-- they often say- call me Professor Talke, not Frank-- "Do you remember me? I was in your class at that time?" and one especially I remember. Do you ever come across Ed Fanslaw ?

Yamashita: I don't know him.

Yamashita: No. He worked also at ReadRite and Ed was an undergraduate student in UCSD and later on he worked at ReadRite and then he went to NHK and he worked for many years at NHK as a...

Yamashita: The spring-- the suspension company.

Talke: Yes, the suspension company and so at one time, he wrote me that email and he said, "Professor Talke, I want to write you this email. You don't remember me, I'm sure, but I took your class in computer-aided analysis and design and learned about the deflection of the suspension springs, and then I got a job in this magnetic recording industry and I'm now a Manager at NHK and I really want to thank you. I have to say my house, my car, and my family, I have to thank you for that." <laughs>

Yamashita: After so many years. That's a very satisfying email for an educator, for sure.

Talke: And it doesn't happen very often, but it happens [once] in a year or once in two years that a student writes and says, "I don't know whether you remember me, but I have learned so much in your class," and that is a really nice and good feeling because teaching is quite a lot of work and you know even now when you teach and have a class of 50 people, you have to stand there at the right time, be prepared and “pretend to know” what you're talking about. <laughs>

Yamashita: Well, I'm sure you know what you're talking about, but still it does take quite a bit of preparation to teach a course.

Talke: Yes. Even-- I could wing it if I wanted, but I don't want to do that because, as I said, they call me a “Senior Professor”, and that [senior] doesn't mean that I'm old but they say [that I am] an established professor and so the pressure is on in a way even more that you say, "Well, what I teach today has to be well presented. It has to be good. It has to be useful," and that has really helped me that I worked in industry because when I teach these classes like computer-aided analysis and design, I say, "Yes, a student needs to know MATLAB, and a student needs to know something about these CAD systems and]he/she] needs to [know] SOLIDWORKS and the problem is, for instance, do you look at eigenmode vibrations of a rotating disk?" or you could say, "A nice problem to use with finite elements is to calculate the deflection of that suspension spring," or you could say, "A nice and interesting problem is to model how a drop separates in a drop-on-demand inkjet problem," and having-- worked in the industry and kind of knowing from having kept contact what a new student really should know, I think that has helped me teaching things that they would perhaps normally not be exposed to and another thing is when in mechanics you can, for instance, solve the problem and you have played with a small hole in the plate and there is a stress concentration and that stress concentration, because the hole is so small, could cause a crack to form and when you teach that to students and say, "Yes, there are actually situations where that occurs in real life, like if you weld something and it's not welded correctly that you could have a crack," and if you know this and have some interest, I think you can teach the students much better and have them be interested in what you teach than if you just say, "I teach what is written in a book without any application."

Yamashita: So over the last 30 years, just graduate students alone, how many do you think you have graduated so far?

Talke: I think I have graduated a little bit more than 30 Ph.D. students and probably the similar number of Master's students, and I have to say I would be hard pressed to know the names of every Ph.D. student, but I would know maybe 2/3 of those, and when you have a student it's almost like one of your own children. You work with them for four or five years, and often they come having their MA-- their Bachelor's degree. They have big eyes and want to do something, but they have very little knowledge, especially in that particular field and so it's really nice to work with them and seeing how they grow and develop and in my 30 years since I knew a lot of the people in industry, often the students after their first and second year, would take a summer job in IBM or in HP and...

Yamashita: Do you encourage that?

Talke: Yes.

Yamashita: ...to your grad students?

Talke: Yes.

Yamashita: ...to take on summer internships?

Talke: They took summer jobs for three months, and that accomplished two things. First of all, they saw what this industry is doing when they were good students, which in general they were because otherwise I would not have sent them. They showed the people in industry that they have a chance to get good students, and that often worked in creating new cooperative projects and so yes, that's what I have had always, that students went to WD or to IBM or to-- not so much, I don't think, to Komag-- but that they were there [in the summer] for one or two years and then they had figured out how to narrow down their Ph.D. project, they knew it's not a project that has no use. I always say you can make a project very applied and still make it as complicated and as theoretical as you want, but it's-- I've, having been an engineer, I like it better if the project is complicated but still useful.

Yamashita: Practical...

Talke: Yes, practical.

Yamashita: ...aspect. You probably have some choice in the students...

Talke: Yes.

Yamashita: ...that you pick, and for the benefit of those people, what sort of things do you look for in a grad student?

Talke: That is difficult to say generally, but I generally-- when the student is, say, from UC San Diego, then I can of course easily talk with him. When they have written to me and applied from outside, I always have tried to meet them, and I think when you talk to a student what you really need is that a student seems to be interested, that he has a good work ethics, and that he wants to do well and you could perhaps say in some...

Yamashita: Motivated. In a word, motivated.

Yamashita: Yeah, motivated. You know that he has a really good attitude, and you could perhaps say that when at one time I had the opportunity to go to Berkeley as a professor from UC San Diego and the discussion was oh yeah, the students in Berkeley are better than at UCSD.

Yamashita: They say that?

Talke: Yes, and maybe it is true because the choice and the selection of the students who are going to Berkeley is perhaps even more discrete and more selected than at UCSD, but I think it is not so much whether a student has the highest IQ. Any student who is-- has good grades to go to graduate school has shown that he or she has a high enough standard, and I think it is much more important that a student has a really good attitude that he is motivated and that he wants to do something that is good and that is new, and I always have thought that this is really the most important thing for a professor, to get a student, have him or her work in the lab for the first year on a number of projects, tell them what is important but let them figure out whether they want to do this or that. The worst you can do is tell a student, "I want you to work on this project," or if you make a student who is theoretically inclined, if you try to make him into an experimentalist and the student who is experimentally inclined if you try to make him into a numerical analyst or a theoretician, and so I think the most important thing is to see by closely working with a student what his or her strengths are and then say, "This is an area where we could work on. That's where we get support," like if we remember the laser texturing on the disks for Start/Stop. If a person is interested in mechanics, is interested in instrumentation and he/she has shown that to you, then you could say, "Okay, let's work on that and look into that," and it's then also very important not to tell the student as a manager would have tried to tell me in IBM, "I want you to do this or that," and then it doesn't work, you cannot say, "I told you so." That is the worst you could do. You have to see that the student gets involved in it [the research project], that he or she learns [about] it, and even if they make a mistake, let them learn from their mistakes. I think I have [had] several students who had difficulties with their professor and changed [their professor to me] and they were doing outstanding work, and that is where I say it is good to let the student learn, be excited, and say, "Wow, that's wonderful what you do," and the worst is to say, "I told you so," or "Yes, that's it, what you're doing now is right because I told you so." That is totally opposite and the wrong thing to do. You have to work as a coach, and so often a student becomes like <cell phone rings> an own child, and after five years it's fun to see them leave and go into industry and sometimes I have had students where I said to myself, "Well, they have done okay or nice. I don't know whether I will ever hear or see from them again," and there are some students where I say, "Okay, they have been so close. You will always hear from them," and you will be sometimes surprised because the opposite happens. There are some of the students that I thought I will not- ever hear from them [again]. They send me a Christmas card, or they write me once a year an email and say, "Here, I'm doing this, and I'm so happy that I can do that," and they ask me, "I have this other job opportunity. What do you think? Should I try it and switch?" and so these students stay with you for many years.

Yamashita: So it's different for each student. It's hard to say how it will turn out, but you want to be independent and... when you have a project, especially from a company and there is some-- like company wants specific results, and sometimes you do have to do the work on those specific goals, I suppose.

Talke: Yes, so in that case you have to say to a student, "There is urgency and so let's really concentrate on that, and that's what we have been doing," and I think in general it has worked out well.

Yamashita: So today, the hard disk technology is basically waning and now it's SSD. I suppose there are some topics in HDD that is still interesting like the HAMR technology perhaps. What are sort of the things that you're working on today?

Talke: Okay. I work with one student on lubricant transfer from the disk to the slider, and that is, of course, with the thermal flying height control slider flying really close. He [the student] is doing some experimental work on that [problem], and then molecular dynamics modeling to see what happens during that high shear situation. We have another student who simulates the HAMR interface, taking a laser and pulsing that laser and looking at the degradation of the lubricant and the fracturing of these [lubricant] chains. Then I have another student in the area of hard disk technology who looks at voltage biasing of the head disk interface. We apply a small voltage on it [the head disk interface], and depending on whether the voltage goes plus-minus or minus-plus, there are differences in the wear situation, and so we have electrochemistry involved and essentially you could say the direction in which the electrons flow that effects the tribology of the head disk interface, and that is something that [is used now] in WD also, I think, or will be used in commercial drives, but these are the last areas where I have my students working on [projects] related to hard disk drive industry. About six or seven years ago, I was in a meeting with some bioengineering professors, and we met with a medical doctor who was an ophthalmologist and he said at that time, "One of the real difficult instrumentation problems is related to measurement of the pressure in the human eye for glaucoma," and glaucoma is a disease, an eye disease, where people get blind because the eye pressure is too high. This is potentially related to the fact that you have this cavity where the eye is in, then you have a hole in the bone and the nerves go-- the optic nerve goes to the brain and when the pressure is too high the fibers of the nerves press against the border of that hole and so he said, "Well, that would be a really nice, great contribution to work [on] and come up with an implantable sensor that could measure the pressure in the eye."

Yamashita: Implantable device inside your eyeball?

Talke: Yes.

Yamashita: Wow.

Talke: What you do is-- you remember people in our age have cataract surgery. They get the lens replaced and so in that lens you could perhaps incorporate this sensor and implant the lens in the eye. So, it's not cutting the eye open but you would find the location during cataract surgery when you get your natural lens replaced with the artificial lens. You could [implant] that [sensor]. Now, most of the sensors in a human body need a power source. When you have a pacemaker-- you remember maybe that people who have pacemakers, after 8 or 10 years they have to have them...

Yamashita: You need a surgery, yeah.

Talke: ...the battery taken out because the battery dies and to think of putting a battery in the eye is something that is totally undesirable and so I had a student, a summer student or visiting student, from Munich six, seven years ago, and I said, "Why don't we look at what principles there are to measure the pressure in the eye without power?" and so we looked at various optical approaches and based on that we came up with the following approach. If you have, like, a cup with a [reflecting surface] at the bottom and a membrane here [on top] and that membrane gets deflected by pressure then the membrane changes its curvature and if we “shoot” a light beam from the outside [at the membrane] and that membrane is light transmitting to the back surface, we get reflected light and we get interference fringes. These fringes can be calibrated in terms of pressure and so we are designing a sensor that is a 1.5 mm square [device] that has this membrane that has the reflecting surface underneath [and] is built up by MEMS technology, etching and depositing layers of surfaces. This sensor is now ready for implantation in a rabbit eye in the next two or three weeks and so we can show that this sensor, and you bring light at it, forms interference fringes, round interference fringes and if the pressure increases, there are more fringes and we can calibrate that and so we think that this is a real novel device to measure pressure in the eye of a glaucoma patient.

Yamashita: So you're ready to test this now?

Talke: Yes.

Yamashita: Wow.

Talke: And so we have...

Yamashita: That's really exciting.

Talke: ...the sensor, 1.5 mm square, ready. We make it [in the lab]. We put a parylene coating around it so that it is biocompatible. It will be put in the lens that is replacing the natural lens of the rabbit or later on of the human being. Then we have a handheld microscope arrangement where there is a cell phone at the end. You bring light into the microscope, create the interference fringes and take them [the picture] with the cell phone and then you could have an app in the cell phone or wirelessly send it to a computer center where these fringe patterns...

Yamashita: Can be analyzed.

Talke: ...are recognized and it gives you for the first time the ability of—if we get that far, that a person with glaucoma could measure him or herself the pressure in the eye anyplace. Right now, when you have glaucoma, you go to the medical doctor, and in the office you use what is called a tonometer. It has a little air puff that deflects your eyeball, and depending on the deflection of the eyeball, they can tell what the pressure is.

Yamashita: They don't know exactly what happens during the daytime, during sleep, and the...

Talke: Yes. now that...

Yamashita: This is one way?

Talke: With our sensor you could not do [the measurement] in the sleep- during sleep, either, but say if I had...

Yamashita: You could take a lot more measurements.

Talke: If I had this device now and could measure [the pressure], I could say, "Does this environment cause my pressure in the eye to increase, or when you run up a flight of stairs does that affect the eye pressure?" and so the glaucoma sensor is not a cure for glaucoma but it allows the medical doctor to administer the right medicine and that is-- you could say if you have some sinusoidal wave and you measure every two weeks, you may get a completely...

Yamashita: Yeah, measure it. Yeah.

Talke: ...totally different result than if you measured every day or every hour. So, that is the idea behind it [the glaucoma sensor] and with this technology we have now-- I have three students working on that, and...

Yamashita: Wow, so it's a significant funding to do this.

Talke: Yes. Yes, I have to say the following: it is really difficult to get funding initially for that because when you go to the National Science Foundation and say, "That's what we want to do," they say, "That's not basic enough," and when you go to some of the people in the industry who would manufacture that sensor they say, "I need to see the principle, and you are not far enough." But now we have the sensor and we have gotten some support for a grant to continue with that sensor from UCSD and so I think we have made really good progress. I have somewhere in my knapsack a little-- I'll show you. It is so small that you don't believe that...

Yamashita: It's a sensor. So you have actual device. That's the case.

Talke: Yes, yes.

Talke: Wow.

Talke: And so that [sensor] can be implanted. That's what I say, and then two years ago I heard in TV and read in the newspaper that there is this problem in hospitals with the superbug and the superbug that is-- that you get...

Yamashita: They can't kill it right now.

Talke: ...bacteria that are not treatable by penicillin, by antibiotics, and so that was related or is related to endoscopes or duodenoscopes. They're putting—[endoscopes are] being put in the body, possibly even in the intestines and then [the endoscopes are] being reused, but because there are mechanical things to deflect mirrors they cannot be cleaned [well] enough. And so, we at got the idea to say “Why don't we use 3D printing? 3D printing is an offshoot from inkjet printing. I said to a student that wanted to work in my group, I said "Why don't you try to see whether you can print an endoscope-like structure using 3D printing?" And it turned out we could use these soft materials, it's called Tango Black, to make devices that look like pipes and they can be printed by 3D printing and they would be totally disposable.

Yamashita: Oh, I see.

Talke: Then we do another addition of that, and that is on a normal endoscope there is a front section and that front section allows the instruments to come out and make a 90 degree curve. And so, we are designing, also by 3D printing, a cap that could be put on any of those endoscopes so that after a [medical] procedure the endoscope cap gets thrown away and you don't have to throw the whole endoscope away but only part of it, and that is really promising and I have..

Yamashita: You can make these kind of complicated devices fast enough to..

Talke: Yes.

Yamashita: ...keep up with the demand?

Talke: Yes. If we could take a little break I can look at it and show it even here.

Yamashita: Awesome.

Talke: I have [brought] a typical [3-d printed] thing along. And so, that is something where I had a student working on with actually two other students. That student, his name is Karcher, had started [his research] four years ago on voltage biasing of the head disk interface. And two years ago I had this Indian student [Anay] who started to work on 3D printed endoscopes and he and Karcher got so interested in it and he's doing such an outstanding job, that he gave up on all the work related to the hard disk drive industry and [is] just working on that [the 3-

-d printed endoscopes], and we have a medical doctor, Dr. Tom Savides, who is an expert in endoscopy and colonoscopy and he works with us. He loves the engineering aspect of it, and the students go once a week to where he has his [medical] procedures and they discuss, and he comes to our lab and looks at what we have and says "That's what may make it even better." And so, we have this wonderful cooperation between a medical doctor and the engineers, and that is what we call now medical design technology. We can also 3D print stents.

Yamashita: Oh.

Talke: ...for inserts in the esophagus, And talking about the esophagus [I'd like to say the] following. Some people our age and even younger, they get this AFIB, that is, atrial fibrillation.

Yamashita: Right, AFIB

Talke: What that means is that your heart rhythm is disturbed [the heart fibrillates]. And so, what the doctors do, they go through the artery into the heart and burn the electrical contacts, and when they do that, then, for 20% of the patients, the following situation occurs. When they burn [the electrical contacts], the esophagus is too close to the heart. And so, they [the doctors] have some sensors in the esophagus and find that the temperature gets too high. So they have to go to an internist to have an internal medical doctor come to deflect the esophagus away so [that] this surgery can be continued, the AFIB surgery. And so, we came up with the following approach with this [medical] doctor. We said we could print an endoscope that has a curve in it. It [the endoscope] has a hole in it [It is like a pipe}. We put a straight "stick' into this curved endoscope, and make it straight. We put this [straightened] endoscope in the esophagus and pull the internal "stick" out, and because the endoscope was 3D printed with a bend, [it remembers the bend and] it deflects the esophagus.

Yamashita: Wow. Just.

Talke: And moves it away from the heart.

Yamashita: I see.

Talke: And the next step of that [research] is to make that EDD device, Esophagus Deflection Device. We have a patent applied for on it so I can talk about it, make this device "smart" and have many little temperature transducers, sensors [on it] so that the device knows exactly where it needs to deflect.

Yamashita: I see.

Talke: And so, we want to make it [the esophagus deflection device] into a smart robot. And so, here, you see we can combine mechanical engineering and robotics, which is very strong at UCSD, and medical engineering and do something that is good for human beings.

Yamashita: I see. So you're getting involved in a lot of…

Talke: Yes, and I really love..

Yamashita: And getting patents now.

Talke: Yes.

<laughter>

Talke: And we have a patent applied for on the eye sensor and on this Esophagus Deflection Device, and students are so eager and interested in that. They see that this is something useful and 3D printing is useful and they see that it's applicable, and that student also started a different project. He studies a hand [in motion] and how a surgeon takes a needle and sews people up after surgery. And, he says, if he puts sensors, accelerometers, on the hand and on a glove and the surgeon works with a glove in training, a surgeon in training, then he can do the sewing and all the accelerometers measure the motion of the fingers. So you can save that motion [digitally] and compare the motion during surgery of an experienced surgeon with that of a new doctor in training.

Yamashita: Oh, I see, and this is for a training device?

Talke: Yes. And so you can compare what actually the hand motion is of you and me, or [the hand motion of] a new doctor in training could be compared to that of a well-experienced surgeon.

Yamashita: Oh, I see.

Talke: And so, that student has gotten into that [new field] and that's why I say you have to let students become excited about it. People have done a real nice job on that disk interface biasing but three years or two years ago he had been at a summer job in one of the companies.

Yamashita: And that distracted him to more..

Talke: And he thought that was not what would be in [his future] for him. So I want to say if I was 20 years younger it would be nice because I would get full blast in that [new field] and would say whatever I do now I can continue doing for the next 10 years.

Yamashita: Well obviously it's keeping you interested. So you have no desire to retire or stop? <laughs>

Talke: Yes. I mean it is interesting and it is also interesting to think about how much chance is involved in all these things because if I had not had that one meeting with the other medical doctors about the sensor, the glaucoma sensor, and if I had not known from head disk and head-tape interfaces that interferometry is a useful thing, where we don't need a battery, [where] we shine the light from the outside [at the interface],

Yamashita: Right.

Talke: [then] I would not have been able to get into that, or if I had not known about 3D printing and inkjet printing and I have some…

Yamashita: There's a connectivity there.

Talke: Yes, contact in..

Yamashita: So kind of..

Talke: ...I have a contact in München, in Munich with Professor Lueth who is doing a lot of 3D printing of other medical devices. So he was saying "Yes, you can combine [those fields] and do this." So that is something that one can sometimes muse about, how much chance contributes in our life to the things that we are doing.

Yamashita: I see. Wow. This is fascinating.

Talke: Yes.

Yamashita: Many engineering departments are doing many medical research, I guess...

Talke: Yes.

Yamashita: I guess UCSD is no exception.

Talke: No, and UCSD has [this great] medical school.

Yamashita: It's very famous, the medical school.

Talke: Yes, and because it is famous and has a medical school there's a program that the Dean of Engineering started maybe seven or eight years ago. He said "We want to combine – cooperate-- engineering and medicine, and because of this program the medical doctors say "Oh, that is interesting. We want to work on that," like with Dr. Savides on the endoscope. I didn't know him and two years ago I wrote him an email and said "I know you are working on endoscopy and I am a professor in engineering and I know about 3D printing. Would you be interested in talking with me about [3-d printing and] the use of that [technology in medicine]?" And he wrote back on the next day "Yes, I'm interested in that," and that's how sometimes thing work out. It's wonderful.

Yamashita: I see. So you developed a lot of HDD technology that expanded the areal density. Now you get to save lives perhaps. <laughs>

Talke: I don't want to say I developed it but there were so many people in the HDD field and one could say if one contributed a tiny little bit making the flying height even smaller, this is great.

Yamashita: Yeah. Well the flying height was for a long, long period was the critical determinant of areal density increase.

Talke: Yeah. It a way..

Yamashita: It was very important.

Talke: ...even it is now, and one of the projects I just want to mention. I had this one student [Uwe Boettcher] seven years ago. He was a double major in electrical and mechanical engineering and he looked at active flying height control. And so we took the read head and the signal of the read head and looked at how much the read head signal changes as you go around [the disk], and in the 10th or 20th time around you could predict when the spacing [would be] increasing or decreasing and we took that forward signal as an input to the heater,

Yamashita: Right.

Talke: and if you change the heater at, say, 20 kilohertz you could control the flying height of the head over the whole revolution. This technology has not yet-- why, it's not been implemented [yet]. It's maybe a little bit too complicated, the dynamic flying height adjustment, but thermal flying height adjustment, that is being done. You say we make contact [with the disk] and then from the contact we back off the current to the heater, and then we fly that close [at 1nm] spacing above the disk.

Yamashita: So this may come into play at some point.

Talke: I would hope that it comes.

Yamashita: Who worked on this?

Talke: There's this student. His name was Boettcher. Uwe Boettcher. He came from Dresden and I have connection with professors in Dresden and he was in that mechatronics field and he came to UCSD maybe, now it would've been 2007. He was really outstanding and did this work. He finished in 2011 and went back to Germany because he has a girlfriend there, and [he] works at Mercedes.

Yamashita: I see.

Talke: And he is doing outstanding [work]. He's now a manager in Mercedes in <inaudible> in Austria. I think that's what he told me, if I recall right, [he works] on the station wagon, on the SUV of Mercedes.

Yamashita: I see. So you had a grad student that went on to many, many different fields obviously.

Talke: Yes, and I have to say starting really with Uwe, my students have all applied skills in the recording industry and then have chosen other industries. The next one is a lady. She works now at a company in San Diego that makes lasers for very short wavelength light exposure. That is Cymer.

Yamashita: Oh, okay.

Talke: Cymer is a really complicated technology that also uses an inkjet device. It's a tin jet, a continuous tin jet at 50 or 60 kilohertz frequency [drop] ejection and then this tin drop is bombarded with I think carbon dioxide lasers and the radiation [plasma] that comes from that [event] is in the very short 10 or 12 nanometer range for [photolithographic] exposure during manufacturing of chips. And so, she went there and then the next student went to Apple and he works on reliability, and then the other student after him, he worked on these endoscopes. He works now at a biomed company, Applied Medical, in Irvine or close to Irvine, and then the student who will finish next month, he also goes to Apple.

Yamashita: I see.

Talke: And Apple interviewed him and asked him something about "Do you know anything about Weibull statistics?"

Yamashita: Weibull statistics?

Talke: Weibull statistics and failure analysis and he said "Yes. I was the TA in Professor Talke's Computer Aided Analysis and Design Class and I know about Weibull statistics and I know about how to describe the bathtub curves and what to do with that," and he has..

Yamashita: That got him the job?

Talke: Yes, [he got] the job three months before he was finished and that is what used to happen always. My students, actually, in the recording industry, they had job offers six months before they finished and I'm happy to see that model is repeating itself again.

Yamashita: That's great.

Talke: Yes.

Yamashita: So we are back and we'd like Professor Talke to show some of the slides on his laptop of the ocular implant and also the endoscope, 3D printed endoscope.

Talke: Yes. Very cool.

Yamashita: So we'll give that a try with his laptop.

Talke: Right. So, Tom, here is this box where we have a lens inside and this implant which is about one and a half millimeters square so it will not show on our video, I believe, but I wanted to just show how small it is. It is smaller maybe on the order of a nano head, one of the smallest..

Yamashita: Recording heads.

Talke: ...recording heads, and if I could show you a couple of slides on this, then maybe we can look at this here on my laptop. And so, you see that is the project on the optical pressure sensor for measuring intraocular pressure in the eye, and the first thing here is this picture that shows how people are affected by glaucoma. You see the view of vision shrinks from the outside, gets smaller and smaller, and eventually people get blind. And that's why the doctor, when you go the doctor, the eye doctor's office, he measures with some devices whether you have peripheral vision and then if your peripheral vision decreases then this is an indication that you may also be susceptible to glaucoma.

And that [picture] is the eye doctor measuring the pressure in the eye by putting a jet of air against the eye and measuring the flattening of the eye, and that has the following problem. If you measure for instance the pressure after a couple of months you may think you are in the safe region and you could say, okay, the pressure variation could have been like that. On the other hand, it could also have been the pressure variation here like that, and you just miss all the important measurements. And so, that's why there's a need for measuring the pressure in the eye as easily and as continuously as possible. And this [picture] is the principle of the measurement device and on the right we show the eye. Here you have the eye. You have the intraocular lens and you have a cornea here in front, and here you see a little red arrow which shows where this small sensor would be implanted on the lens that is to be implanted during glaucoma surgery in the eye. The principle of the sensor is shown here. You have essentially a cup with a membrane on top. The bottom of the cup is a reflecting glass surface and this membrane is a silicon nitride membrane. You shine light from the bottom surface through the silicon nitride membrane. It reflects on the membrane. Some of the light goes through to the backside and is reflected on the back side and you get these two interference fringes. The light beams that cause interference fringes, and the interference fringes, are shown here like this. And so, you have to say what one needs to do is to miniaturize this principle and this device so that the spacing between the membrane and the bottom of the membrane [cavity] is about less than 10 micrometers; that is, below the coherence length of the light, and then this sensor is miniaturized so that it's one millimeter [in size] and does not obstruct the vision in the eye, and the principle works then that at low pressure-- let me see whether I get rid of this here, at low pressure you get maybe only two interference fringes. At high pressure you get many more fringes and when you have a device here like-- let me first show-- well, yes, when you have this device here [fringe read-out device], you can measure the fringes in the eye because you have here the camera in the back,<inaudible> the cellphone camera for that. We have a LED light here, a beam splitter. And so, the light gets-- we shine the light from the outside at the sensor. We measure the interference fringes and interpolating and calculating the pressure from those fringes, and here is the fabrication of the sensor. It starts with a glass substrate. We put a silicon nitride layer on it. We put another layer of SU8 on it. We do etching, another membrane, and then we dice the design into this one and a half millimeter area and use binders and optical grade glue [epoxy] to prevent it from leaking, and that is a penny here. That is the size of the sensor and around it you see the lens. That is the lens that is being implanted. And so, the sensor is a small part on that lens and then as I said we use the outside light [source] to get the fringes. We are close to doing rabbit tests, probably in two weeks, where the sensor is implanted in a rabbit. Now, there are problems with implanting a sensor in a rabbit because a rabbit will not cooperate to allow you to put the measurement device exactly in the right place and there are two objectives that we do have. We want to see how we can measure it [the fringes], but we also want to see that it [the sensor] is biocompatible. And so, we enclosed the whole sensor in material which is called parylene which is a biocompatible material. And here is a [picture of the] change in the pressure as a function of the outside pressure and the change in the interference fringes. And so, we can calibrate that before we implant it [the sensor] and then [we] know how the fringes correspond to pressure that we want to measure, and as I said that is the set up. We have here the eye [points to the picture in the slide]. We have here the sensor and that allows us to measure [the fringes and the pressure]. The first device that we want to build is for people who have lost their cornea, and in that case one needs to do the following. One needs to implant a support structure which is here [shows to the slide]. That is shown here. That is the support structure, and on top of the support structure you put the cornea that is being donated and then you have a little lens that you have to assemble. So in this situation you could put our sensor in like this place here [points to the slide], or you could put the sensor like it's showing here in that situation, or you could also put the sensor in the lens, the artificial lens and then have a connection to the inner of the eye where the pressure goes along this way and deflects the sensor, and that is actually one of the nicest ways that we would say this part can be 3D printed and it is part of the cornea grafting operation that you do. And so, we have to first experiment with a living rabbit, to be done in the next few weeks. We have..

Yamashita: So the next example is the endoscope.

Talke: Yeah. That's what I'm showing you next; and here [points to the slide] are parts from corneas from rabbits.

Yamashita: Oh.

Talke: And we know that this is working. And so, here is now the next device that I talked about, that is this 3D printing of an artificial [esophagus] deflection devices and these 3D printed endoscopes, and let me just show you: These are endoscopes [points to the slide]. These are stents and here we show in the next picture what can happen when you have A-fibrillation surgery. This shows the heart [points to the slide], and the surgeon burns the electrical contacts and these contacts or the heart is very close to the esophagus and the esophagus could get damaged by the heating due to the ablation. In that case a surgeon has to come and try to deflect the esophagus. And so, we came up with a device that does the following. It is a 3D printed curved rod and that curve can be any place. This curved rod gets straightened out when we put that “stick”, this inner tube, in and we insert that in the esophagus, pull the inter “stick out” and the memory effect makes the bend to reoccur. And so, that is shown here [points to the slide]. It [the esophagus deflection device] is almost straightened out when the insert [“stick”] is inserted, and then you pull it [the insert] out and it moves again [points to the curve in the esophagus deflection device]. These are various devices that we can 3D print. We can print material with various stiffness by alternating material, and that is what is called a Stratasys printer [points to the slide] that allows us to print that [devise]. This printer prints various materials and is [costs] about $200,000.00 or $250,000.00. Expensive. Now, there is also some mechanics that you have to study, Tom, and that is, we can print these samples and put them in an Instron [testing machine] and see how these printed material behave, whether it's biaxial oriented, whether it's isotropic or anisotropic, and these are things that we all need [to] do. And so, that is what we have presently designed [points to the slide], where we have this rod or tube with a curvature here at the end, and it will be straightened out and once it's pulled out it moves the esophagus. That [points to the slide] we could make into a smart robot, having sensors all along so that it measures the temperature and whenever the temperature is high it would automatically say "We need to move."

Yamashita: So I think the important comment to make is that Professor Talke worked on interferometer for head disk spacing measurements that now is being applied to measure pressure in glaucoma.

Talke: Yes.

Yamashita: This is very connectivity between basically..

Talke: It's interesting. Yes.

Yamashita: ...technology to..

Talke: Yes.

Yamashita: ...medical science.

Talke: Yes.

Yamashita: And the 3D printing is based on inkjet printing..

Talke: Yes.

Yamashita: ...concept which Professor worked on many, many years ago and now that's being applied to make some unique tools.

Talke: And so, I say to my students, sometimes, Tom, when they learn something that may not be interesting to them. I say "Don't think that this subject is boring and you don't need to know it. You never know when in your life it becomes handy that you learned something", like that one student who learned something about Weibull statistics. It comes in really handy at some time and I think that is one of the things that we as engineers should really say "have an open mind always and see"..

Yamashita: It could get you a job at Apple.

Talke: Yes. Yes. Right?

Yamashita: Yes. So you mentioned earlier you wanted to give some credits to grad students.

Talke: Yeah.

Yamashita: Like if you need to do that..

Talke: Yeah. Let me just say from my IBM days I would like to give most credit to my coworker Ray Tseng who came from Berkeley and he worked with me on many aspects of mechanical and read back signal analysis. He studied what happens when the spacing gets really small between the slider and disk, and you remember, Tom, there is something that people call the rarefaction effects.

Yamashita: rarefaction?

Talke: Rarefaction effects when the gas cannot be considered anymore as a continuum and there is a number that is called the Knudson number that is very important, and here's another of those examples. Ray worked on Knudsen number flow which is also described as rarefied flow in Berkley as a student in a totally different environment, studying what happens when a space shuttle goes outside of the environment of the atmosphere. And so, that is another of those examples where something comes really handy in. Then in terms of my students, I would like to give Chris Lacey a very big hand for making major contributions to instrumentation. He worked on this flying height measurement investigations for the tape with me and then he implemented that on the hard disk, and that made Phase Metrics a big success. Another of my early students is Joshua Harrison, and Joshua came to me with his baccalaureate degree. He had a baccalaureate degree actually in biomechanics and he got his Ph.D. He worked for a while as a professor in Australia. Then he worked at a manager at Seagate, and then he left Seagate and went to Stanford Law School and then he became a counselor for WD and after a few years he started his own law firm and is still working for WD but is not an employee of WD. So he's a private lawyer. Another of my really outstanding students I want to acknowledge is Michael Wahl who was also one of my first students in the first three, four years and Michael has his Ph.D. He went to Phase Metrics and then he went to several startup companies doing optical pattern recognition also for the manufacturing of heads, and then he is now-- well after that he worked for a number of years in the automotive industry, combustion industry and combustion studies, and he's now an independent consultant. And then I had another student who was really outstanding, Michael Duwensee, who after graduation went to Hitachi. After that he went to Apple and now he is at Tesla, and then I have a number of students still working at WD, that is Vijay Prabhakarem, and Bernhard Knigge and Min Yang, who used to work as an engineer at WD but she is working now in a materials company here in the Bay area. And then I have had a number of post-docs who also have done really well. Post-docs are also a great resource and one of the most outstanding post-docs is Professor Gerhaeuser, who worked on some aspects of inkjet printing [with me at IBM]. He went back to Germany and was one of the co-investors of the MP3 technology and the Fraunhofer Gesellschaft [German research organization] made so much money on the royalties of these patents that he had an institute with about 500 people in Germany and has done really outstanding work, and then there are many others with whom I have had either long or short term collaborations and again, I would like to acknowledge all of these people and I say thank you to all of you.

Yamashita: So I'd like to add that Ray Tseng was my coworker in Komag. He passed away unfortunately just recently and he was just a great individual. He's sorely missed, his passing. So, the last thing I wanted to ask you is there any other things, hobbies, activities that you're involved with that you might like to share with us?

Talke: Yes. I'd like to just summarize and say right now I like hiking in the mountains, especially at Lake Tahoe, in the Sierras. I have hiked most of the John Muir Trail and hiked on some parts of the Pacific Crest Trail. When I was younger I used to do rock climbing and actually I did quite a few climbs together with Professor Bogy in the Sierras. I also climbed in the Alps. I enjoy skiing and as we get older, Tom, you say every year "Should I try again?" <laughs> You worry about breaking a leg but..

Yamashita: Professor Bogy recently broke something I understand.

Talke: Yes, yes. He went skiing and he hurt his hip and had quite a lot of-- how do you say? Had a lot of rehabilitation to do. And so, yes, my kids now ski better [than I]. My two kids that are-- my three kids I should say, are all engineers. One, the youngest, works as a robotics engineer at the Navy. My daughter works here in Saratoga as a high school teacher and she was a mechanical engineer and worked at several companies in the semiconductor industry, and then when she had children, [working in industry] that was not what she could do [anymore]. And so she became a math teacher in high school, and then my oldest son is a professor in Portland in environmental engineering. In general, I enjoy nature and the challenges of nature and I hope to be able to do that for a few more years.

Yamashita: Great. Thank you very much. I think this concludes our interview. Thank you very much for coming and hopefully people that will see this interview will find it very interesting.

Talke: Very good. Thank you very much, Tom.

END OF THE INTERVIEW

