Oral History of Erhard Schreck

Interviewed by:
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Recorded May 31, 2022
Mountain View, CA

CHM Reference number: 2022.0081

Marchon: Today is May 31, 2022. It's a great pleasure to introduce Dr. Erhard Schreck to our Oral History Series dedicated to the History of Digital Recording. Dr. Schreck belongs to the select group of intellectual property centenarians, not because of his age but because he holds over 100 published U.S. patents. He's one of the few experts in hard disk drive tribology. Tribology is the science of sliding bodies which usually involves friction, wear and lubrication. The reason why it's so critical to disk drive technology is because the magnetic head is riding and sometimes sliding very close to the spinning disk surface under extremely high velocity of close to 100 miles per hour. In the disk drive industry, tribology therefore refers not only to the reliability of the device but also the push to lower and precisely control the head disk distance, also known as the flying height. During his career, Dr. Schreck has helped to reduce this flying height from a few micrometers to just under 1 nanometer, which is about the length of just a few air molecules. This has enabled over a millionfold increase in storage density. Dr. Schreck, welcome. Let us start the interview with your childhood. Where were you born and where did you grow up?

Schreck: Okay, first thank you, Bruno, for the invitation and the nice introduction. Yes, so I was born in a small town-- small town means 50,000 or 40,000 people-- in Ravensburg in Germany. So that was, what can I say, it was a very nice environment I grew up in. You could roam around as a kid outside. Yes, there was no worries about crimes and anything. The kids just came home when it was dark. So that was very pleasant for me to explore nature without any limitations with my friends, so that was good.

Marchon: And in school did you have early interest in science? Were you doing experiments at home and things like that?

Schreck: Yes. The early interest I think I need to credit my dad. He was a simple toolmaker, but he was very talented in building mechanical devices, all kinds of things. And I'm still wondering today where he had this knowledge from, because I really never saw a lot of books or saw him reading, but he knew a lot of things of science. We don't talk about black holes now, but in general, more than the average person knows he knew actually, and that got me definitely interested. And we had a model shop, due to his profession. In Germany we have basements and he beautified it very nicely, and we had all kind of tools and materials and he taught me very early on. First it was like a Holy Grail down there, you know. <laughs>. I was not allowed to use his precious tools, but more and more, he had more confidence in me using the tools and he gave me a lot of freedom and so I was more or less the toolmaker for our friends also. When we needed to set up something, they all knew, "Oh, Erhard, you got the basement there. Can you make it?" <laughter>

Marchon: Did you have any close calls with safety problems and exploding things?

Schreck: Well, yes. We built pipe bombs. <laughs> And there were close calls I would say, and friends got injured, not too badly, but it happened. Coming out from World War II, my dad hated all kind of shooting devices. So, when he saw me even with a slingshot, which I built many in this basement, <laughs> he was very angry. And I was kind of inventive with building other shooting devices, and accidents happened..

Marchon: But your dad had the foresight to think that perhaps that would lead you to having a career in science?

Schreck: I don't know if he had this in mind. He definitely tried to interest me in technology and clearly, the setup he provided for me, this availability of machinery and tools, and he taught me a lot of tricks on how to make things. And then the one fascinating part, I think I will never forget is-- hopefully I never forget-- is when we needed a spring, a steel spring. We needed a long one, meters long. And I thought, "Okay, I don't know where to buy a meter-long spring". Then he said, "Let’s make it ourselves." And he showed me how to make a spring with the wires and two woodblocks and you just wind and it makes a spring. And that was fascinating. So, tricks like this I think that stuck in me. And even according to his standard, I think I never really came up to his perfection. He was a perfectionist. I think I'm one, too, but maybe <laughs> not the same type. So, he taught me these little tricks and that made me who I am. It's fascinating.

Marchon: At what stage did you think you wanted to be a scientist or an engineer? And were you good at school, by the way? Were you good at science?

Schreck: I was definitely horrible in languages, French, for example. <laughs> I failed miserably. <laughs> In math, I think I was doing good, but in physics, that turned out later in high school and part of it was because I had an excellent physics teacher. So, I would say, I credit my interests partly from my dad and environment I had there, but then the physics teacher was really motivating. Because I saw in him a person who didn't care about work hours. I played badminton at the time and the gym was next to the physics lecture room. When we played badminton and came out at 10:00 at night, I saw the lights on in the lecture room and that was because the physics teacher was preparing the experiments for the next day’s physics class. He had no limitation on himself and how much energy he spent, and he actually told us one time, we had 30 people at the time in the class. He said, "You know, I know exactly all the work I do, I do it for 3 people." We had 3 good people in the class in physics, and luckily, I was one of them. And when he said this, that he's aware that he does all this work for these 3 people, maybe that was even wrong, I don't know. Maybe he should have taken care more of the other ones I think now? <laughs> But at the time, we were proud that the teacher did all this work for us. And he did what I always liked, experiments. And I'm an experimentalist, clearly, and probably this is because even today, many experiments we did at that time I remember very well. Like having a wire with a weight going through an ice block overnight because the ice melts from the high pressure. And then in the morning you would come back to school and the wire is cut through the ice block and the ice block is intact. So, experiments like this make a change in your mindset. And I think this really fascinated me about nature, that you have what almost looks like miracle events, but you can explain it with physics.

Marchon: Then comes college, time to decide what to do and where to go for college. So again, was it very early on, many years before college that you knew you wanted to go into physics? Or how did that happen?

Schreck: I don't-- I don't really think so. It's kind of funny how sometimes things happen. The University of Konstanz, was only about 40 kilometers away, around 1 hour drive. And there was a lake in between so you needed a ferry. Normally you could drive around. But there was a new university. It was very small. We only had 2,000 students. And the classes were very, very small, so we had a very intimate contact to the lecturer. That was really great. They had a solid state physics department, but they didn't have all these variety of departments like Munich or Muenster or the bigger universities. And then I had a friend there who graduated one year before me and he said, "Oh, Erhard, why don't you look at Konstanz? Maybe you'll like that one." He was in biology and he said they have a nice physics department. And yes, I did have interest for physics. And because I played badminton and had to go to the practice, it was convenient that two times a week I could simply drive home for practice. And I was at the University at the same time and the University was in a nice setting: there was the lake, there were the Alps, so you had everything for skiing, windsurfing, all these things were there, too. It was very attractive from everything I would say. From the smallness of the university, the close contact you had with the professors, that was all a very ideal setting at the time.

Marchon: Did it come to your head that perhaps you could aim higher and go to a fancier university in Germany?

Schreck: No, never. You know, this is funny. When I came to the U.S. the people always talk about, "Oh, this is a great university. This is great and this is great." And I think I did not have this elite thinking somehow. I don't know if this is good or bad, you know. Only later in Germany they also tried to set up these Center of Excellence universities and the rating and honestly, I don't know <laughs> is this needed or not? I'm not quite sure. I think a good setting is definitely helpful, but good people can come out of any setting I find.

Marchon: So, you went to physics. Was it clear in your head that physics could lead to engineering? I know in France, for example, you know, the boundary is fairly fuzzy between physics, chemistry and engineering and people often don't make the distinction. Was it very clear that you wanted to be an engineer? Or did you think perhaps you could be a scholar?

Schreck: That's an interesting question. I think I always liked experiments, building things, yes. But I also liked mentoring, so that I usually participated in mentoring younger students, and I typically found it very rewarding when you teach young people, and they find interest. Or you start developing, and help them to develop interests, I think this is extremely rewarding. And looking back at this, I always thought again of my high school teacher that must have been nice for him to see that even a small fraction of 30 people were really super interested in what he was doing, and paying attention. But scholar, I think it was never really on the top of my list. I always liked it, but I always liked to be involved by myself with experiments.

Marchon: Making things ?

Schreck: Making things, yes.

Marchon: So which discipline did you like best in your undergrad studies? Solid state physics, mechanics?

Schreck: Mechanics actually always fascinated me because I, in a way, I think it's underrated <laughs> Because there are so many things in mechanical engineering or in mechanics which even today are not fully understood and make things work. I also liked automating things. This was the time when computers moved into the lab, and at the time everything was slow with 2400 bauds when you needed to connect something. But I helped, on the side I helped to simplify and automate experiments for other people, just help them to get the tools and the infrastructure in place so they could be more efficient. That's the thing that I always liked too, sort of the combination.

Marchon: So then comes graduation. You went on to do a Ph.D. Could you tell us about this, where you went and how you chose your Ph.D. subject?

Schreck: Well, the Ph.D. subject, how did that come all about? Oh, we got a new professor into the university, Professor Dransfeld. He came from the Max Planck Institute (MPI) at that time and he had some more industry connections, which as you probably know in Germany, the universities are more like more ivory towers: they do not have spinoffs for startups and all this, at least not at the time. So you were more or less free to do what you wanted to do. It's not like here when I started working at IBM and we worked with Frank Talke in San Diego or with David Bogy in Berkeley. We provide the tools for the graduate students over there so they are completely prepared and have a running start when they join the industry. That's not in Germany. In Germany, you're kind of free-spirited. I didn't think when I did my Ph.D. work in Germany: "Oh, where do I get a job with this thing." This is not the thinking. When Professor Dransfeld came, he had some connection to VARTA, a battery manufacturer. And at the time, this was in the eighties, they were interested in lithium batteries, and they had some thoughts about it. And there was a finding that lithium as a thin film has different ionic conductivity. And my professor said, " Erhard, do you want to investigate this ionic conductivity as a function of thickness for lithium iodide?" And that's what I did. I picked up some electrochemistry, and it was more interesting for me for the experimental challenges. Because there was no battery in the end, there was no real something you finish, that you can use. It was only the study of the conductivity. And I think I finished just fine. I was happy with it. But it was clear to me that this was not something I wanted to continue. like people who work 50 years in the same field. And that was clearly not what I wanted to do. But I finished my Ph.D. in a good way and then I was happy that I could do something different. <laughs>

Marchon: During your Ph.D. work, did you publish scientific papers in refereed journals?

Schreck: Yes. Again, this was Germany. There was no super push on how much you publish. You expected for your Ph.D. to make maybe one publication, to condense down your results. And that's what I did, though I had more than one also in collaboration with other people. But for the Ph.D. itself, that's all that was needed. And to be honest, I question a little bit the publication urge we have here. I think most publications are not of high quality, to say it in a simple term. And if I compare publications from today, I think the publications from the '30s or '20s, people more or less wrote them almost like books. And they also wrote what did not work, not only what worked. And I thought it was much harder to do than the way we publish today. So, I have a little bit of a mixed feeling to publications. I think a good publication takes a tremendous amount of work.

Marchon: Earlier you mentioned the early days of computing and maybe even personal computing. Did you have access to lab computers, and did you have any interest in computing then?

Schreck: Yes, we did, and I had access. And so yes, the university at the time, we just started to buy personal computers. There were a lot of different brands, as you know. We had a computing center and I spent a lot of time in the computing center with the punch cards, as you remember, so that was good. And because not too many people were using the mainframe there was always room for me and maybe two or three other guys. And we were sitting there at night, and did our programming. So, there was a really nice environment.

Marchon: Did you program in Fortran?

Schreck: I used ALGOL 60. One thing I did was to write a full word processing program which the university almost tried to set as standard to the university for writing publications. It could handle everything, references etc... And I wrote it while one person wrote his Ph.D. work. <laughs> So whenever there were new needs, I modified the program, and in the end, it was a solid word processing program. And yes, that was a finished product. But also on the side during my Ph.D., I wrote a carpool managing program, instead of having whiteboards for the students who looked for carpool opportunities. When you looked at the whiteboard, it was already last week gone, when you were looking for something now. And I thought that should be on a computer. Making a long story short, I then thought “maybe I can make money with that”. <laughs> I programmed that thing and if they wanted an address, they needed to put in some money to get it. That was the thinking. I went to get a computer from a store in town and I said: "I’ll do some advertising for you, so your name will show up." So he gave me a free computer and I did all this. Then at first the university was fighting it and said, "No, no, no, we cannot set this up. We need power and who pays for the power?" You know, this is Germany. <laughter> In the end, I got them to give me a space with an outlet nearby <laughs> near the cafeteria. So when people would go to lunch, they could check the computer. And sooner or later, the press from a Germany-wide newspaper showed up. They came and reported: "University of Konstanz, first university with automated computer carpool." So suddenly the University loved it. <laughs>

Marchon: You became a hero from this, yes ?

Schreck: I became kind of famous. Not famous, but yes, they knew I was doing this. And then they gave me a space in the library, so we set up the computer in the library. It was quieter there. And this is the funny part. Again, I like to help people. It makes me happy when I can help them. So, what I did very often after I had eaten, I'd go to the library and just sit next to the computer and listen when the people were using it. And I had a little book next to it where the people could make notes what they liked and disliked. And I saw how the people liked it. And the feedback was positive. And that gave me a lot of enjoyment. And by just seeing this, I completely forgot about the money part. <laughs> Because this gave enough feedback for me or positive feelings, forget the money.

Marchon: Better than money, yes.

Schreck: Better than money, absolutely, yes. So that was great. This was operating for a long time, but then I left to the U.S. and I got another friend continuing the maintenance. And he didn't only do maintenance, he converted this thing to web-based and put it on the web, and it went very well. And then there was another University in Stuttgart, with people who basically copied our interface and everything. They also put it on the web and had the nice slogan: "Kangaroo and off are go”. <laughs> And they charged money. And we were kind of angry because they used our interface. I said, "You could at least give us some credit where you got this from," which they did then. But they made money with it. So, these were the motivation from the other side. We were just happy to provide this service.

Marchon: I also understand that you had some early interest in intellectual property and patents in the area of automotive.

Schreck: Oh, yes. Thanks for asking this. Yes, there was this idea with the electronic windshield wiper which today you find in almost any car, any newer, a little bit more pricy car. So yes, that was an interesting development. I had an old car and it didn't even have the interval…

Marchon: Intermittent wiper ?

Schreck: The interval wiper, you know, where every 5 seconds it moves. So, I thought I needed to do something about it. And I came up with this idea for an optical detection system where -- and this is Germany again --- where you have winter, snow, ice on the windshield. So I needed a detector that was inside the windshield, so you don't scrape it off when you need to clean your windshield from the outside. And I came up with this optical system which uses a total reflection of a beam inside the windshield. And that worked extremely well. And through another colleague who knew someone in the automotive industry, he connected me to a person from Audi/VW. And because he always said, "Erhard, you need to do something with this thing. This works so well." And the person actually came from Stuttgart to Konstanz and wanted a test-drive to see how the system worked. And it was beautiful. It was rainy on and off, like it very often was in this area and the thing just worked beautifully and he was impressed. But then in the end, it never came to anything after he asked me how much would it cost to integrate this. I said at the time it would be maybe 10-15 German Marks, and he said, "way too expensive! In the automotive industry we look for cents, you know, and pennies. So, this will never make it." So, at the time I just gave up and that was it. Then I thought about patent and I wrote one, but I never submitted it. I don't know, maybe I was too cautious about this. Today I would know better. I could easily have gotten a patent on this one, but I didn't. And then it was sitting there, maybe around 1980 when I did all this. And it was funny, my colleagues from the lab, they always showed it to other people and they would spit on my windshield to make it work <laughs> when it was not rainy, and it worked beautifully. The only problem I had was this thing fell off once in a while. There was no such thing as Superglue, but that was not a big deal, I know these things can be solved. And that is probably something I kept until today, when you submit patents. Very often you have evaluators on the other side that say, "but there's a problem. How do you solve this?" This is not the point of a patent. In 2 years, you have new materials and new ways of doing things, so what is today your unresolvable problem, you can fix in 2 or 5 years. So, I'm never really discouraged by these things. But so, nothing happened because the guy from Audi/VW thought it was too expensive. And then when I was done with my Ph.D. work in '87, I thought, "Man, this is still not on the market yet. <laughs> I cannot believe it." Not even the Japanese, because the Japanese were usually a little bit ahead of the German automobile. German automobiles did not even have power windows. Everyone was frowning at air conditioning. "We don't need something like this, we're the Germans. We can take this heat and this cold." So horrible... So nothing happened.. <laughter>

Schreck: And then I thought, there is Bosch, the famous company who does car electronics. So, I wrote them a letter that I have this idea and if they wanted to know more about it. And they invited me, and I drove there and gave a presentation. The room was full of engineers, and they were all, from what I could tell, interested. Someone came out and complimented me then after the presentation. But they sent me off and didn't pay for gasoline. They didn't give me a lunch, nothing. When I look back at this, I said, "This was really miserable." <laughter>**.** And then I didn't hear anything from them anymore. I felt it worked so good because I had it in my car. It was really an enabler for safer driving. It prevented you, when you have a wet road and you want to pass another car, and you go close to the other car. But then you get all this spray water on, so you need to turn on the windshield wiper, and then you need to watch the left side if it's free to pull over, all these things. I thought, "Man, this is so easy, this automated system. It just does it." So, I thought this should be in the car. That's why I went to Bosch. And then after presentation, there was no more contact. This was in 1987, and I think it was in the mid-90’s that I saw these automatic windshield wipers showing up in high end cars.

Marchon: And was Bosch the first one to do it ?

Schreck: Actually, I don't know. I think, I'm pretty sure in Germany it was, yes. I don't know what Japanese cards did. In Germany, I never looked if it was a Bosch brand. But I looked up the patents and there was one from Bosch. And the principle hadn't changed, it was the same thing. I thought initially that the beam needed to go across the entire windshield to get a reliable wiper function. It turns out no need, and maybe 2-3 inches is enough.

Marchon: Just need drops to fall between the detector and the beam?

Schreck: Yes, that was enough. Basically where the rearview mirror is on the windshield, this is a good location. And the beauty is, you cannot damage it from the outside. You still can scrape off your ice. VW at the time told me: "Oh, yes, we worked on something like the system you have. But we have a sensor outside." They had a thermistor, a little heater. And when it rained and the water came on it, it cooled it. That was outside and it was not on the windshield. By the way, today, Tesla uses a camera. But at the time, we didn't have a camera. I always thought about cameras, but there was no way you can make an inexpensive camera for this. <laughs>

Marchon: Interesting. So Erhard, you graduated and you got your Ph.D. in your pocket. You came to the U.S. Tell us about--

Schreck: Well, first came the change. I said that ionic conductivity was nice for the Ph.D. work, but not something I felt I was married to, and that I needed to continue. My professor was also an excellent experimentalist, in the way he was thinking, and he frustrated me sometimes. One day I was doing an estimate for a certain experiment about the magnitude of the effect, and it took me two days to come up with a number. Then I went to him and he sat there, and then in two minutes he said, "Yes, you're right." <laughs> So physics was his second nature. And when he attended lectures by theoreticians, <laughs> he was able to summarize the entire lecture in a very simple way at the end of the presentation, so everyone could understand. So he was my type of guy: thinking in simple terms. I never liked quantum mechanics, I must say. And I think he never appreciated it either. <laughs> But he was very good in doing this very basics physics thinking which explained also very complex processes. So that was for me very intriguing. And he was fascinated by Scanning Tunneling Microscopy (STM) which was done by Rohrer at the time in Zurich, which is only another one-hour drive away. He appreciated this simple mechanical setup that you can map atoms with. Now this was all in Ultra High Vacuum (UHV), so we always thought, "Hmm. This cannot be really simplified. This is a complicated system." But he said, "Are you interested in this? I would like to set up a workgroup with this technique." And I said, "Yes, definitely. I like that one, too." Then he thought and we both agreed, maybe this could be done much simpler. Perhaps it could work without the UHV and we can just do it. So, he sent me there, as he had connections to the IBM Research Lab. And then he arranged that I could do a post-doc there. I learned at IBM Research which was like a holy facility when I was there.

Marchon: That was the Zurich Lab?

Schreck: That was Zurich, yes. There was Rohrer-Binnig who got the Nobel Prize. And while I was there, there was Bednorz and I forgot the other person's name, for the high temperature superconductors, who also got the Nobel Prize? And I felt like, "What am I doing in this place with all these Nobel Prize winners? This is wrong." <laughs> But there is also an interesting anecdote when they got the Nobel Prize, they could not celebrate on the IBM premises with wine, because there was no alcohol permitted. <laughs>

Marchon: Worldwide in IBM, yes.

Schreck: Well, not in France.

Marchon: Not in France?

Schreck: In France they had beer and wine. <laughs>

Marchon: Oh, they had a special authorization.<laughter>

Schreck: Yes, so we had to go outside on the street, on the sidewalk, away from the premises to toast. That was really funny. So that was my first contact with IBM Research.

Marchon: Was it within your Ph.D. program or after?

Schreck: No, that was after. After I was done with the Ph.D., the professor asked me if I had interest in this STM technology and I did, so that was my opportunity to go there. And at the time, I had already done a little bit of work in Konstanz. I liked software, and I liked programming. I had written a very good

STM analysis program to display the shapes you get, the images and all this, and I even sold one copy <laughs> to a startup, so that was interesting. Then after this one year, I came back and set up the STM/AFM workgroup in Konstanz under the same professor. This was new at the University of Konstanz, this kind of work. I think it actually went very well. I like simple approaches in experiments, so for AFM detection, instead of using piezo in all these funny things, I used an electric microphone that you can buy for a dollar or so. And the membrane, where we put the sample on, is vibrating. I did estimate that the sensitivity should be good enough and we could actually get atomic resolution with it.

Marchon: You used voice coil actuation?

Schreck: Well, this was capacitive. The electret microphones work capacitively, but you're right, the voice coil could probably do the same thing.

Marchon: But maybe with lower bandwidth?

Schreck: Maybe lower bandwidth. This thing was really sensitive and I felt actually good when at some point, Binnig, the Nobel Prize winner for the STM, approached me and said, "I like your idea with this microphone. It is so sensitive." And at the time, he was looking for a sensor to detect gravitational waves, and he thought "maybe this type of capacitive microphone scheme would be sensitive enough." It didn't go anywhere, but at least he felt it was a good idea for that purpose. As you know, today, they do it with interferometry.

Marchon: In LIGO, yes.

Schreck: Yes. So, that was good and again, this AFM/STM technology was something in my direction, it was understandable. It was simple and fascinating how much signal and sensitivity and knowledge you could get out of this.

Marchon: And very multidisciplinary, right?

Schreck: Absolutely.

Marchon: You need to look at it with physics, mechanics--

Schreck: You can do anything you want. Chemistry.

Marchon: Image processing.

Schreck: Yes.

Marchon: Signal processing, yes. So, from what I understand, you learned a trade at IBM and then brought it back to Konstanz to build up a center there.

Schreck: Right. And you asked how I got to the U.S. At the time I did my Ph.D. work, there was G.P. Singh who was transferred from MPI (Max Planck Institute). He was from India and he stayed at our university for I think five years, as he was waiting for a visa to come to the U.S. During that time, he stayed in Konstanz and I worked with him on this ionic conductivity also. And then he got the visa and he left. But at some point, things change, as nothing is static, and many of my friends from the university left to other locations and I felt like, "what am I doing here?" . Even though Konstanz was a nice place, I wanted to see something else. Then I contacted G.P. Singh. I didn't know at the time he worked at IBM in the Almaden Research Center. And I asked him in January: "G.P., do you have space for a post-doc or something?" Then he said, "No, not at this point but I'll let you know." And then in April, he responded back and said, "I now have an opening," and this is when I just came over to the U.S. The idea was to work as a post-doc for one year, but that got extended one and a half year, and then I got a permanent job opportunity. But I had no idea about disk drives. This was the first time I saw a rotating disk, a spin stand, a head flying. But at the same time I just saw a lot of opportunities with this thing. And there was a head flying over disk, that looked to me like a capacitor <laughs>, so you can apply a voltage and you get the Coulomb forces. You can play with this. And he had something in mind where he put me on to measure some thermal asperity temperatures, when the head flies and hits an defect on the disk, you get this frictional heating. And he wanted to know because there were publications that said, "this reaches flash temperature. It's basically glowing, at 700 degrees." And people observed this. And he said, "maybe we can measure this." And he had already designed a structure in the head that was supposed to do this measurement. And it turned out the structure, the way it was designed, did not work. And we thought "this project is gone. We need to do something else." Then I realized that the structure was made like a thermocouple, with different junctions. There was the magneto-resistive element, nickel-iron part, and then there were two leads, tantalum I think. So, we had dissimilar materials making contact and I realized, "the entire structure did not work for this experiment, but I can use this contact of the dissimilar material as a thermocouple," and that actually worked. So, I could move my structure over the asperity and on the one side I got a negative peak and on the other side I got a positive peak, so I knew exactly that this was the thermocouple effect. And, so, we could measure, but not very accurately I would say, because at the time I didn't have the capability to do thermal modeling. We detected the large scale, that basically is the average temperature, and then calculated back to the real peak temperature. That was very inaccurate, but we got some numbers out of it, so that was good.

Marchon: What year was that?

Schreck: That was in 1990.

Marchon: MR (Magnetoresistive) heads were just starting at the time?

Schreck: MR heads were just starting, and they were just a fascinating thing. They were just starting and there were basically a similar structure. Today we have what we call the ECS, this Embedded Contact Sensor, which is simply an electrical resistor on the air bearing surface, which gets heated up or cooled when it comes close to the disk. Then the reader at the time had about the same size, like today, these ECS sensors. <laughs> I almost claim (I shouldn't say "invent), but I discovered the use of the MR element as a contact sensor. IBM at the time had a project they called Tahoe, because of skiing. They put a lot of lubricant on the disk and the head was like water skiing. So, they thought, "this should last forever." As you know, reliability was always an issue. But with this lube flooding, this lake of lube, things should work forever. But then it was never quite clear if the head was still flying, or if it was in contact with this thick lube? And with the MR sensor, which I then used, I could lower the flying height which could be done two ways: you could reduce the pressure in a pressure chamber or you could change the RPM. So, I changed the RPM in that case. And then you could come down when you lower RPM, the fly height decreases. And the moment you get the frictional contact, you see the resistance change and you can measure it. So, I could clearly show with this experiment that we're in contact with the lubricant and producing real friction. So that was very new I think to prove it directly. And I think one of the things I always liked was to use existing devices in a different way. Because the device is already there but typically a device has not only one function. You design it for one main function but when you think about it, it has a lot of side functions; you just need to find another purpose. And for the MR reader at the time, because it's a magnetoresistive, the resistance changes as a function of the magnetic field, but the resistance of a metal also changes as a function of temperature. That's the only difference.

Marchon: All this was done at the Almaden Research Center?

Schreck: That was all done at Almaden Research, yes.

Marchon: And during a post-doc. And how long did that last, and what did you do next?

Schreck: I liked this head-disk interface really a lot. <laughs> And even 25 nanometers sounds high today, but at the time that was fantastic. And coming from this AFM/STM microscanning background, you had respect for this spacing. Then there was, luckily, somebody else who had already thought of it, using capacitance measurement when the head flies over the disk, you can just measure-- It's like two parallel plates almost, and then you have a capacitor. And they built these capacitance measurement systems at IBM. IBM had an excellent electronic department. Don Horn was one of these geniuses. He built everything-- He just could do anything. You asked him something and he'd build it. He never told you how he did it, but he built it and you got a black box that did exactly what you wanted. <laughs>

Marchon: And it worked.

Schreck: So that was good. And they had these capacitive sensors of 40-50 picofarads. And at the time the sliders were still somewhat big. The slider I worked with was 4 millimeter long. That is huge compared to today. So, they could actually make individual little capacitors on each corner of the slider. If this is the slider, you had a capacitor here and here and here and here. So, you had 4 capacitors and then I had a 4-channel capacitance meter. And what I did with this, I studied the dynamics when the head hits the TA (Thermal Asperity), so I could see how it's jumping up and then it's doing the oscillations from the air bearing damping or wiggling. Or when you do a shock experiment, and you touch the disk. And so that's another thing I played with. But it also helped, and at one point, it helped a program where they had flying height issues. We didn't have the sliders anymore with all these individual capacitors, so I only could measure the full capacitance. But by knowing the pitch, the crown and the camber, I could calculate the total capacitance and when something changed, at least I could get an idea, not as accurately as if I had individual sensors, but I could get a rough idea how the slider was behaving when it was doing seek, something like that was a problem. And then also because you applied the voltage, you have a Coulomb force, attractive force. You can use this to lower the flying height and if you apply a little voltage step function, you can study the dynamics of the slider. So, it gives you just infinite opportunities to sort of play, but it's not play because you really want to understand the dynamics of the slider flying.

Marchon: Did IBM let you publish all this work?

Schreck: Actually, for the contact thing on the ski slider that did not work, IBM had this internal technical publications, which is all confidential. This was not allowed to be an outside publication. And on the capacitance, the same thing, I never published it outside. For the reason that I said before, I never feel when I do a work that I'm done. So, I never feel I'm ready to publish. <laughs> I don't know where the end is, you know? How much do you need to know to say this is now a very nice, round, finished piece of work? That's maybe the problem when other people go and say, "Okay. I get this little piece and I publish it." And it may be not so bad, so it helps other people get started earlier in it too.

Marchon: Did you have any patent submitted?

Schreck: Well, at IBM, my first patent made me so proud. <laughs> People were talking about contact recording like Celia Yeack-Scranton. Like you said before, we need to fly lower and lower. So, we can fly very low and hopefully not contacting the disk. But then the other extreme would be you purposely go in contact. And then there was an idea that we make a very tiny sliver which was only 30 micrometers wide and I forgot now, 10 micrometers thick. It's like a cantilever. But it was so light that the loading force on the disk was extremely small, and the idea was we can avoid the wear and integrate the head on this and basically, this would be a new contact recording scheme. One problem was when this was dragging over the disk, it was kind of jumping. The disk wasn't super smooth, but you got all these jumps and when you get these jumps you cannot do the recording. I worked with Bernard Hiller on this, as he joined around the same time. Our idea was to push this thing and fly backwards, so the air would come at an angle and push the beam further on the disk. And that made flying more stable-- not fly, but behave more stable. That was our first patent and it was really great. <laughs>

Marchon: Okay, so at what point then did you decide or did people in the Product Division hire you?

Schreck: Well, first, because the work was going on well, they extended the post-doc for half a year. I was working up in Research but part also down in the Product Division, with Reinhardt Wolter who was heading the HDI (Head Disk Interface) department at the time. And somehow I think probably G.P. talked to him and said, "why don't we try to keep him." Then Reinhardt made me an offer in his division for a permanent job. At the time, I had already something lined up in Germany because I was only prepared to stay there for a year or one and a half. Then I thought, "this is a once in a lifetime opportunity <laughs> to stay in California," and I really liked the environment, the scenery, the coast. It was hard to beat. Even Konstanz was beautiful, this was paradise, too, <laughs> no doubt about it. So, I said yes and this is how I started. But I was always planning to go back to Germany. I said, "I'll take this job now for 1, 2 or 3 years. But then it just kept on longer and longer and I liked my work and I was like a kid in the candy store. Because I always had the freedom. I could choose what I wanted to do, so nobody told me, "Erhard, you need to do exactly this or this." This was not the case. I always could pick what I wanted to do and it typically also helped the program and the development and other people to learn something, so there was a good part. And I learned a lot and I still do. In IBM, they are experts everywhere, no matter what you think. And IBM had this capability at the time with email. Nobody else had this, the Bitnet. You could communicate worldwide with anyone in IBM and universities. Universities who had IBM computers were also on the Bitnet network. So that was another incredible difference to everything else. I felt the capability, you have a question and then maybe you ask someone else do you know someone, an expert in this area, and sure enough there is someone. And it doesn't matter where, in Yorktown Heights or in Zurich or somewhere, you always found someone. And it was incredible. That's all I can say. And maybe I can talk a little bit more later when I changed job. But till '96 this kept me completely happy with all my work.

Marchon: So what were the major technological issues or breakthroughs that you worked on over that tenure at IBM? You were 6 years in this Product Division?

Schreck: Part of it was still flying height related, like I mentioned before, with this capacitance measurement, there were flying height issues. It wasn't clear how the head was behaving when it was seeking fast. I could measure the dynamics of the head, and if it made contact with the disk or not. So that helped. And then this went back to the air bearing designers who then had a better understanding of what's going on. I also worked on the load/unload scheme, when you go down the ramp on the mobile drive. There are certain vibrations that you want to characterize. I worked with shock events. There were discussions. Typically, the mobile devices used glass disks because they're more robust, whereas aluminum disks, they're softer for the normal desktop drives. And then one thing I really was proud of was the Wallace spacing formula. Basically, the magnetic signal decays exponentially when you go away from the recorded track. And we use this today. This is one of our finest tools I think we have for fly height measurement in the drive. We can today measure it to 10 picometer accuracy. And this fascinated me. And then again, probably a little bit with my liking for software and programming, I developed what I called magnetic read back mapping. Basically, when you read back the signal from neighboring tracks, you produce an image. You have line by line by line like the AFM where you have all these lines and then you put it in a 2D plot and you have an image. And that's what I initially used when the head was bouncing on to the disk, on the aluminum disk it produced an indent and when you tried to read back the signal, the signal is gone because it's too far away. It's decaying exponentially so at some point it's gone. And I could characterize the damage you get from specific shock events in terms of accurate area and data loss. And I remember when I presented this the first time there was one older senior person, he got up and clapped and said, "This is the best talk I ever saw on this subject". Because I could quantify without going to optical instruments, where you still don't have the magnetic signal information, I could directly say, "Here we lose so much amplitude or SNR, whatever you want to use as the metrics," and could say "so many bits are gone," basically. This was the magnetic read back project, and the way I could implement it at IBM. But I still felt that at the time in IBM the work was very departmentalized, so you had your area and other people had their area. Like, I never talked to a servo person while I was in my HDI field. I never even talked to a firmware person who did something related even to HDI. Because this was just separated. And in a way, I felt limited. The interaction, the cross-functional interaction was not, I felt, was not there in a simple way.

Marchon: So that was the early-1990s to mid-90s ?

Schreck: Right, mid-90s, yes.

Marchon: And so, IBM invented the disk drive, right, the RAMAC in 1955. Then the big players like Hitachi and Control Data came. But then in the eighties and nineties, you had all the small players like Seagate, Maxtor, Quantum, etc.. who all started to compete with IBM and I think IBM in that period of time actually had some very hard time competing with them.

Schreck: They were behind. When the thin film disk came out, Seagate was the first one with the 5.25 thin film disk. My first experiment was still with this 14-inch particulate media, you know, the brown media, whatever they called it. And luckily, just right at this time in the early nineties, then the thin film disks became popular, and this is when IBM also realized this is what they needed to do. And so, all my initial main work was done on the thin film disks. I didn't really like these big ones. They were scary when they were spinning. <laughs> So much energy in those things.

Marchon: Too much energy. Okay, so the IBM business, or at least on the hard disk side, wasn't too healthy. Is it the reason why, with some of the reasons you mentioned about the compartmentalization of technology at IBM, you left IBM?

Schreck: Yes.

Marchon: Could you say a little more about that and what company you joined then.

Schreck: So I joined Maxtor in '96. One thing IBM did was, whenever you submitted a patent and the patent was not granted, or the patent committee decided it's not worthwhile, they published it in I think it was called "IBM Technical Disclosure Bulletin", in a booklet. So, it was published and public knowledge. Nobody else could then get a patent on it, so this is how they protected this. They didn't want to go for the patent because that costs a lot of money, but they published it and this "IBM Technical Disclosure Bulletin," this was full of all these things that were not considered good enough for a patent but there was so much knowledge in the “Encyclopedia Britannica” of this type. <laughs> And other people outside IBM looked at those, that's what I learned when I left. When I left, I realized there are smart people out there, too. In Maxtor there were people from other companies. It was just a mix of all kinds of other company people. And every company does things in a little bit different way, but clearly, these people were not oblivious to what IBM was doing because there were patents and there were these publications and they were faster in implementing the ideas from IBM. And that was clearly an advantage. And for me, one big difference was going from IBM. All I did in IBM was spin stand work, which was excellent for the learning phase, but at some point, you also want to see how does a real drive work and this was the opportunity I had at Maxtor. Maxtor had Guzik testers for recording aerial density (ADC) evaluations, but everything else was done in the drive. The drive was our tester. I still remember just seeing the first drive connected to the computer. At that time, you could still open the top cover and the drive was still working. <laughs> You know, it's not falling apart or not working because the track density is so high now and you deform everything. You could open the top cover. You had it connected to the computer, and you just typed "seek" from cylinder 0 to maybe 30,000 at the time, and then whoop, it went to the ID. And just seeing this simple mechanical motion fascinated me. And that just gave me a lot of new ideas for what I could do. So I should say that initially, I wasn't really planning to leave IBM. I felt IBM was a little bit behind in the pay scale, so IBM was an excellent company because they provided lifetime employment --

Marchon: At the time. <laughs>

Schreck: Yes at the time. But when I joined, they had the first layoff, I think in '93 which was a shock for all the people. But before, there was generations of people working at IBM. The dad was working, the son or daughter, because IBM didn't lay off people. But clearly at some point the salary was not as competitive and because money was tight, I sort of got the hint from my manager who said, "Look, I cannot really increase easily. But if you come with an offer from outside then we can work on it." Then I thought, I can maybe do that. And at that time, people had already left from IBM to Maxtor among others. So, I went to Maxtor, and Tadashi was one of the people also. I went to Maxtor initially only to kind of get an offer and maybe go back.

Marchon: And negotiate.

Schreck: But I tell you, the moment I walked into Maxtor and talked to people after half an hour or an hour, I knew that this was the place I wanted to work. And there was no way back for me to IBM. I thought, "As long as Maxtor is giving me a decent offer, I’m done." And that's exactly what happened. I just saw immediately the opportunities I could have in Maxtor with my expertise where I could contribute and that just made me very excited. And then I went back to IBM and then they immediately gave you a new opportunity. But it was too late. Once you made up your mind, it's actually lots of pain. Most people know when you look for a new job and you work for a company you like, it gives you sleepless nights. So, once you're over this you're really done. <laughs> So then I joined Maxtor and this was I think still the 10 best years. And then there's the time with you in IBM in the Research area and that was great, too. But this was clearly 10 solid years, maybe 8 <laughs> because in the end it wasn't so great either. But the work environment, the no-barriers among departments. I could talk to anyone. And nobody felt offended. If I came to the servo person and say, "Oh, how about can we change this or can we do this?" Or they came to us, HDI, and say, "Why do we need to do this?", and we talked about it. And that was hard to beat, this interaction.

Marchon: Tell me about some of the technical innovations you worked on and implemented.

Schreck: The magnetic readback mapping, what I said before. At IBM, I was limited then on the spin stand. When I went to Maxtor, we hired a former engineer in our group, and I implemented this same technique in the drive. And this became-- I'm still proud of this one-- this became the major Failure Analysis (FA) tool in the drive before you tear it down. So many times, you didn't even need to tear it down because with this magnetic readback mapping, you could see what HDI problems were happening on the disk. You could see scratches, dings, magnetic erasures, all these things you could study even without taking the thing apart. And then we developed (actually Jack Tsai came up with this idea), we developed the magnetic marking where you have a problem on the disk and then you put a magnetic patterns around it, and then you can tear it down and inspect it with other tools, like the Candela analysis tools, or AFM. But the magnetic readback mapping was a superb tool before you tear it down. And one other thing which only I could do at Maxtor because we had the firmware support, there was no limitation. At that time, you may remember, we used the laser bumps at the ID because the head was landing on the disk and to avoid stiction, we needed this corrugation on the media. And this was done with laser bumps, also invented at IBM. So many things were invented at IBM.

Marchon: Seagate

Schreck: Seagate did it first?

Marchon: Has the original laser texture patent.

Schreck: Oh, I didn't know that.

Marchon: Rajiv Ranjan.

Schreck: Oh, I didn't know.

Marchon: With some CMU people as a matter of fact.

Schreck: Yes, yes. Maxtor was not making their own disks and own heads like IBM. IBM had heads, disks, pre-amp, channel, everything in house. We had to buy them from vendors, and people very often said, "Maxtor is not really a great company because they just buy these components and put them together." It's much more difficult to put these different components together and make it work, with the variation each one had. We got laser disks from different vendors, obviously, and each vendor had their own way of doing the bumps. And they all had their own shapes and densities. And sometimes there were issues in the drive with the laser bumps. So, I could use the magnetic readback mapping. Normally, without firmware change, you cannot go in this landing zone. So, I asked our firmware person: can we extend the servo to the ID? And we could. And then we could map the laser bumps with the magnetic readback signal. And I have published that one. We did the direct comparison of AFM traces and Wallace spacing traces and they were identical. So again, without tearing down the drive, taking the disk out and inspecting the laser bumps, we could measure in the full drive and drew our conclusions. So, the magnetic readback mapping became for Maxtor a major tool and obviously, there was a lot of work that needed to be done in the drive because each drive is different. You know, the newer drives had different parameters. So, there were actually at least one person always involved in upgrading the tool for being compatible with the new programs. But yes, I think I was very proud with that technique.

Marchon: So, at the time you had all these small companies that became big like Seagate, Conner Peripherals, Quantum, Maxtor. Some of them were vertically integrated like Seagate and some of them were not like Maxtor. And I think at the end there was always the discussion, should we get vertically integrated or not? And I think Maxtor started to do their own media, their own disks with Maxmedia? But at the end, was Maxtor successful and did it flourish as a company? Or did they get through some hard times? And if they did, why do you think?

Schreck: We did, but we recovered. When I joined, Mike Cannon was the CEO and I think he was what they call a turnaround CEO. He definitely brought the company back into profitability. Here in California, we had all these technologies, and in Longmont was production and drive development. And at some point, I think the Longmont people complained and said, "these people just play around." Pantelis Alexopoulos at the time was the CTO. So we then also developed drive programs. And one program we did was actually a thinner drive, not 1-inch but I think 17 millimeter height only, which is always a tricky thing when you introduce a new form factor, usually that is not so welcome. But the argument on this drive, and this was successful from all I know, actually very successful, it was only a single platter drive and only one surface was used. And the benefit of this was we only needed one head. And that makes it cheaper. The head is an expensive component. And we could do this because at that time we had the highest aerial density in the drive. There is what they call the sweet spot in the capacity that the market always favored, the main thing that people buy. And with this one surface and the highest aerial density, we could actually hit the sweet spot, and the design was just sort of ingenious. There was the baseplate, then you put the head in. It was on the bottom, facing up. Then you put the disk on top of it and then you screw it down and that was it. The top surface of the disk was unused, and this was so simple, and it was also simple for experiments, because you could just easily swap out the disk, put the new one in or take the head out and put the new one in. This was such a beautiful drive design for experimental purposes, and we just all loved it. And they made it more efficient because only one surface was used. They processed two disks in parallel: they put them back-to-back and basically treated it like a single disk. And I always thought, how do they get this thing apart? But somehow this worked that you could pry them apart fairly easily, without bending them. That was good because you treated them like a single disk, but you got two pieces out of it. That was a successful project. Also I think Maxtor invented, and has the original patent for the TFC, or thermal fly height control. And we worked on the implementation, and I was proud to be part of that team that was tasked with how to integrate this TFC into the drive, what kind of power control we needed to make the fly height and time constant characterizations. So that's what I did in my team: all these thermomechanical evaluations. And also, the integration, what the pre-amp needed to be doing, how to control the feature. Initially it was thought that we could do all this in six months. <laughs> And then it took two and a half years or so.

Marchon: But was Maxtor the first one to ship?

Schreck: No. Unfortunately, not. Maxtor went for the full luxury implementation where we wanted to control in situ the flying height. And we thought we had everything protected on this technology with our vendor. So, here's maybe the disadvantage: if you don't make your own head, you need to talk to someone. And the moment you talk to someone, easily they talk to someone else.

Marchon: And very quickly the whole world, yes?

Schreck: Yes, very quickly the whole world knows. I don't know how Apple keeps their secrets, but that's what it is. And then Seagate beat us to it because they went for the simpler implementation. The problem is once you go to a lower flying height, the manufacturing of the slider has tolerances. So, when you go to 10 nanometers, it's becoming very tough to go to seven nanometer and have a reasonable yield where all heads fly at seven nanometers. And this was the big benefit of the fly height adjustment that suddenly you could use a wide range of the heads fabricated because you could make up for the variation with your fly height adjust. And Seagate did a very simple implementation where they basically took the high-flying heads, then adjusted to a fixed value and brought it down and that was it. There was no interactive control. And that helped already a lot, and this was the first implementation. And I think we were probably half a year or three-quarters of a year later with our better implementation. And unfortunately, at that time was also a decision made that the product, this was a mobile product, was not needed and it was not good for the market at the time. Later on, it turned out it would have been very good, but these are the decisions that sometimes come out and from various marketing evaluations and then they turn out they're not right. In the end, we had built the mobile drive with the full fly-height adjust control, but that did not become a product.

Marchon: So, Erhard, we talked a little bit about Maxtor and the transition from desktop computing to mobile computing and the transition from 3-1/2 inch drives to 2-1/2. And you mentioned that Maxtor didn't do the transition quickly enough. Could you talk some more about this?

Schreck: We had desktop and mobile programs. We also did (I think IBM was actually the first one) the micro drive. And I probably do not have enough knowledge to say what exactly would have been the ideal transition or speed for different products. It seems like even the marketing team did not exactly know what was the best fit at that time for the market. All I know is that I think our desktop drives were well-received. This 17mm drive I told you about, with one disk, was a good success and there was a follow-up with two flavors. Then the 2-1/2 inch, unfortunately, never became a product. This was at that time when Maxtor merged with Quantum. And I probably shouldn't say too much because there is a lot of politics going on with it, but at least from my engineering side, I can say that Quantum had the server drives. They also had already worked on a small 1-inch or maybe 1.7-inch drive. People always say one plus one is more than two, the synergy thing, which really works. I felt we were promised that with the merger, we would have a much bigger variety in drives. But it didn’t take long, and one after another, these programs were canceled. Other people know clearly better what the financial reasoning was and all the marketing reasons, and I cannot speak to that one. But initially it looked like yes, this is a good enhancement for Maxtor, and it turned out it was not.

Marchon: Were there bad days then in technology. And did you leave Maxtor after a while even though that was one of the best places you worked in?

Schreck: Well, yes.

Marchon: Was that because the business was dead?

Schreck: Right. In the end, we got bought by Seagate and some of us had the option to join Seagate in other locations, but I don't even know if anyone took this offer. I could have gone to Longmont or Minneapolis, but I decided I didn’t want to move and that’s where I (that was the funny part) <laughs>, that’s where I thought, okay, maybe I should go back to IBM, which by that time I think it was Hitachi? I forgot actually.

Marchon: HGST?

Schreck: Yes, HGST. We can call it IBM, it's still the same people, same everything. <laughs> And this was exactly what it was. I came back from Maxtor where I felt things worked fast, and things had a sense of urgency. <laughs> I need to be careful here, it's a recording. It was definitely different coming back from Maxtor to HGST at the time, or to IBM. And it had not changed. It was nice for me to meet all the same people. I felt home right away again, and I think we were welcome, they recognized us. <laughs> And I just felt after a while that I got used to another work style. I think I was only there nine months, and this opportunity came up with Headway. I didn't know much about Headway. I knew who Headway was because we worked with them at Maxtor too. Headway was simply a head manufacturer, a component company. So, I joined Headway, I worked there a total of 4 years. But after 2 years, it’s a component company, so you only focus on one piece. And my responsibility was reader reliability. And I noticed pretty soon that I was missing the entire drive. So, after two years, I felt this is not ideal, and I was about to leave, but then the opportunity came up in Headway starting the HAMR project, the heat-assisted magnetic recording. So that was brought to me, and they said “Erhard, do you want to maybe do this work? This is new, and we can do some kind of a research activity here.” People thought this is what I like, and that is true, that’s what I liked. So, I said “Yes, I stay, and I do this HAMR thing.” So, I did set up the HAMR lab, hired people, and the benefit was TDK, since Headway and TDK were also working together. TDK already had worked on HAMR for longer, and they actually had already made quite nice progress. So, I did not start HAMR from scratch overall, I could benefit from the Headway work they did already. But I brought new ideas to the program, or to the project I should say, and it was clearly super interesting. I thought the pace was increasing from IBM to Maxtor, to Headway. Headway was a smaller company, so the people who did wafer processing were also closer to me, so I could see how they worked. My impression was the speed, how they tried different wafer flavors, layout, head variations. It was just incredible how fast this went. Now I cannot completely speak for IBM because at IBM I was the HDI person. I had no business to really get involved with the wafer people, or anyone else, those were separate. It was impressive how fast Headway worked. When they decided to do something, they’d do it 100%, not halfway: “Let’s see how things go.” So, there was money available. I remember one case where I went to a trade show in San Francisco, and they had a near-field optical microscope worth perhaps $250k. I came back in the evening to Headway and talked to the president and said “This would be really helpful for us”. The next day, I could buy it. It was a small company, there was no bureaucracy involved. That was just fantastic. So, we set up this HAMR lab, and what I brought, my interest was still either spin-stand or disk drive, and we set up a HAMR tester, and HAMR head evaluation to quantify the light quality and the intensity. At the beginning, these HAMR heads only lasted milliseconds, so that was all you got to work with. My goal was to be able to servo-write with a HAMR head (we also had a HAMR disk from a vendor, Showa Denko) because nobody knew if this was actually working, and how this would go. It was, I would say, a reasonably long path to do that, but in the end, my team accomplished the

HAMR servo writing. At the time, the HAMR technical leader from TDK was very frustrated about the progress. I think Seagate started HAMR in 2003 and they still have no product today, so it is very slow progress overall. He was frustrated, and we just actually accomplished this servo writing, but he didn't know at the time. He just arrived in San Francisco for a quarterly meeting where everyone got together. On the way back I told him "we can do the servo writing now." He also felt like this was a great milestone for the HAMR progress, to see that things were working this far. For me, that was my personal milestone. But there were things going on where I also became less and less happy with Headway because I still missed the drive. Even with HDI, the tester, the things I built up, it wasn't so appreciated in this environment, because there was not the full drive knowledge behind. This was the component. Usually, Headway gives you the component as a drive integrator, and says "You tell me now is it working for you or not" So, that was different, and after that time, again, I felt "I'm missing the drive, I need to do something else." But I'm not a quitter, I usually finish what I start. This was my milestone, and after we accomplished this servo writing, I felt like "that's the time." Yes, I took a time out there, <laughs> a sabbatical then.

Marchon: Sorry to interrupt, but you mentioned that Seagate started HAMR in 2003, but I think they started when they acquired Quinta, which was 1998. So...

Schreck: Oh, even earlier.

Marchon: Yes, so the Quinta acquisition by Seagate was in '98, which actually led--

Schreck: So this is when they also had HAMR?

Marchon: Quinta was heat-assisted, near-field, and by the way that was the demise of Al Shugart who got fired by the board at Seagate.

Schreck: Over this?

Marchon: He was fired because he spent way too much money. That's one of the reasons. <laughter> But that was '98, so here we are, 24 years later, and HAMR is still not in a product, and we can talk about that a little later.

Schreck: You're right. It's even longer.

Marchon: But, so, you were so frustrated that you really wanted to put your hands more on the finished product, the disk drive, and so you joined HGST?

Schreck: Yes, you called me, or we got in touch, and you offered me this opportunity, joining the research environment, your group. That was really very intriguing, again, because I felt like "Yes, this is great, this is what I like," the variety of activities. So that worked out well. I would say looking back, that initially, it was described as "Erhard, here is a researchy project, HAMR." It didn't take too long when they thought "This researchy thing <laughs> is maybe not what we really want. When can this be in a product?” <laughs> Then the pressure started building up, you had weekly progress meetings, and HAMR was slow. It’s very tough every week to hear “What is the progress?”, when sometimes <laughs> there was no progress. I hated this. <laughs>

Marchon: Yes, how did you feel about coming to a company like HGST that started very late in HAMR? I think part of the IBM legacy was steering the technology more into patterned media, which also went nowhere, when Seagate was going into heat-assisted recording. So, you came to IBM/Hitachi/WD, which had just started. As a matter of fact, we asked you to spearhead at least part of the HAMR program. And so did you feel that we were way behind?

Schreck: Really way behind, I left Headway after we did the servo writing, and we had already a fully integrated head, which was made by TDK at the time. So, yes, when I joined your team, I think my focus was to spearhead the HDI, and then do some more mechanical work. It was way behind. But also, I still liked HAMR because first of all, there were many naysayers who said: “This is never going to work.” I always felt like “Yes, it can work.” Part of it was basically disproving all these people. But that it’s so hard to get a technology into a product, I think many people are surprised by it. I still think it’s a viable path, but obviously it’s completely different <laughs> with an HDI environment of 400-500 degree media temperature, and 200 degree in the head. We hate temperature, <laughs> and here you do the worst thing you can think of, and then you say “Make it work for five years”. <laughs> But the nice thing about this was joining your team. I knew things can at least go this far already, and there was not a secret, it wasn’t like I brought a lot of unknown things we could do. It was simply hard work. Luckily, we got early integrated heads, while other people who worked a little bit earlier had to do external recording with and external free beam which was even more cumbersome. So luckily there was already good progress, even if the lifetime was not really fantastic.

Marchon: So that was 2011 when you joined ?

Schreck: It was 2011

Marchon: so it’s 11 years ago. We still don’t have a HAMR drive that I can go and buy today. I know there are HAMR drives now in customer’s hands that Seagate is touting, and perhaps WD also. I think Seagate, in some of the investor calls, said that the technology is ready, but they’re waiting for the 30 terabyte capacity point to ship it. What do you think? I know that some information is confidential, but as far as the technology goes--

Schreck: -on the bigger picture, we don’t have all the details from Seagate. Obviously, we would love to get one of their drives to look at. What is interesting, you probably also would agree, many times when you see competitors do something, what we say in Germany is “they also cook with water”. It's rare, I cannot even cite a case where you suddenly take something from the competitor, look at it, and say “this is fantastic, we never thought about this.” Typically, it’s all incremental improvements, and here a tweak, and there a tweak, and it makes it better overall. We had the same when we merged with Quantum. I remember there was the rumor that “Quantum has higher areal density. They have a better channel efficiency,” whatever. When we merged with them, they set up a taskforce to look into all these details.

There was nothing standing out that they did differently. It was all little incremental improvements that made it overall better. There's clearly one thing in HAMR when you go from spin-stand to a drive: things work differently, there are surprises. On the spin-stand maybe you don't have the same servo pattern, it's just different how the physics works. But in the end, you can explain most of it. So why is HAMR not a product today? The simple take is that getting high areal density is still a challenge, and when you look at the papers and the projection, people think four terabit per square (is achievable). Remember that today, we're around one 1.1 with PMR, or ePMR, the energy assist PMR. 1.1 terabit per square inch with HAMR is on granular media, supposedly going to four terabit per square inch. But today, to at least my understanding, the Seagate drive is well below 1.5 terabit per square inch. The HAMR head is more expensive, so if you don't get enough areal density you still need to put in all these heads and disks, and there is no cost savings. So, what do you do with this? Look, WD just announced, which I found impressive, I don't know if you saw it, a 26-terabyte drive. This is SMR, shingled magnetic recording, the same technology in non-shingle is 22, so that is actually pretty nice. Shingled magnetic recording, after many, many years, is becoming more accepted by the customers, also because the performance has improved, with the algorithm. So, it comes down to areal density. Seagate has demoed on spin-stand an areal density of maybe 2.4 terabit per square inch, if you take everything into account, which is really nice.

Marchon: With HAMR?

Schreck: With HAMR. But this is not, from all I and we understand, this is not what's in the drive. There's always this compromise in HAMR between performance and lifetime, and you need both in a product.

Marchon: Do you think HAMR is ever going to be out there, in the market?

Schreck: I think absolutely, and why do I say this? One thing is I believe in engineering talents. I think we have-- and I say this, I think, in all companies, we have excellent engineers, and if they get the right resources, and time, and put their mind to it, they can solve the problems. So, I believe strongly in this capability of our engineers. It will work. How quickly? Obviously, it already took way, way longer than anyone expected. I mean, how often did Seagate-- not to blame Seagate, but the point is still how often did they announce we will have the product by end of the year? Way too long because there were always other issues. But in the end, I believe Seagate has managed most of the problems of the HAMR interface in the drive. But it's still the areal density that needs to come up to make it viable.

Marchon: I know some people might say perpendicular recording was also a laboratory curiosity for a long time before time was ripe to implement it into a product. Which we did in '05, or '06.

Schreck: This is so radical, HAMR. It's a change. Tell me another example where a drive undergoes such an extreme change. Even MR (magnetoresistive) heads, how long were MR heads in development at IBM? I thought that was at least eight years.

Marchon: MR heads? Yes.

Schreck: Yes, it took a very long time. HAMR is probably one of the longest projects. Look, there is MAMR on the other side, and energy assisted ePMR is something in between. It still helps to improve the areal density today, but not by 2X or 3X. It's going slowly. But it still helps to increase it until the HAMR will be kicking in.

Marchon: So, Erhard, in almost two hours, we went all the way from your childhood to today, including your forty-some years in your HDD hard disk career. Reflecting back at your achievements in the disk drive business, and looking at all your inventions and innovations, can you tell us which invention you're the proudest of? And perhaps which inventions you've had that you're very proud of, that actually never made it to a product?

Schreck: Yes. <laughs> don't you like my random numbers which never made it <laughs> in a product? Thank you.

Marchon: Let's talk about it.

Schreck: Random numbers was a very interesting project at Maxtor. Typically, we talk about SNR, signal-to-noise in the disk drive. You want to read your bits back, but there's a lot of noise around it, so you need to spend quite an effort to extract the signal you want from all the noise. I thought "With all the noise, maybe we can use the noise for something else," and the something else would be random numbers. Because random numbers are a key for encryption technologies, so there is a good use for random numbers. Random numbers are used in a variety of fields, experiments, physics. So random numbers are a good thing. You can do mathematical algorithms that produce you strings that also look like random numbers. But if you start with the same seed, you get the same string, and that is different from the real random numbers. The real random numbers, it's just the nature which makes—every time it's different, and here the thought was: let's use this noise from the readback signal from the read channel and see how we can convert this noise to a random number sequence. I was lucky at the time, there was a former friend in Germany who was working on random numbers. He had some interest in it at least, and he had just a sabbatical opportunity. So, I could invite him to Maxtor¸ and we worked on this random number project. In the end, we were able to use the disk drive to produce a reasonably good bandwidth, like five-hundred kilobits per second in random number stream. The idea was that the disk drive is really suitable for this because first of all, it can produce random numbers, and if you need a faster bit stream, you can buffer all your random numbers on the drive. It's already a storage device, so whenever the drive is idling, it could produce these random numbers, and put it in a certain area on the disk. When suddenly you have a high demand, you can just pull it off with your super high read bandwidth. So that's what we demonstrated, and so I learned a little bit about random numbers. There are two funny anecdotes I would want to say. While we were working on the random numbers, suddenly there was a New York Times article <laughs> about-- yes, it still makes me laugh, it's so funny, about the lava lamp. So, most people know these lava lamp where you have this two-phase liquid, and it's like a bubble coming up, and changing the shape, and then going down due to the convection, there's the heat lamp underneath. So, this seemingly chaotic system, someone took and exploited it to extract the random numbers with-- I forgot now, but I think it was one bit per minute. It was really extremely slow, but it made this New York Times article, and we worked on our disk drive random numbers with five-hundred

<laughs> kilobit, and nobody noticed. <laughs> So we thought that was really funny, <laughs>. And then this was during the dot com time where you had startups that came out like wheat everywhere. <laughs> So there was a startup in Florida which came up with this new compression algorithm, which was 7-10 times better than the zip compression algorithm we use. So that's what they announced, and we invited the person, because if you can compress your data stream, that is proportional to your bandwidth. If I can compress my data stream 5X, I gain 5X in data rate. This is just very intriguing for everyone who works with data streams. So, the person came out and gave a presentation, and no matter how much you understood from his presentation, what we understood were our random numbers. One key property of a random number is that you cannot compress it. <laughs>,no way. We had our data stream, and we made a disk with a hundred megabyte, which is reasonable. In theory, even if I give you a hundred megabyte, you don't know if this is a real random number, because this may be just it. If I give you two-hundred megabyte, it maybe just is the repeat from the hundred megabytes. So, you never can be sure if your random number is the real random number. You can have a high probability, but the sequence, the length, you never can be sure. But a hundred megabyte was definitely a good number for him to work with. So, we gave him the CD and said "take it home, compress <laughs> it, send it back to us," and we never heard again from him. <laughs> I liked this project because it made a secondary use of the disk drive, where you had already all the components there, and it worked quite well. We thought this could enhance Maxtor products at the time, because we could tell the customer "Here, you get free random numbers." I think even today you can buy hardware random numbers in computer chips. You can add to your PC, and it's a real random number source, and some of them use radioactive decay, which is really random. But you can also use electronic noise from diode junctions. This noise is not a perfect random number and you need to do some processing and throw away some parts of the signal, but then you still end up with a reasonable high percentage of good noise. So, we thought this is nice for Maxtor products, and we could add this feature. It's basically free because all you need to do is this little firmware change. Then, I never forgot this, marketing said "We don't want the Maxtor drive to <laughs> be different." <laughter> We both sat there and said "<laughs> well, what is that now?" I heard this actually many times since, because if you offer a new feature in your drive, the customer usually doesn't want one source. The customer wants multiple sources because I could suddenly run into a problem. Manufacturing could be in an earthquake area and suddenly could go down and not able to deliver drives. So, the customer needs to have an escape route. So that's why they like that all the different flavors from different sources are the same, so that's the thinking they have. But on the other side, you would say that if you build a product with a new feature, you're in the lead. The other people will follow maybe a few months later, they can do the same thing. Then it is on par with each other. We thought, back to random number, the best way if you want to encrypt anything is what they call a one-time pad. That means any text or information will be encrypted with exactly the same amount of random data. The point is, if you have a lot of data to encrypt, you need a lot of random data, because you just used them up. It's like you used them, and that's it. So, if I have a hundred megabyte of random data and I use a one-time pad, I can only encrypt a hundred megabyte of data, that's it. So, the need for a large supply of random data we clearly saw there. But obviously, it wasn't, I shouldn't say good enough. It wasn't different enough from pseudo-random numbers because for most practical purposes, the pseudo-random number is as good. I cannot tell you from a hundred-megabyte string if this is a pseudo random number generated string, or a real random. I cannot. So, this is where maybe the argument for many people is my pseudo random numbers are just

fine. Even I could run in the case where I use the same seed, and I get the same sequence. But that's just it. So that was a good thing.

Marchon: So, conversely, of your hundred plus patents, which one do you think had the most impact in the hard disk business?

Schreck: Many of the patents solved part of the problems in the drive. I don't think I have one patent where I would say this made the drive work, without this it wouldn't. I don't have a patent like this. Most patents are incremental improvements to drive technology, which helps the drive be better. But it's not a go, no-go patent. I would say that a really very valuable patent is the thermal fly height control (TFC). The way this came about on the Maxtor side is we were in a room, and we were thinking, brainstorming about fly height control. In the end we had two technologies left, one was piezoelectric, and one was the thermal. I was stronger on the piezoelectric, and I could see the piezoelectric actuation was more suitable system than the thermal, with the slowness and everything. So, I was on the patent with the piezo, and other people were on the patent with the TFC. If I had been on the TFC, I would tell you that the TFC is my strongest patent, because clearly the thermal fly height control makes the drive today, and without TFC the drive wouldn't be what it is today. That is for sure. But when you look at the initial dynamics, the way it works, you wouldn't say this is the ideal way of doing it. That's why I thought the piezo, with its fast actuation, and the low power consumption, is like a capacitor and is better. With thermal today, we consume maybe 50 milliwatts, and this power consumption is an issue. You can bring up arguments saying that thermal fly height control is not ideal. But once the people put their mind to it, they make it work. The way it's integrated today in the overall system, it just works very well. This is not a good case, where you have multiple choices. You need to pick one to make progress, that's the key. But very often you can say "I picked this one. Oh, it's so painful. I don't know if you should continue." You most likely succeed if you put enough engineering power behind it, and after 50%, turning around and switching to the other is probably not the best solution. I think this is my dilemma with ideas: you always have multiple solutions, and the key is picking one. Making a decision is better than making no <laughs> decision, I think that's it.

Marchon: And like you said, the thermal fly height control is a seminal patent from Maxtor. But then it takes another hundred inventions to actually make it work.

Schreck: Yes, so there is one from Dallas Meyer, from Seagate, it's a patent. It was a little bit different. Basically, when this is the slider, we know the thermal fly height produces this little bulge here in the read-write area, and the Dallas Meyer patent put some heater in the middle of the slider and changes the crown. That also causes a fly height change. But now there are things, from what we understand, from the interface. Let's say I had a perfectly ideal slider, and now we're flying at 10 nanometers. Now if I bring it down to one nanometer, that will not work because now I have such a large area coming in contact, and the van der Waals forces basically collapses my air bearing. This was not the reason why TFC was introduced, but luckily today we know that it only produces a small area, so that means the van der Waals force is small, and it's not collapsing, even if you go down to a nanometer. So, these are interesting details that very often come out later when you keep on progressing and implementing something.

Marchon: We're getting close to the conclusion here. Do you see the end of disk drive technology anywhere soon?

Schreck: Yes, I saw it 30 years ago. As you <laughs> know, everyone said it comes to an end because we have optical, and 3D, and now we have probably DNA. I don't know, something will kill the disk drive. No, there's no quick end. I can say this from WD, there was a time where the people thought the rotating storage is coming to an end, when the solid-state and non-volatile storage came up. And everyone thought "solid-state memory will come down in cost, and then the disk drive is here, and then there's a crossover point." It didn't happen the way it was predicted. It still is today roughly, depending on the application, five to eight times more expensive, according to Facebook, who obviously is a huge consumer of storage. The rotating storage is here to stay. There is nothing that will replace it in the near future. We need to make it less expensive because everyone shows this exponential growth of data generation. We need to make the areal density higher so we can have affordable storage and set all this. Even with HAMR taking a long time, maybe MAMR is another branch of energy assist storage. The rotating disk drive, I think it's just hard to beat in the simplicity. Once you have your recording technology all set up, we still can improve what we do today, with mechanics. Yes, now we're back at the mechanics. I said at the beginning, I love mechanics. We always thought a watch is a fantastic mechanical device, but our disk drive beats the watch <laughs> in many areas. So, my belief is the disk drive will be around for a long time, and if young people want to join the disk drive industry, and have this eagerness to work in this field, it's a tremendously interesting area to work in. That's what I would say.

Marchon: And my last question, Erhard, is, reflecting back again on your career, and the success you had, is there something that you could have done differently that, if you were to do it again, you would do differently?

Schreck: Given the situation today, I should have bought more houses. <laughs> But--

Marchon: <laughs> Talking about your career.

Schreck: I failed completely in that career path. <laughter> No, okay, I'm 30 plus years in this field, and very early on, when I was still a postdoc, I went back home to visit, maybe two, three times, and I gave presentations at my university about disk drive technology. And even there, people didn't know what was in a disk drive, how it really worked. I saw how people were fascinated, even from my simple presentation, when I showed them just the basics. When you tell a physicist "here is a device, and the head flies at 30 meter per second at a height of one nanometer", they just get glary eyes, because this is a fantastic accomplishment. For me it doesn't matter if it's the servo, the channel, or the chemistry at the interface. It's such a large variety of problems that look at you. Some you can solve, some are tougher. But there is no time where you say "It's all done." So, for me, getting in touch with disk drive technology was a real enhancement. It suited me well for my variety of interests. I don't know if I could have found a different field. I sometimes thought about medical devices, where I feel there is more immediate sense in helping other people. In the disk drive industry, I often ask myself "What good does it do?" Today, social media wouldn't exist without the disk drive, that is very clear. And with the way social media has developed, you sometimes ask yourself "Can I say now I'm not responsible for this?" This is an ethical or a moral question that comes up. Today I cannot set myself apart and say I have no responsibility in society, because the disk drive has a big impact on society, with the storage capability. So, from that, it also has obviously a lot of positive effects, so you always need to balance the negative and the positive. Luckily, I think the disk drive has more positive benefits than negatives, and that again fits my personality where I feel that it is doing something great. It is still giving me the excitement to help discover new things, sometimes solve problems and help the products move forward. I think I cannot say what should I have changed to feel better. I'm happy with it. <laughs>

Marchon: With these words, this concludes the interview. I'd like to congratulate you again for your great career. You're actually still working…

Schreck: I'm still working, yes.

Marchon: so I wish you the best for the years to come, and I'd like to thank you very much for being a good sport, and agreeing to spend two grilling hours answering our questions. Thank you very much, Erhard. This concludes the interview.

Schreck: I just want to say one last thing. I also want to thank you for being part of my career. You offered me opportunities, and I think we both agree we have great colleagues in the community. It is a small community, but in a way, it works very well. That's how I look at it. Thank you also for helping me in my career. <laughter>

Marchon: Thank you, Erhard.

END OF THE INTERVIEW

