Oral History of Jack Harker, with Denis Mee

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Chris Bajorek: I'd like to welcome you to Jack Harker's interview in the series of Computer History Museum interviews of pioneers and technologists who made key contributions to the development of magnetic recording technology in general, but in particular in the form applicable to hard disk drives. Jack is a very unique candidate for this interview because, if I'm not mistaken, you may be one of the few if not only people who has spanned the period from the creation of first hard drive, the RAMAC...

Jack Harker: There aren't many of us left.

Bajorek: And all the way through, I remember-- and we'll talk about it later in the interview-- to the first drive that shipped with a magnetoresistive head.

Harker: Yes.

Bajorek: The Sawmill drive?

Harker: Yes.

Bajorek: So that period spans an extraordinary segment, right, of the evolution of hard drives.

Harker: I was a very lucky person. I was lucky to be in the right place at the right time and picked the right job.

Bajorek: And we'd like to capture your salient experiences for the future. So, I'd like to start out by finding out a little bit about your personal history, and where were you born, where did you grow up, and eventually I want to lead to how did you get to IBM.

Harker: Okay. I'll be happy to do that. I was born in San Francisco. We lived in Berkeley, but in those days, women went a week early to a major hospital and stayed a week. We moved from there to Los Angeles, moved from Los Angeles back east to Scarsdale, moved from there to Seattle, from Seattle back to Berkeley, and then by February of '46, I graduated from Berkeley High. I was supposed to graduate in the spring, but I accelerated so I could get a semester at Berkeley, UC Berkeley, because it was very obvious at that time that when the war ended and all the people came back that colleges were going to be crammed, jammed with people, and if I could get a semester in, then I was admitted.

Bajorek: You were in. You were ahead of the queue.

Harker: Yep. Then in June of that year, just before I turned 18, I enlisted in the Navy. I enlisted to what I think was a very remarkable program. It was named after a commander, Eddie. The Navy, in the middle of the world war, found itself with a lot of electronic equipment on board its ships and more and more complex electronics, and they needed people to maintain it and repair it at sea. So they started a program to train electronics technicians, and that's what I signed up for.

Bajorek: Were you able to volunteer for that or did they draft you into that?

Harker: No, you had to volunteer. If I'd waited until I was 18 I would be drafted. But I could volunteer a few days before, and I went into boot camp. Then you went to one-month training at a school in Chicago, which was a wash-out course because it was very fast paced. Now you took a three-month course, which I took down in Houston, on radio. And essentially, you learned how to design, build and repair radios and the theory of vacuum tubes and designing. Then I went for a six-month stint at Treasure Island, for RADAR school, and by the time you graduated, you could operate, maintain, repair any piece of equipment the Navy had at sea. I graduated as an Electronic Technician's Mate Second Class. I went to sea. The war was over by the time I finished the training. I spent a couple of weeks in Honolulu, which I enjoyed. We went around to the canal, and then we made two trips to Italy with our hangar deck filled with bunks, five high, to bring troops back.

Bajorek: Interesting.

Harker: It was an interesting time. I was discharged in '46. I went back to Berkeley. Berkeley was just jammed with people, UC Berkeley, and I became unhappy with the impersonal instruction. So I had gotten to know a school outside Philadelphia, Swarthmore, when I was in the Philadelphia Navy Yard, and I transferred back to Swarthmore. It has the smallest accredited engineering school in the country. And it was a wonderful education. I graduated there in 1950. Meanwhile, Betsy and I had become close.

Bajorek: You met Betsy at Swarthmore?

Harker: At Swarthmore. It's called the "Little Quaker Match Box."

Bajorek: What was she studying?

Harker: English. And so I graduated in '50. And in '50, jobs were hard to come by. So I went on back to Berkeley to study Reservoir Engineering.

Bajorek: At UC Berkeley?

Harker: At UC Berkeley. Because at that time, that looked like a promising field.

Bajorek: Now, the degree or your studies at Swarthmore were in Mechanical Engineering?

Harker: And I went back to Berkeley to study Reservoir Engineering, which was in the Mechanical Engineering department.

Harker: And I was a lab assistant. That fall, Betsy came out and we were married, and we-- Betsy fell in love with the Bay Area as much as I have. But I proceeded and I graduated with a Master's degree in Mechanical Engineering with the specialty of Reservoir Engineering in February of '52. I'd had a job offer from Magnolia Petroleum, outside Dallas, to run a small laboratory. And I went down there for an interview in January. However, my hotel room, I had to have an air conditioner on. And I came back and Betsy and I talked it over and decided we really didn't want to leave.

Bajorek: You didn't want to leave the Bay Area.

Harker: So I turned the job down. My advisor would have nothing to do with me. It was the first time a graduate of his had been offered a management job.

Bajorek: And you turned it down.

Harker: So fortunately, IBM put a small ad in the *Daily Cal* saying that they were going to open a laboratory in San Jose. That-- and I think you've got a copy of it there.

Bajorek: I think I have a copy of that ad that might be worth putting in the file with this interview.

Harker: Yep. That little ad just announced that they would entertain applicants. So I sent an application in and I was called for an interview and I was hired. I reported, started in May of '52, and I think I was their 19th employee.

Bajorek: And this was a laboratory, it just had been started?

Harker: It had just started about that first of the year. Rey Johnson had been brought out to manage the lab. Rey was one of IBM's inventors. He had come to IBM with the invention of the test scoring machine. He had just completed the development of a serial interpreting card punch, the 026 card punch, which became a ubiquitous machine all over the world. IBM realized they needed more electrical-- electronic people. Cal Tech, UC Berkeley, Stanford, were really major universities that had that kind of talent. And they found it very hard to recruit people from those universities to go back to Endicott or Poughkeepsie. So they decided they'd have a lab out here, and the tools to recruit the talents they wanted. About the same time I started, another fellow started, John Lynott. John came from food processing machinery, where he'd been working in the ordinance division. He had come up from being a draftsman. He had no formal education, but he was a very talented designer. But he was accustomed to a very different scale of design. He was designing vehicles. He said jokingly that the only tools they were allowed to use were a cutting torch and a drill press, and they were going to take the drill press away.

Bajorek: No tools that are good for advanced instrumentation. He wanted to exaggerate that.

Harker: So he and I were assigned by Rey to design a page plotter, a machine where you could print a character any place you wanted to on an 8-1/2 x 11 sheet to be able to make plots and label them.

Bajorek: So that was your first assignment.

Harker: This was our first assignment. And John never designed anything like that. I came out of academia. I'd never had anything I'd designed built. But we made a machine, and it worked. That was my first patent.

Bajorek: Interesting. And this was in...

Harker: '52.

Bajorek: '52.

Harker: In '52 and '53 we went from there to several printer projects. Rey had an interest in printers. But meanwhile, Rey's real heart felt desire was to find a way to mechanize the punch card tub file.

Bajorek: Can you clarify what a tub file was?

Harker: Okay. If you had a punch card accounting system and you were doing billing, you had an inventory; you'd have a punch card-- pre-punched cards for every item in the inventory in a tub file where you pick one of the cards out to identify an item. And you'd also have your customers' data on cards in this file. So if you had an order, you'd read the order and you'd pick a card that had the customer information, and then you'd go down the order for each item and you would pick an item card, and then as you picked it, you'd put these in a punch. And the punch would advance it so you could enter the quantity and that kind of data. So you'd wind up with a deck of cards that represented the customer order. Rey wanted to mechanize that tub file. So one of the fellows that worked for him, Art Critchlow was given the assignment to come up with all the ways he could think of of storing that information mechanically, including, you know, maybe a mechanical picker to pick the card-- Art studied it, came out with a report that had three or four such items. This is the report.

Bajorek: You might want to read the title of the report so we'll all get the...

Harker: Okay. “A Proposal for a Rapid Random Access File”. These were the senior management of the laboratory at that time-- for the camera. This was John Haanstra, Art Critchlow, Lou Stevens, Rey Johnson, Bill Goddard and Manning Hermes. And in this report, one of the proposals was for a set of disks.

Bajorek: Yeah, he had several-- he had configurations like...

Harker: Plates.

Bajorek: Cartesian type drives, stacks of disk that would be accessed with a common actuator.

Harker: Yes, so Rey really latched onto the disk and that started the project. The key problem was if you had this thin disk that had a waviness in it, how did you mount a magnetic head that had to be within at least a thousandth of an inch.

Bajorek: Above a cluster of disks, yeah.

Harker: Above the disk in order to read or write from it. But that problem was solved by Bill Goddard and John Lynott working together. They figured if they made an air bearing where it had a carrier that held the magnetic element, had air holes in it, and it used pneumatic pressure, it could be pushed against the disk with a spring.

Bajorek: And establish an air cushion?

Harker: And the air cushion would maintain the spacing. And that was the invention of the magnetic head writing-- pressurized head writing on a disk. With that in place, the project moved ahead and gathered steam.

Bajorek: Because that was a key enabler for that concept.

Harker: That was the key enabler. And the first model was called the file-the-card machine. And it had a horizontal shaft, a disk, and an access mechanism that would go from disk to disk and then push heads in between on an arm in between the disks. It worked, sort of. In order to get disks flat enough so you could operate on them, we had to use engraver's plates.

Bajorek: These are aluminum?

Harker: This is ALMAG alloy. They're very flat and expensive, about an eighth of an inch thick. And we'd get them in two-foot sheets, so we had a two-foot diameter disk. And we made the disk by first drilling a hole in the center of the plate and then you had a wooden arm with two routers on it, one of which came from Bill Goddard's own shop, and a pin in the middle. And you'd just rotate this arm around and it would cut, you would cut the…

Bajorek: Two concentric grooves, right?

Harker: Yes. And that was the sort of thing, the level of sophistication we were using. Then the file-the-card machine worked. It was attached to a 26 card punch, and it could read the card and magnetically record it and then punch a card with the information that was recorded. About the same time, a couple of studies were done. One was a response to an RFP from the Rome Air Force Base.

Bajorek: A request for quotation.

Harker: A request for proposal for an inventory management system that said they wanted to manage 50,000 parts, 100 character records for 50,000 parts. And we never did bid.

Bajorek: That particular...

Harker: Thank goodness, but it formed a basis for what became the RAMAC, because the RAMAC file stored 50,000 hundred-character records. At that time, Lou Stevens took over the drive project and Rey sort of backed off. He had other things he wanted to work on. And John Haanstra was the lead person in defining the 305 system. He had a small group, Murray Lesser, Matt Gibson, Bill Marrin, I think one other. And they came up with a proposal for the 305 RAMAC, which was a transaction processing computer. And as far as I know, it is the first that was designed that way.

Bajorek: And these may be some of the notes?

Harker: These were his original notes, yes, and there are the names, Tremeling and Leary, on the design of such a machine. That was accepted and the design proceeded. And that was the story of the development of the 305 RAMAC.

Bajorek: The first system that used the first disk drive?

Harker: That used the first disk drive but also which used online storage to process a transaction.

Bajorek: In real time?

Harker: In real time, updating all the affected records. The file design got changed considerably. Lou Stevens had his ideas. He wanted a vertical shaft for ease in changing the disks. And I was assigned to the project along with John Lynott. Trig Noyce was our manager. Don Johnson, and Norm Vogel joined it. We were the mechanical design group. Wes Dickinson and Jim Davis where they did the servo design. And Al Hoagland was a consultant on the magnetic head, and Len Seader did most of the electronic interfacing. He came up with the idea of a self-clocking system. I was assigned the part of it to design the drive mechanism and the rail on which the carriage would operate. John Lynott designed the carriage and the arm assembly. Don Johnson designed the file structure. Norm Vogel came up with a very elegant design for the air-fed head where the head was mounted in a cylindrical housing. The exterior of the head which fit inside that housing was sort of barrel shaped. On the front of the head, you had the magnetic element in the center and air holes spaced around it. On the backside, you had three little holes with pistons in them that faced a rigid plate. So when you applied air pressure, the pistons would drive the head towards the disk and the air bearing would keep it away.

Bajorek: And that's how you balanced it.

Harker: And it was spring loaded so it would retract itself, and that's how the 350 head worked. I wound up designing the drive mechanism, which was a capstan and cable that drove both the carriage up and down and the arms in and out and to do this I had a capstan and two counter rotating magnetic powder clutches that I appropriated from one of our tape drives that drove the tape reels. And that was strictly an on and off application, but I figured why not use them as a servo. And I put beveled face plates on them so I had a rubber pinion that came up and rotated and I got the counter rotation. That pinion was a constant problem. And it all worked. The file went together and was going together nicely.

I think Lou understood that I was getting sort of restless. I really had other ideas. And John Haanstra had taken a fancy to me and was sort of mentoring me, but hey, maybe you can do more than just design these sort of machine parts. So I was assigned to work with John Haanstra and a couple of other fellows on looking at feasibility of transistorizing the RAMAC because transistors were just coming out. And we started such a study. But part of the way through it, I think it would have been '56, there was a conference in Williamsburg of IBM senior management, where the company decided they couldn't operate as a monolith any more. They had to form divisions. And at that time, a Development Division was formed and Research was formed. And because John Haanstra and I had moved over with Rey Johnson, and Rey and Lou had separated the labs and Lou had the Development Lab and Rey had an Advanced Development Lab, but that became the Research Lab.

Bajorek: West Coast?

Harker: The West Coast Research Lab. So John and I were in Research. But very shortly after when the divisions were actually formed, John was brought east to be the assistant manager of the General Products Division. So, I was assigned to a project that was underway under Bill Goddard in Rey's lab, the Advanced Disk File. And the basis of it was to be a self-acting air bearing. Jake Hagopian had demonstrated, as is easy to do, if you have a spinning disk and you have a small, flat-- Lord Rayleigh did this some time earlier-- flat penny, you could hold it against the disk with your finger and it would float. And Jake had the idea using this to support a magnetic element. And that was the basis of this file. And if you didn't need the air supply, you could put a head on every disk, and you wouldn't have to have this XY mechanism, so you would have much faster access to the data.

Bajorek: And could electronically switch.

Harker: You would electronically switch.

Bajorek: Between heads.

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Harker: And there'd been a mock up of a proposed model of this. It never operated. And that was about the time I joined the project under Bill Goddard. Shortly after that, a decision had been made to manufacture the RAMAC in San Jose, so there had to be a larger Development organization, a Product Engineering group, and a Manufacturing group, so IBM was in a very heavy recruiting mode. And Bill Goddard was asked to lead that recruiting effort. And I was made project manager for the mechanical part of it. Al Hoagland was managing the magnetics and the electronics, and initially there were, I think, five of us. Sam Baio and Paul Gilovich, both of whom are draftsmen, had just started with the company recently. Al Osterlund and myself. And Russ Brunner, five of us. Ken Haughton came over on loan from Research to help us figure out how to make the air bearings reliable, because as we were operating them on test stands, if you loaded these heads down, when you got within about 200 microinches of the surface <bang>.

Bajorek: They'd crash.

Harker: They'd crash. Not everything but inconsistently. And Russ Brunner and now Ken Haughton took that problem on. My contribution really, I said, "Well, look, we've got to make these things really flat." And that showed that they all failed consistently at 200 microinches. And Ken and Russ went on to develop, along with the support of Bill Gross and Bill Michaels in Research doing analytical work, the idea of having a curved bearing to form a stable platform. It seems surprising, but at that time in the early '50s, no one had ever analyzed a slider bearing with a compressible fluid. Theory of slider bearings was well developed and they essentially operated like the bearing is on a lever, and as it comes down, the angle decreases until you reach the surface. The trouble is, with the compressible fluid, the pivot points a little bit above the surface. And so, by the time you get down to that level...

Bajorek: You could have a metastable system and crash.

Harker: Yes. That's all been well documented. I won't cover it. Al Osterlund took the job of how do we mount these heads so they can have the freedom of motion. How do we load them, because he had put about a pound load on each head to bring it close enough to the disk, and then you had to have a mechanism to do this.

Bajorek: Before we go there, Jack, one of the things I wanted to capture is, it seems like these were marvelous times for very creative model makers.

Harker: Oh, yes.

Bajorek: Without the world's best model makers, you wouldn't have been able to craft these complex electromechanical structures, or hydraulic structures.

Harker: Part of Rey's genius, when he started the lab, we didn't have any designers or draftsmen, but we had model makers. And these were essentially tool and die makers. He had set up a machine shop, and he encouraged, when you were working on a project, you'd have a model maker assigned to you.

You were expected to do the design, and the model maker would tell you what was wrong with it. It was a great learning experience. Yes, there's a picture of the model shop.

Bajorek: This is from a publication called *San Jose Quarter Century of Innovation*. And on page 35, there's a picture of a group of model makers.

Harker: A picture of a group of model makers. One of them, Ed Ursuny was the one assigned to me when I was on the RAMAC.

Bajorek: It may be fun to read their names for the record.

Harker: Ed Johns, Charlie Morgan, Bill Mueller, Ed Ursuny, Bud Ritts, Harry Wisdom, Ray Chadly, Chuck Blackley, Dean Hodges, and Frank Mauer. And Dean Hodges was the manager.

Bajorek: Interesting.

Harker: Actually, what Rey encouraged, he'd have a couple of the model makers stay in the evenings one or two days a week so the engineers could come in and learn how to run machine tools.

Bajorek: Hands-on?

Harker: Hands-on experience.

Bajorek: You could develop hands-on experience.

Harker: And they carried on, well, Chuck Blackley was actually, both he and Norm Vogel, who did the head work, which was very fine work, both had experience as watch makers. And the two worked very closely together to get that design. But back on to the ADF, well, Al Osterlund took the job of the head suspension, which was a gimbal arrangement to give two degrees of freedom and a torsion bar to provide the load.

Bajorek: One head facing up, one down.

Harker: Up and one down so that you would have them between two disks. Then, you had to build an array of those on a carriage with a loading mechanism, and you add up all the loads and you had to pull about 25, 30 pounds, so you had a very powerful solenoid, and you wound up with a fairly massive carriage. And the problem then was how do you access this one? And we looked at other various alternatives. Paul Gilovich and I worked on this. Sam Baio worked on the structure of the file. And we decided hydraulics was probably the best way to be able to get the amplification of power required, and the problem was how do you build a hydraulic drive that will accurately position the heads on this track.

Bajorek: And will also move them, right?

Harker: And move them.

Bajorek: Long distances, you probably wanted different degrees of motion, fast, slow and...

Harker: The object was to do it within a tenth of a second from any one track to any other track. So we had to come up with a design for a hydraulic actuator.

Bajorek: That would be good to just show into the camera this actuator assembly with the array of arms and heads.

Harker: Well, Paul and I came up with an ingenious scheme, we thought, which we called a piston adder. And this was a set of pistons that interlocked and had stops machined into them, so that—in a cylinder that always had pressure on it, which would compress them so they would all be interlocked tight together. And then we could port hydraulic fluid through a series of ports driven by solenoid valves to pour fluid at the same pressure but with a larger area into the areas between the pistons, and that would expand them. And this did it as an adder. We also had a fluid adder, which actually, by separate pistons, metered volumes of fluid into a common chamber that drove a finer increment, and then for the final position, we used a set of pistons with bevels that drove into a rack and these were arranged as a vernier to establish the final positioning. And this all went together as an assembly to provide the access mechanism for the file. Like this.

Bajorek: Essentially probably the first complete actuator, right?

Harker: Yes.

Bajorek: That was able to handle an array of heads that penetrated into an array of disks, stack of disks.

Harker: Now, this had about a 12-inch long bore. And we had to go to a gun drilling place to get the precision.

Bajorek: Necessary for that long a bore.

Harker: For a straight bore. Meanwhile, the disk array was a horizontal array with bearings on both ends for stability, and in the middle they were separated, and there was a hub in the middle of the shaft so you loaded the disks from both ends and you could free the bearing on one end, raise a lever under the center hub, and that would allow you to put disks on one end and then you could lower it and operate from the other. And that all operated together and was a basis of the advanced disk file. Well, along the way, there had been two commitments made for this trial. The first one was for a system for the Atomic Energy Commission called "Stretch." And what they needed was a file that was essentially a high-speed

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buffer. And they wanted to read at least 35 heads in parallel, read in and read out. And this file was proposed as a part of the Stretch system. And a contract was let. Also, it was committed to a system under development in Poughkeepsie called "Sabre" for American Airlines, which was the first reservation system, and the 1301 was to be the storage unit for the airline reservation system.

Bajorek: So the 1301 was the commercial file that evolved from the advanced disk file technology program.

Harker: Yes. So at this point, Research thought we've demonstrated feasibility.

Bajorek: It's time to move on.

Harker: And Lou Stevens agreed to take it.

Bajorek: I guess, by now, the RAMAC team needed a new product program.

Harker: And so several of us transferred with the project back into Development. And the program started to be staffed from the 350 crew. Lou had, again, different ideas. He still wanted a vertical shaft.

Bajorek: Yeah, because this one is clearly the horizontal, right?

Harker: Yep. There was no question of adopting the actuator and the bearing technology. So the program moved. But again, I got a little restless and Lou and I agreed it was time to part company. So I went off. He assigned three of us, Don Stevenson, Hal Sinclair and I, to come up with a design for a low-cost RAMAC. Half the cost, half the capacity, half the performance.

Bajorek: And half the size.

Harker: And half the size. We went around the company again, learned what people were doing, and in our travels, we went to Endicott.

Bajorek: I recommend that we take a pause here because the tape is about to run out.

Harker: Okay. And we'll pick up.

Bajorek: We'll pick up at this point at the next segment.

END OF TAPE 1

Bajorek: Jack, before we move on to our subjects, I thought it would be good to revisit a couple of potential loose ends on the RAMAC file. I thought it might be fun to try to recollect and document for posterity, who were some of the most important contributors or innovators who made RAMAC happen?

Harker: Well, obviously, Rey Johnson was the key person that made it happen. Lou Stevens ran the program, and he was a very aggressive person, but it wouldn't have happened without him. The file-the-card machine that was designed by Bill Goddard, John Lynott the mechanical design. Jim Davis did the servo work. Ray Bowdle and, let me think, Dave Keene were the ones that interfaced the card punch to the file electronics. Len Seader, I think, was the one who did the file electronics, the read/write electronics. And that was pretty much it for the file-the-card machine. I think that earlier I cited the people that worked on, the original designers of the 350.

Bajorek: Yes.

Harker: As part of the RAMAC.

Bajorek: Yes.

Harker: And the people that started the design of the 305, John Haanstra and his group, Jim Haywood was the electronics manager, and I think Ray Bowdle and Dave Keene were also part of that design team. And that's about what I remember.

Bajorek: That's good. I appreciate that. I just thought it's an opportunity to capture who did what in those early days of our industry. And we started, in a previous segment we just ended, where you had described the work that led to the foundation of the advanced, what became the 1301 file. And Lou Stevens takes that on.

Harker: Yep.

Bajorek: You guys again have the argument horizontal versus vertical spindles?

Harker: Well, there were a few other things, too.

Bajorek: There were other things. And you moved on to the low cost file-- started the low cost file program.

Harker: Well, I moved on, with Don Stevens and Hal Sinclair, we looked at a low-cost RAMAC.

Bajorek: Oh, because now-- oh, yes, yes. And you tie it to low-cost systems, entry level systems.

Harker: That became part of the low-cost systems when Larry Wilson came out, and I wound up as a one-man project to design a low-cost file. And we went on from there.

Bajorek: And then you also, it's about at this time that you decided you needed more education? Who made that decision?

Harker: IBM put the program in place. They wanted to encourage people to get advanced degrees. So they set up a system, call it a scholarship, but actually it was a job assignment where they paid your salary, the tuition, books, what have you, to go get a degree. And the first group that went off was in 1960. And there were about-- there were a number from different parts of the company-- but there were about five of us from San Jose that went off. Our managers had to nominate us, you had to take the GRE, and we were expected to do very well and all that. And we went off to Stanford. And it was interesting. I went off, was supposed to get a PhD. I already had a master's degree in Mechanical Engineering. Well, first, in my case, and I think most all of our cases, there was a sudden shock when we went back to school at how much smarter students had gotten since we had left school a decade ago. So with the first semester or two, it was hard work, and some of us didn't make it. Some dropped out. Some did very well. I did okay. But I really began to realize this isn't what I wanted to do. I understood what it took to really honestly get a PhD. You had to dedicate some fair portion of your life to it. And I decided I really enjoyed working more, which set off an interesting set of dialogues. By that time, I was working for a professor in the EE department. I had gotten interested in linear system design. And both he and the San Jose management thought I should keep ongoing to school. I said, "No, I want to come back to work," which I did. I wound up getting a master's degree, MSEE.

Bajorek: Okay. So you end up with a Master's in-- ME from Berkeley, and a Master's EE from Stanford.

Harker: Yes. And actually, it was very useful because I learned a couple of things, a lot about myself. I also learned confidence, that even though there are a lot of people smarter than I was, if they couldn't make me understand something, it probably wasn't my problem.

Bajorek: You became dangerous all of a sudden. You could understand what you managed, right? One of---

Harker: Well, it helped. It helped a lot, because I certainly have had a lot of people working in my areas that were a lot smarter than I am.

Bajorek: But it's interesting how you, you know, in the Navy, you were trained in electronics or the equivalent, right? Electrical Engineering issues?

Harker: Yes.

Bajorek: Then you studied Mechanical Engineering at Swarthmore and Berkeley.

Harker: Yes.

Bajorek: And then you do complex electromechanical product work, technology work, and then you go back and reinforce the electrical engineering aspects of it.

Harker: Yes.

Bajorek: So, unique mixture, I mean, rare mixture of both, right?

Harker: I said it from the beginning, I've been very lucky. I've had a lot of opportunities.

Bajorek: And I think when you get back from Stanford with your MSEE, your reentry is into the photo digital space, right?

Harker: No, it's into the image storage to the Cypress Image program.

Bajorek: The Walnut?

Harker: Well, Walnut was already underway, was close to delivery, and I was involved because of the idea of a follow-on commercial product.

Bajorek: And we'll go and film the segments in front of the hardware that's in the collection at the museum.

Harker: I'd be happy to.

Bajorek: So we'll do a segment on the photo digital file and we'll do a segment on the 1301, which is-- 1311-- which is the outcome of the low cost file.

Harker: Low cost file.

Bajorek: We'll stop and take a break at this time.

Harker: Okay. Thank you, Chris.

END OF TRANSCRIPT 1

Bajorek: We continue Jack Harker's interview by positioning him in front of one of the products that he helped develop during part of his early career in digital data storage.

Harker: Yes.

Bajorek: So, Jack, tell us a little bit about this extraordinary product.

Harker: Well, when I came back from Stanford, in the fall of 1962, I joined program in the Advanced Systems Development Division, under Lou Stevens, the idea being to develop a commercial image storage and retrieval system. The genesis of it was a project called "Walnut," which had been developed in ASDD, for the Agency. It is a random access store for photographic images of documents or whatever, that could randomly retrieve them and display them on video. We looked at configuring a system that we thought would be commercially viable. Spent a fair amount of time and effort on it, and we had defined a system and the key of the system was a storage file, which would store a large number of film chips, 35x70mm chips, that could be randomly retrieved.

Bajorek: Now the chips were designed for that Walnut file or for a subsequent product.

Harker: No, the chips were not designed for the Walnut file, which used 16mm film. This was for a follow on product, to get a random access capability.

Bajorek: For digital data storage, not for images.

Harker: No, initially for images.

Bajorek: Also for images, okay.

Harker: Yes, the original project was just for images.

Bajorek: Just for images. Okay.

Harker: And we would store the film chips in a, what we call a cell, which had 32 film chips, 35x70mm, then there're grooves in the inner side of this cell. And these we designed to be pneumatically transported from the storage unit, to an exposure station, to a reader station. And this worked by having these trays, and you had --

Bajorek: A stack of that.

Harker: Stacks of them, and in each tray there were five places by three, to store cells, on each end. But in the middle, there were openings that went clear through. So when the trays were all in and aligned, you had a clear column.

Harker: A tube -- formed. When you wish to access a particular cell, you would move the tray that that cell was in, so that that row of cells --

Bajorek: Would be in there…

Harker: -- was in line with that column. And then pneumatically you had valves at the top that would select one of the positions, and put air in there, which would blow the cell out and into the system; on the return, it would come back same way. In the bottom of those, the positions where the cells were stored, there was the opening, with a Mylar strip on it. And that let you blow it up, but when it came back, it cushioned it --

Bajorek: And had it come to a stop, to a point.

Harker: Come to a stop.

Bajorek: Right.

Harker: Well, the problem was, we really didn't find a commercial market for it.

Bajorek: For the imagining part.

Harker: For the image part, the expense of the system couldn't be justified by the savings of a well-designed application. About this time, the Atomic Energy Commission issued a request for proposals for a trillion bit, random access store. My belief is that it was triggered by a project that research in Yorktown had done, on a photo disk that was used as a language translator, and was exhibited at the New York World's Fair. Jack Kuehler who at that time was a project manager, he had delivered Walnut, saw this as an opportunity. He and Ray Kirby put together a proposal to use this --

Bajorek: This technology.

Harker: -- this technology --

Bajorek: For data storage now.

Harker: For data storage. Where you would use an electron beam recorder to paint bits on a film --

Bajorek: On each of those.

Harker: -- chip. You would then develop those; you would then store them in the file; and then you would bring them out to a reader, which would have a flying spot scanner to interpret the data. It was a elegant concept, and it was accepted.

Bajorek: Could we move over to the other part of the --

Harker: The, yes.

Bajorek: -- exhibit here. I think this is a writer, right?

Harker: This is the electron beam writer. The problem here was you had to bring unexposed film into a vacuum chamber, a roughing chamber.

Bajorek: This is a --

Harker: That's, this turret is that. This is the mechanism to select the chip out of a cell.

Bajorek: Right.

Harker: And to then rotate it around and bring it into the roughing chamber. When the pressure was sufficiently brought down, it would go into gated positions here, and when the pressure was further reduced, it would be entered into the electron beam chamber.

Bajorek: It's a high vacuum chamber.

Harker: Which is a high vacuum chamber.

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Bajorek: Probably up here, yeah.

Harker: This is the electron beam assembly. Because the filaments on an electron beam wear out fairly rapidly, we had to have a turret for the filaments.

Bajorek: Multiple filaments to --

Harker: So that when one filament came to end of life, you would shut down automatically, index another one, and then you'd refocus the beam and --

Bajorek: Resume operation.

Harker: -- and resume operation. As you can see, it's a complex piece of mechanism. But in fact, it worked quite reliably.

Bajorek: How many did you actually build?

Harker: We had contract for three, one for the Lawrence Livermore and one for Lawrence Los Alamos. And one for Lawrence Berkeley, their application was cloud chamber data, where they wanted to store it essentially forever. We delivered those systems in late 1969, which was a good year out past when we should've delivered them, but I think more people were surprised that we actually delivered it, than they were disappointed that it was late.

Bajorek: Because you started the Cypress file, right? We call this the digital data store file, the Cypress-- you started 1966. So three years wasn't bad for a machine of this complexity. And technology of this complexity.

Harker: So, and it passed acceptance tests at Livermore; we installed the systems. And then we had sort of a dilemma. We still knew that we had engineering work to be done. There were things we knew were deficient --

Bajorek: To further refine it.

Harker: Weren't sufficiently reliable in the long term. So we wanted to keep an effort. And I did succeed in getting the corporation to accept contracts for two more systems, from security agencies. And to expand the systems that we delivered to Berkeley, to the full capacity. But then we had a dilemma. We had no mission. This was an outstanding group of people, and we'd actually formed what we called the Cypress company. Because when Jack and I started figuring out how we're going to do this, we realized we were going to need support for procurement and manufacturing. But to do through a normal product release, when you're only going to build three of something, doesn't really make sense.

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Bajorek: So you've got to customize -- independent business unit--

Harker: -- independent business unit. And it was quite successful, morale was high, we had a lot of talented people. As we phased out of the manufacturing, those people folded back into their departments, but the engineering lab had no real mission for such a group, and the proposal was we'd just place people as there were places in the company.

Bajorek: As they, as they finished their assignments.

Harker: I stewed on that. And I came up with a proposal that I made to Bob Evans, who was then the president of the Federal Systems Division, "Why don't you establish a West Coast laboratory?"

Bajorek: Yes. You want to keep the team intact.

Harker: Yes. And negotiations went on for several months and it was about to come to fruition. However, about that time, a dozen engineers out of the disk area left to form a company called ISS.

Bajorek: I see. They left to go form a competitor.

Harker: Yes. And this upset the company some. And Chuck Branscomb was president of the Systems Development Division, came out, found there were really morale problems, there were people unhappy. So as a result, he put Al Shugart back to be the manager of the DASD group, which was a popular decision. And he asked me to keep the group into DASD Technology --

Bajorek: But move it into --

Harker: And report to Al, and take over the responsibility for the file technology.

Bajorek: So you kept the group intact but changed the mission.

Harker: Well, we changed the mission and --

Bajorek: From photo-digital to magnetic recording technology.

Harker: -- as we wound down the Cypress program, we'd move people to enlarge the technology, which clearly needed to be done. And that --

Bajorek: That was an interesting milestone. But a couple of questions.

Harker: Sure.

Bajorek: Why, by the time you took on this challenge, with the team, tape recorders already existed for digital data storage.

Harker: Mmhm.

Bajorek: Why not a tape recorder of a trillion?

Harker: Because the RFPs call for a random access device.

Bajorek: And the tape is serial.

Harker: And, you know, could we have done it with disk files? Well, it would've taken a lot of them, at that level of technology.

Bajorek: The capacity of a drive at that time was --

Harker: -- time was the 2314, which had about 35 megabytes.

Bajorek: Megabytes.

Harker: Per spindle.

Bajorek: It would have required at least a 30 or --

Harker: Yes.

Bajorek: -- spindles.

Harker: And, you know, if we had known the future of magnetic recording --

Bajorek: You may have made that bet.

Harker: We might have made that bet. But we didn't.

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Bajorek: Interesting. But this still is, stands out as the first digital data storage file that achieved a total storage capacity of a trillion bits, right.

Harker: And operated for years. We finally, because the people who we had as a support group were moving on or retiring, parts were hard to find, IBM withdrew maintenance, and the Agency was very unhappy with us, because they really liked the system.

Bajorek: See it worked, right, it worked?

Harker: Yes.

Bajorek: In spite of its novelty and complexity, it worked for-- when do you think was service interrupted?

Harker: It was the late, it was late '70s.

Bajorek: So it went for at least a decade.

Harker: Yes.

Bajorek: About a decade of field use. Amazing, amazing. Well, fantastic. And it's good to have this hardware in the museum, and to be able to film you right in front of it.

Harker: I do wonder, when people come and look at it, if they have any idea what it is. <laughs>

Bajorek: Well, I think this should help clarify it.

Harker: Okay.

Bajorek: Thank you very much.

Harker: Okay. Right.

[break in audio]

Bajorek: So, Jack, you-- after your contributions to the 350 file that was part of the RAMAC system, you spent time working on the Advanced Disk File program, which eventually became the 1301 file. But I think we pick up at the point where the work you guys had done, in technology, for the Advanced Disk File, is now in the process of being transferred to Product Development.

Harker: Yes.

Bajorek: As the 350 team, right?

Harker: Yes.

Bajorek: Which had completed its series of products, now could do a new product.

Harker: That's right.

Bajorek: And it takes over the development of the Advanced Disk File program, and you decide to do something else.

Harker: Well, we transferred, there were five of us that transferred, from the, it was then in the Research Division, to the Development Division. Hal Sinclair, Al Osterlund, Russ Bruner, and Paul Gilewich , and myself. But Lou Stevens had very different ideas about how he wanted the file configured, and we talked it over and we agreed it was time for me to move on.

Bajorek: You agreed to disagree and move on, huh?

Harker: <laughs>. So, he assigned Don Stevenson, Hal Sinclair and myself, to look at, propose, a low cost RAMAC. A successor, a low cost successor to the 305. And he suggested to do this, that he-- we take a trip around the corporation, solicit ideas from people. And we did so. The most interesting part of the trip was when we arrived in Endicott, which was the home of IBM's punch card equipment. And we were ushered into the offices of Larry Wilson, who was a very senior executive --

Bajorek: Running all the punch card business.

Harker: He had all the high speed punch card equipment, and he had just developed a new line, that had just gone on the market. We thought it'd be nice, and he was being courteous, but it turns out he spent the rest of the day with us, and even into the evening. We went out, they wined and dined us. And we sure were puzzled.

Bajorek: Why is it that you were so popular with them?

Harker: Yes. And then later we found that he was just taking an assignment to move to San Jose to start building a series of low cost systems for IBM. And these systems would become the basis of what became the General Systems Division, the Series II, Series III, and so on. And obviously when that happened, our idea of a low cost RAMAC was put aside. Don and Hal Sinclair went on to other things, and I remained, a one man project to design a disk file for the low cost system, which naturally was the low cost file. And I figured I'd use half-size disks. They were --

Bajorek: 24 inch.

Harker: -- 24 inch, down to 12. I'd have about half the capacity, a couple of megabytes of storage, which in those days was a big deal. And I'd try and figure out how to make it as simple and as cheap as possible.

Bajorek: Now they, you said that you dumped RAMAC aside. There was a connection. At RAMAC, goals were to halve a everything, right?

Harker: Yes.

Bajorek: Half the size, half the cost of the original RAMAC.

Harker: Yeah, yep.

Bajorek: So it wasn't necessarily out of line with the low cost system.

Harker: No.

Bajorek: But you felt those were necessary but not sufficient goals. You needed more aggressive goals.

Harker: Well, yes. I studied what-- had some mock-ups made and did a lot of design work. And along the way, when we transferred the project to development, and Advanced Disk File, Al Hoagland remained in Research. And he started a program for a removable single disk drive. And he figured by making the disk removable, he could make it competitive with tape drives.

Bajorek: Tape.

Harker: And I saw a study which said, "Yes, if you had enough capacity and if you weren't updating every record, but only a small fraction of the records, you could outperform a tape drive." And I scratched my head, I said, "That sounds like a good idea." So, the low cost file will have a removable disk pack.

Bajorek: Disk pack.

Harker: And that was the basis of what became IBM 1311. And my original goals were to, reaching a cost target I set was $2,000.

Bajorek: In contrast, RAMAC's file was $40,000?

Harker: Well, a file, the 350 was, I don't know, in the range of $25,000. The 1301 was more expensive than that, and those were in 1950's dollars.

Bajorek: Yes.

Harker: And but I thought you could make a working disk file for a couple thousand.

Bajorek: That's an extraordinary stretch goal.

Harker: And there was a very creative product planner, Chuck Hester, who looked at the proposal and said, "You know, if you can do that, we can sell 20,000 of these."

Bajorek: Extraordinary number.

Harker: Well, nobody had ever thought of selling 20,000 of something like a disk file.

Bajorek: Of anything.

Harker: Well, card equipment.

Bajorek: Right.

Harker: But not computers.

Bajorek: Right.

Harker: So, we had a hard sell. I started working on an engineering model. I had the support of a model maker first, and then Jim Carothers came over to do the electrical work. Bob Pattison came over to help with the mechanical work. And we sort of were off as a program, except it was very hard to get people to believe that we could do this. So Chuck Hester and I had a wooden mock-up made of essentially just this pack and actuator.

Bajorek: This upper part of the file.

Harker: And we took this around the corporation. Back to Harrison, to the White Plains, headquarters. And when people saw it, they sort of fell in love with it, and we were off and running.

Bajorek: Interesting.

Harker: And so the program built up, and the basic design -- this is the disk pack with the cover removed. This is the actuator. And as I said, I wanted something very simple, so this is just a simple hydraulic piston, that's driven forward by a gear pump, which is here. And you can operate it at two speeds, one just by letting the pump capacity govern the speed, or you can valve in an orifice on the outlet, so that it slows down. And the logic was simple. When you started up, it was retracted all the way so the heads were off the disk.

Bajorek: Off the disk.

Harker: So when you started the disk, after they came up to speed, you just moved to a home position. And there was a mechanical detent on a wheel, along with another disk that had slots in it, and had a solar cell to sense the track crossings.

Bajorek: An optical detector basically.

Harker: And you'd come to a home position. In doing so, you bring the heads off the disk and unload them. And to start an access, you would drive forward and allow them to load onto the spinning disk surface. Then, to proceed it had a two digit counter, that -- because we had a 100 tracks -- and you would load the address into the counter, and as you started forward, you'd count down. If the count was less than ten, you'd never go into high speed mode; if the count was more than ten, you would go into the high speed mode until you reached ten. And when they had a carry that would actuate the valve and slow down.

Bajorek: Slow down the motion.

Harker: And then you'd just engage a pin as a detent to the wheel, to stop. About as simple a mechanism as you can think of. And the head suspensions also, because we didn't have to have a loading bar, as we had on the 1301. The head suspension was much simpler, too. It was interesting, when I started, I figured I'd have eleven disk pack with ten head pairs. I showed that --

Bajorek: In the mock-up.

Harker: -- mock-up, to Larry Wilson, and he, "Nah, that's too big." So I went back and scratched my head and said, "Well, I'll be a little more aggressive on density, so I'll cut it in half." And that's what the 1301 wound up being. Interesting comment, though --

Bajorek: But I notice the actuator is still the tall --

Harker: Yeah, we designed the actuator to have ten head pairs. And somehow through the whole of the development process, it never got changed.

Bajorek: You kept it as a taller actuator.

Harker: But later on, the successor of this was 2311, and then came the 2314. And I'm sure that one of the motivations, because the 2314 went back to a 11 disk disk pack, that the machine was designed to accommodate it <laughs>

Bajorek: Yeah, and you didn't have to redesign the actuator.

Harker: <laughs>

Bajorek: It was there for that size. Now, the timeframe of this, the program, when did the program start, in 1958?

Harker: '58.

Bajorek: And when did this ship --

Harker: Shipped in 1962.

Bajorek: That's a very quick cycle, too.

Harker: It was a fairly short cycle. But I'd been pulled off the program early in 1960, because the ADF --

Bajorek: Yeah, the Advanced Disk File --

Harker: File, was in trouble.

Bajorek: -- what became the 1301 was in trouble.

Harker: We, at that time, were using vertical recording, with steel disks. And we were having a heck of a time with a number of problems. We had problem, massive defects on the disk, because we couldn't get custom made steel. We had to take what we could buy.

Bajorek: Right.

Harker: And the defect rate was just unacceptable.

Bajorek: It was the magnetic defects, basically, in the steel.

Harker: Yes.

Bajorek: Yeah.

Harker: And so a decision was made that we would go back to oxide coated aluminum disks.

Bajorek: Back to a longitudinal recording.

Harker: And back to longitudinal recording. The trouble was that we, the heads, we could not sustain reliably the gliding heads on the disk that we had. And actually, so I was brought in, Al Hoagland was brought back, and Al Shugart was put in charge. And for about three-four months, we worked at getting the program turned around. And we were making good progress. But I had already taken a commitment, I was going to go back to school, on an IBM scholarship in the fall. So, I set, turned the machine program over to Yang Hu Tong, and I kept the small group to work on the gliding head, and disk. That was Russ Brunner, Al Osterlund, Chris Coolures, we hired Chris Coolures into the company.

Bajorek: Interesting, that's how he got started, huh?

Harker: Tom Tang was the other member. And we made a lot of progress, but the problem we had with the disk, and it wasn't until I had gone off to school, Ken Haughton came over from Research to take the group over. He and Russ Brunner came up with the concept of measuring vertical acceleration on the disk.

Bajorek: Yes, the vertical runout.

Harker: We call it X double dot.

Bajorek: Yes, yes.

Harker: And by putting a specification on the vertical acceleration --

Bajorek: You eliminated that --

Harker: We eliminated the problem. And the machine worked reliably. So, that was the solution to the 1301. This machine rode on that technology.

Bajorek: But getting back to the 1311, there's a couple of revolutions here, right? One is you decided to go with a removable disk pack.

Harker: Removable pack.

Bajorek: So that'd be much more compact.

Harker: Yep.

Bajorek: You couldn't remove the pack of 24 inch disks, so --

Harker: Well, and it had to be inexpensive enough.

Bajorek: -- and portability drove you to smaller size.

Harker: And basically, this mechanism was a basis of IBM's products for better than a decade: the 1311, 2311, 2314. It also was the basis for all of the competitors that came along, because it was simple and there was nothing that, particularly proprietary that you could claim, except the best claim was the cover that went on here when you turned the handle of the cover, it released the disk back from the spindle. And when you put it, another disk back on, and when you turned it, it locked to the spindle, and unlocked the cover. And that was probably the most significant patent we had in this thing. That was long after I had left the project. So --

Bajorek: But looking at it from a, you know, at the forest from the distance, now, and I'm a newcomer to the field. I think this file contains the elements that are even in today's disk drives, because first of all it has, I think it was the first file that had a array of heads on an actuator that accessed --

Harker: No, it happened earlier. The 1301 drive had already introduced parallel heads and the self acting slider.

Bajorek: Okay, so the, you think 1301, clearly if it had the dedicated heads, right?

Harker: Yes

Bajorek: One per surface, it was an architecture that stayed with us ever since.

Harker: Yes.

Bajorek: It did not have removable disks.

Harker: Yes.

Bajorek: So perhaps the key architectural features that are even in today's files were all pioneered in the 1301.

Harker: Well, yes, they were, the removability turned out to be transient.

Bajorek: Yeah, why was that? Was it application or was it a contamination issue? Or --

Harker: With the 1311, disk packs became a big business, because you would sell about ten disk packs for every --

Bajorek: Per spindle.

Harker: -- per spindle. Because people would use them to remove data. By the time the 2314 came along, you had about 30 megabytes per spindle, and you had large operating systems with System 360. And if you were running a computer installation, and you had your operating system on your disk storage, you didn't want people coming in and removing it. So, it was clear to us that we were going to go away from removable storage. And we'll talk about that in the Winchester session.

Bajorek: Just before we break out of this, though, did you have to take special precautions with contamination control in this design, in implementing filtration.

Harker: Not initially. For the 1311 our spacings were still about a hundred micro-inches, a ten-thousandth of an inch. And it was forgiving. 2311 had problems, and they put brushes, all mounted brushes on the actuator, which turned out not to be a very good solution. With the 2314, the air was filtered.

Bajorek: The air that came into the disk filtered --

Harker: Disk array was filtered. The first sealed array came with Winchester.

Bajorek: Okay. Very interesting. Well, thank you very much for --

Harker: Thank you, Chris.

Bajorek: -- clarifying what the background to this product. And it sold about 20,000?

Harker: Yep. Chuck Hester's prediction was pretty good.

Bajorek: The forecast was pretty good. Fascinating. Thank you very much.

Harker: Thank you.

END OF MAY 30, 2007 SESSION WITH HARKER ALONE.

Chris Bajorek: Welcome to the continuation of Jack Harker's interview [May 30, 2007], but in this phase of the interview, we also asked Denis Mee to join us, so the rest of the interview will be a joint interview of Denis Mee and Jack Harker. Denis is another key technologist and pioneer in this industry, in the hard drive industry, and shared many interesting moments through their joint employment at IBM with Jack Harker, so we thought it might be good to interview them together. So, Denis, welcome to the interview.

Denis Mee: Thanks.

Bajorek: But before we get into that joint period when you two overlapped at IBM, I thought it would be good to pick up your pre-IBM history, starting all the way, where you were born and where were you educated, and any job assignments you had prior to joining IBM.

Mee: Okay. Thank you, Chris. I was born in England, grew up in The Midlands, went to high school during World War II, and at the end of the war went to Nottingham University to study physics. I actually had been accepted at Cambridge and got bounced out of there because of all the service men returning from the war had priority.

Bajorek: They crowded academia.

Mee: Yeah, so, that was a disappointment, but it turned out to be a great move for me, because Nottingham was one of three universities that specialized in magnetism, and I stayed at Nottingham until 1951 and got to do my thesis on the magnetic properties of ferromagnetic materials. So, that got me going in the magnetics area, and I managed to parlay that through the rest of my career and make something great out of it.

Bajorek: Very interesting. And the exact degree, was it a baccalaureate or masters? What was the degree you got from Nottingham?

Mee: Well, at that time, when I joined Nottingham, it was called a university college. So, they actually did a London degree, so I got a London bachelor's degree of physics. And then when I started the PhD, Nottingham became a university and I got a Nottingham PhD, one of the first Nottingham PhDs.

Bajorek: Very interesting.

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Mee: The other interesting thing where I was lucky about the research project was I did get to meet a few of the big names in magnetism, because it was a rather popular area of looking at domain structures on single crystals and verifying some of the theories of Louis Neel. I am going to do a little name dropping here occasionally. Louis Neel had predicted the domain structures in iron and cobalt, and we were able to verify that by some technique like an iron filings experiment but much refined for making the domain walls visible. So, it attracted the attention of Richard Bozorth at Bell Labs who was studying the same stuff. Now, that was kind of good news and bad news. It's good news that it got more credence and got a lot more attention because Bell Labs was studying the same stuff, and Bozorth was working with William Shockley on that. But it was bad news in that anything that you do as a small group can be totally over whelmed by Bell Labs capabilities. But we managed to find a piece of that that was okay. So, I got my PhD. And my examiner--in England, you meet with your examiner who's from another university for about three hours--was Professor Stoner of Stoner and Wohlfarth fame. So that was another name that I was going to hear a lot more about later on. Actually, at Nottingham, I also had my first encounter with a magnetic recorder. At the end of the war, there were quite a few war reparations, and Nottingham managed to pick up a couple of German magnetophone recorders, which were way ahead of anything that we had in England or in the U.S., so I spent many, many hours at night trying to get the damned thing to work, unsuccessfully. But that was my first use of a magnetic recorder, and that recorder did have the advanced tape in there with the plastic base and oxide particles on it. So, again, the work of Nottingham was kind of the start of my career in magnetic recording.

Bajorek: But, you know, from your summary, if you had wanted to plan it on purpose to be more connected with key pioneers in the field, right, you couldn't have done better than what happened?

Mee: Right.

Bajorek: Again, it reinforces how lots of things help-- being at the right time at the right place helps a lot.

Mee: Yes, being lucky. That's true. So after that, I did have two jobs in England before I came to the States in 1957. First was-- well, when I left Nottingham in 1951, there was not a lot of choice of jobs. The only job in physics that I could get to locally was to work in the Nottingham lace industry measuring cotton. But then I got an opportunity to go down to Wales into the steel industry, electrical steel industry. And I worked there for three years. But I always wanted to get back into magnetic recording, and the opportunity came in 1954 when I joined a company in London that was trying to develop magnetic tape for data storage. So my first encounter with the computer industry was in 1954, and it was a government project to upgrade magnetic tape, which was mostly used for audio recording. IBM, at that time, had just come out with a 1/2-inch tape drive, 1954 or there about and 3M supplied the tapes for IBM. My job was on a British government-sponsored project to try to get to the same point that the Americans had reached.

Bajorek: What was the name of the company?

Mee: MSS Recording Company. Their business, their main business was making phonograph disks, and then they got into the magnetic audio tape business, and this project was to get into the digital recording business. The one name I will mention for the history museum is that the customer there was Maurice Wilkes of Cambridge who was one of the pioneers of the computer, early computers. He was

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after faster storage and very keen on getting the most advanced tape drives that he could find. So I got to meet him then. He was awarded a medal by the history museum, I think, a couple of years ago here. I got to meet him again.

Bajorek: Interesting.

Mee: That's the end of my name dropping.

Bajorek: Not quite. I'm sure that you're probably not done. So then, the next move was to the U.S.

Mee: I was working on this project to improve tape, but I'd also developed a flux sensitive magnetic head for reading tapes when the tape is stationary. We didn't use magneto-resistance effects in those days, but there was a device called a flux gate, which I think you would be familiar with, a balanced magnetic circuit that could measure a magnetic field when the tape is stationary. So I developed that head on that project, and we had it built by another company nearby that manufactured multitrack magnetic heads. This company was run by a Hungarian engineer who decided that he wanted to hire me. I told him, "If I'm going to move I am going to move overseas, would like to go to the States." And he said, "Well, I can fix that for you, and I have a Hungarian friend in New York." And I didn't think much more about it, but he was actually correct. He was a friend of Peter Goldmark who was the director of CBS Labs. And within a month, I'd had an interview with Goldmark in London and signed up to come to New York. So, two months later, there I was.

Bajorek: You landed in America, huh?

Mee: Landed in America, right. And I was at CBS for five years. That was probably the most exciting time in my whole career because I was working in the entertainment business trying to do technical work in the lab in the back room there, and so you were seeing both parts of this business. It was really quite wonderful.

Bajorek: Were you actually able to concentrate on real work given those distractions?

Mee: Well, I got to work in the television studios a couple of times when there was a strike. Once was with some-- I won't do any more name dropping-- but with some well-known people. Anyway, it was a wonderful experience, and we developed a slow-speed audio recorder in a contract with 3M and 3M provided the high-quality tape. And the idea of this recorder was to put it in an automobile so you could play audio in the car. CBS had developed a long-playing disk, which was the 12-inch long-playing disk, and they made a miniature version of that to put in a car, but their wonderful pickup, that was balanced, did jump off the grooves occasionally, and so they wanted a magnetic tape equivalent, and that's what we developed. And the people that we were interacting with most were companies like Phillips and Ampex and Grundig who were also trying to develop the same thing. And the approach that we had to go to a very narrow tape, 1-7/8 inch per second, is the one that was adopted eventually and became the forerunner of the compact disk--

Bajorek: The cassette?

Mee: Compact cassette, yeah. So that was a great project, and at the end of that, I was offered a job by 3M and I actually accepted that job and went out to go look at houses and so on.

Bajorek: In St. Paul? This was going to be in St. Paul.

Mee: St. Paul, yeah. And I casually mentioned on that trip that I was kind of about to get out of the East Coast for a couple of reasons, one, that joining 3M was great, but also I had some allergies to ragweed on the East Coast, and you want to get away from that. So, we compared pollen counts on the East Coast and St. Paul. It was 30 on the East Coast where I was, and in September it got up to 120 in St. Paul. So that was kind of the end of my career with 3M.

Bajorek: That was not the right direction to go, right?

Mee: Right. So then, completely out of left field I got a call from somebody at Yorktown Heights that I'd known that was previously at the Franklin Institute, and he said, "You know, you might be interested in talking to IBM Research since they're looking to get into some new areas of magnetics." And their specialty, of course, was magnetic memory, film memory and ferrite memory. They were doing nothing in magnetic recording. And so, I was hired to join a device group there but was told, "You may not work in magnetic recording for a year or two because of the previous experience you've had."

Bajorek: Just to avoid competition?

Mee: Yeah, competition, correct. So, I was finishing up my first book on magnetic recording at that point, so I spent some time doing that, which was published in 1964. And then I got into the area of magnetic thin film memory and ferrite memory for three years at IBM Research. But that, again, was so fortunate, because it was the thin film memory stuff which was really the thing that started me off thinking about thin film heads.

Bajorek: For recording.

Mee: Right. I mean, I joined in 1962. By 1964, the 360 was announced with a semiconductor memory and so that's kind of the death knell of the magnetic memory research activity. And so we were looking for new things for magnetics experts to get it to. And so then I said, "Well, can I propose some magnetic recording stuff now?"

Bajorek: Now could I get back to my first love, right?

Mee: And, the answer was, "Well, no. You shouldn't get into anything that is the current technology. It's got to be beyond that." And Jack has often wondered how I got into this other area. I was boxed in. So, but the thin film head idea was fine. So we started that project.

Bajorek: In Yorktown?

Mee: In Yorktown, 1964. And I mean, the original thin film head, as you know, was really a copy of one element of the thin film memory. And all you had, you had two strip lines going through a magnetic thin film circuit. So what was necessary was to make a gap in the magnetic circuit, and you did that with an electron beam scribing process that Alec Broers did for us and Ian Croll and his group made this head, and we could actually do some recording with it. The trouble is, with a single turn, the current you needed rather high. And so by then, Dave Thompson was on board and the multi-turn project was being started by the time I left.

The second project I proposed was to get away-- I mean, there's always this desire to get away from this magnetic recording head media interface that gave us trouble forever. Stop laughing, Jack-- <Laughter> And so I proposed that we start a magneto-optical beam addressable memory project.

Bajorek: Is that right? I mean, this is the first admission on your part of being associated.

Mee: I would never have told you, but he knew-- <Laughter> The thing at Yorktown Heights was that they had incredibly wonderful materials research labs there. And they were working on all kinds of ferrites and garnets and some alloy films and so on. So, there was this potpourri of magnetic stuff.

Bajorek: This was a candy store.

Mee: This was IBM's advantage, and I guess I was really motivated to, all the way, even, you know, through the San Jose career, to try to take advantage of the IBM Research resource that was second to none and get it somehow into our product stuff. That's what we'll be talking about that later, but that was really the key thing. So, under that umbrella, I could propose the magneto-optical project because IBM research did have some excellent new materials for magneto-optical recording. I worked on garnet films gadolinium iron garnet, which is a room temperature device. I always felt that if you go below room temperature, you're in trouble. However, there was another group that had the europium compound work.

Bajorek: Europium oxide?

Mee: Europium oxide and iron doped europium oxide. Europium oxide, we work at 25° Kelvin beautifully. The iron doped stuff I think was more like 77° or 80° Kelvin.

Bajorek: Oh, easy, with liquid nitrogen, that's all you needed.

Mee: Right. So, I think that's probably where I parted company with Yorktown, because I wanted to work on the room temperature stuff. But I quickly realized, though, at Yorktown, that trying to sell this stuff from the outside-- and you've gone through the same cycle--into the tape business or the disk business is just a very difficult sell. So, that was the kind of motivation for the move.

I used to go to the IBM internal conferences in those days called ITLs, was that Interdivisional....

Jack Harker: Technical Liaison.

Bajorek: Programs, yeah.

Mee: Where there were so many small efforts going on in different divisions related to magnetic recording, they'd bring them all together and people would talk about what they were doing. So, there was work going on in Germany, and the manufacturing research department. There was work going on in England where they were starting their...

Bajorek: At Hursley?

Mee: At Hursley.

Bajorek: Germany was in Sindelfingen.

Mee: Work going on in the Components Division on the thin film head. And all these things-- and it was beam addressable storage all over the place, including San Jose. So, they bring all these together in the ITL meeting. And that's really where I met Otto Kornei, who was in the advanced technology group at San Jose. He was well into his 60s--I think he retired a couple of years after that. But he had had a previous experience working at Brush-Clevite, and he'd developed a lot of magnetic recording heads. He knew a lot about heads. He loved this thin film head. I mean, there's a champion in San Jose.

Bajorek: That was a big difference.

Mee: That made the difference. So that got me out there. I joined his group and brought those two projects with me and then formed another group, I don't know if you remember, the AMRT project in San Jose, where I started to try to use the abilities of all these other groups that I'd met at different locations to support the thin film head program and support the beam addressable drive program. And so I kind of, by the time I met Jack, I was already trying to make use of this external resource. And those were the two projects that I brought to the table when the TAD organization was formed. The last thing I'd say before we talk about TAD together is I remember meeting Jack just after the announcement was made. We hadn't-- I don't think we'd met before, but he said, "We've got to get together on a Saturday morning and we'll talk about what you're going to do, Denis."

Harker: <Laughing>

Mee: And we sat down.

Bajorek: But in what context? Now, you had joined the group.

Mee: Well, I had joined the Advanced Technology group in San Jose, and it was also supporting the development activities, again, somewhere from the outside looking in.

Bajorek: Was it part of the Research Division or not?

Harker: No.

Mee: No, no. This was already.

Harker: This was Adtech <inaudible>.

Mee: Closer to development but not as close as I wanted to be. And the formation of this organization that we're going to talk about that Jack did was the key move to get into working together with the development people.

Harker: Now let me start out, when I came back into the laboratory after photo digital, and I took over the George Santana's group, which had the file technology, was doing the technology for all the projects, again, I looked around the lab and there were a lot of scattered resources. There were not just in magnetic recording but the whole technology community was just bits and pieces. And the way the lab was organized, the product programs were under the product manager. All these other groups reported to the lab manager. And there wasn't much...

Bajorek: Linkage or cooperation.

Harker: Linkage between them. And in some ways, I think, you to comment, Denis, but my feeling was that Adtech was being told "You shouldn't work on things that development is doing."

Mee: Yeah, that's true. The film head was lucky in that respect because development was not, wasn't doing it.

Harker: Wasn't interested in it.

Mee: Right.

Harker: So, that's when there were some interim back-and-forths, but it was clear to me that one, we had morale problems, two, we had resource problems, three, we weren't moving the technology particularly aggressively. Each product was an increment on the last product. And by that time, we had gone through the early part--and this we've recorded with the Winchester history--where a group of us outside the file area but reporting to Al, got together on President Eisenhower's funeral day to say "Gee, we don't like" -- the proposal then was to build a mid size file by taking half the heads and disks off a 3330. And we didn't think that was a very aggressive proposal. So, this was the start of what became Winchester. And we looked at new technologies. I know Ken and I-- I don't know; were you with us when we got up to talk to Jay Muller to Data Disk?

Mee: No.

Harker: And we saw he had this tri-pad head. And he said, "I'm recording in contact on disk." He was doing a video recorder.

Mee: Yeah.

Harker: Well, we managed to get several of his heads and we actually measured them. No, they weren't in contact, but they were pretty damned close. So we wanted that, and Joe Ma started a project in ASTD for a single disk file for Rand video buffer for the Rand Corporation, and did that using those heads. And that was the first time we had a lubricated disk. So, you know, it was clear, we had things we thought we could do. But the organization wasn't helping it.

Bajorek: Yeah, it was disjointed.

Harker: Yeah, and as I wrote in my proposal to Vic, you know, organizations don't solve problems, but they can make them easier or harder to solve. So I proposed that we put all of the technology groups together, an Advanced Technology group, a Product Technology, Development Technology group, and a Product Engineering technology group, and that we integrate the lab support functions into these organizations, so that they had a role in defining what we did. Vic bought the proposal and the result was that we reorganized, what was it, in mid, late '69?

Mee: Yes.

Harker: And that's when Denis and I...

Bajorek: September, that's when you guys connected.

Harker: Yeah, that's when we connected.

Mee: Right, and that's when he told me, "You can drop the magneto-optical project." <Laughter>

Harker: Well...

Mee: Let me finish my sentence. It was music to my ears because I wanted to get into magnetic recording, but I'd kind of fallen in love with this other stuff. And fortunately, there were champions in Research. Andy Eschenfelder had moved out to San Jose, and George Fan was in Research. These were the champions for it.

Bajorek: And they took that, they carried it.

Mee: So we handed that one over to them. They immediately changed it to the europium oxide 25° Kelvin project and put a fairly large effort into it for some time. However, the thing that Research did do in parallel with this is there was another group with Gambino and I think Chaudhary who were developing chalcogenide materials, and they eventually became the universally accepted magneto-optical storage material using every product from the late '80s onwards. So, it was a success in the end because it was room temperature stuff and it had a large magneto-optical effect.

Bajorek: We're about to end a tape, so we'll take a break to change tapes, and we'll continue. We'll pick up from here.

Harker: Okay.

Bajorek: So Denis and Jack, we want to pick up where we left. And there's one detail I wanted to fill in Denis on your personal history and that is, when did you meet your wife, Molly, and was it while you were still in academia or after you had come to the States?

Mee: That was when I was in high school.

Bajorek: Oh my gosh, high school sweetheart.

Mee: Right. In the British private school system, they had separate boy schools and girl schools. So, that was it. From then on we were an item as they say.

Bajorek: How did you meet because you were in separate schools?

Mee: Yes, it's part of the same system so, yes, I used to beat her up at tennis and I think that started the relationship. Molly was the one that was always willing to move. I mean I- we moved 11 times and whenever it got mentioned she was, okay, here we go. And on the recruiting visit from Peter Goldmark, when he came over to London, moving to the States and emigrating was a big deal and- for me and I guess it was for her too but once he told her that we were going to come over first class on the Queen Mary that was it, she was sold, she was packed ready to go.

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Bajorek: That's very good. I appreciate you filling that important detail because without her you couldn't have done much of what you did.

Mee: Would not have done, no.

Bajorek: And same true with Betsy for Jack.

Wanted to then have you amplify on one other detail now moving back to your professional career. Two details actually. The book you published, your first book, the title is The Physics of Magnetic Recording. Can you amplify a little bit on that? What stimulated you to craft that book?

Mee: Well, it was 1960 when Peter Wohlfarth, in London, was editing a series of books called “Selected Topics in Solid State Physics”. And my book was going to be the second of that series. The first book was written by William Fuller Brown, I’m name-dropping again. Brown, I mean one of my idols as far as magnetic theory is concerned, the father of micro-magnetics, had written a wonderful book for the first book and Peter asked me if I would write one on the physics of magnetic recording. I quickly said yes, and I think if you ever asked me in this interview are there things that I regret doing it's book writing.

Bajorek: But yet, this was not the first time right?

Mee: Well, the thing was, I still had a job at CBS, during those three years, which was very time consuming. I was working in the City and commuting from Stamford for a while. So this book was getting written on weekends. So the whole episode through that period was kind of a fine line between getting sacked by CBS for not being there on time, or getting a divorce for not being home with my wife on time. So it was a time consuming business and I got into several more books and I learned that lesson over and over again.

Bajorek: We have a habit as humans to forget what lessons we learned from the first time we try something. The second item I wanted you to amplify on is the failure of, or the need to stop, the film memory program. How it enabled or energized- well, you moved forward very quickly with film heads.

Mee: A group of about 15 people that were working on advanced film memory and advanced ferrites, the whole idea was to make memory cheaper and cheaper. So there were batch ferrite technologies which were thought at one time could be useful for magnetic ferrite heads. I mean , one of the reasons for getting a magnetic head application was to try and make them cheaper. But the film head was the one that was quickly picked up. But all that background knowledge that they had at Yorktown about the magnetics of thin films and how to control them was to come in great use for the inductive head. But even more so down the road for the magnetoresistance head. I mean it was just used over and over again, you would see the same names cropping up from Yorktown Heights. They didn't all move to San Jose and they were just a wonderful resource for many, many years.

Bajorek: It's reminiscent of the discussion you and I had Jack in the early part of the interview.

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Harker: Yes, the photo digital group. After Al Shugart was made product manager for DASDI and I was asked to report to him with my group and take over the file technology. We continued to have people leave and the existence of that group, the Cypress group, met- we could backfill without loss. Even when Al Shugart himself left and took away close to 50 people we were not hurt for resource. A lot of experience left but a lot of talent came into the business. And some times therefore, you know, these things which are failures as products build a base to go on and do something else as long as you can find the right thing to do.

Bajorek: Yes, it's probably not the last time we'll hear about that in this area. We'll hear of additional and more such incident.

Mee: Well I was going to also add though that the organization that Jack described, this technology organization of integrating Advanced Technology and Development and Product Engineering, was different to the previous organization in that it welcomed help from outside, not just from San Jose. So for a film head project…

Harker: I figured I had acquired a line into Research and I was- I wanted to take advantage of that.

Bajorek: And the European labs right?

Harker: And the European yes.

Bajorek: Sindelfingen.

Mee: Which I don't think had occurred before. I mean it was human nature in a way, the Development group, was so busy trying to meet their schedules and everything with what they've got, in a way the last thing they want to do is put in one more technology. So the way that you had it set up though you had this group that was coupled in with the Development people. In other words, what we came up with that was decided we were going to use it, Development folks knew that I think.

Bajorek: You didn't have that wall.

Mee: No, there was no wall.

Harker: Well this was true with the film head development. The product managers didn't want a film head, the individual project managers. Ken Haughton had the Winchester head, which I will talk about a little bit, which was again, a departure of technology. But I literally had to edict it that the next product was going to come along with a film head. And then just to make life interesting for Denis, I set a criteria that the organization that received the technology decided what was necessary to qualify it to transfer.

Bajorek: Not the other way.

Harker: That's right. So George Santana could set the criteria for Denis to meet. But likewise it worked beyond that because when the film head was going in production Lou Blenderman could set the goal for George Santana

Mee: To meet.

Harker: … to meet about the transfer. And the result was we had really quite smooth transfers of technology

Bajorek: Well you had a built in mechanism. If the technology had passed that hurdle then they couldn't argue about it being ready right.

Harker: Yes.

Bajorek: Because the receiver set the hurdle, the bar. Well, let us pick up then. TAD. Just what did TAD stand for, the acronym?

Harker: Technology and Advanced Development. The groups were as I've described and it worked well. The hardest problem of integrating the group was with the people in the Materials Lab and the people who had been in the lab support groups because there was a- they had a fear that they were just going to be subverted into solid fire drills for the product programs. And we had a number of offsite meetings to try and figure out what- how you-- because I told them, yes, you know, we're- I wrote a document called the TAD Game because I felt that we had a rather- a unique opportunity in the corporation. We could decide what we were going to work on. Now, there wasn't anybody who could tell us what the next technology should be. But that carried a responsibility with it which is when we did that we had to make sure that we carry through on it and it was on schedule and if there were problems, yes, everybody in the area would get called on. But that was part of the price we paid for the privileges we had. And I think that got across. The first real departure was the Winchester head.

Bajorek: What came out of the TAD organization basically?

Harker: Yes, but TAD also came out of the opportunity that there was this advanced computer system lab in Menlo Park that got shut down and we were asked to use the resources. Well, one of the groups there was a semiconductor packaging group. And so we knew we had to come up with a- we had this tri-pad head, we knew it worked, but it wasn’t a manufacturable item. It was hand built. So we need- we knew we needed to come up with a new design for a head. So what we did is we took three experienced head designers, developers, Eric Solyst, who had done the head for the 2305 which was a solid block of ferrite, first one of those, Mike Warner, who was a very creative young engineer, Eric Solyst who had been through the manufacturing side. We assigned them up there to this group and told them you're going to develop the head. And in doing so we also worked with Manufacturing so that they assigned two or three of their key engineers in the head area. And the agreement was that through Development those people would report to Development management. When it was released to Manufacturing, the whole group would transfer to Manufacturing as long as they were needed. And it worked very, very well. And out of that came the Winchester head which Mike Warner designed, has a patent on. And that was a new generation of technology. And it…

Bajorek: And it set the base right for…?

Harker: Yes.

Bajorek: …the air bearing, that type of head, the start stop and contact. Those are key elements that are pervasive in today's files all the way through the latest files that we're shipping today.

Mee: Now they've got the spacing down from 50 micro-inches to 18. Huge move.

Harker: So it made a big difference. So, that was the first one. But then as soon as that was in place and going well, Denis' film head.

Mee: Well, I don't…

Bajorek: Just to back up, when you joined the TAD organization, which function did you manage in TAD, just film head? All the Advanced Development in that organization?

Harker: Yes, disk- we had a film disk program too. You can talk to that.

Mee: I will. I mean I think the correct motivation was that we wanted to bring in film technology into the head and the medium. As it played out, of course, the film disk was a much bigger challenge from the point of view of getting a manufacturing level capability to do big 14-inch disks. And it was really only when the disk diameter started to be reduced in the eighties that that became a reality.

Bajorek: Facilitated the ability to master films, disks.

Mee: Right. But apart from that I think- I mean there was the desire to get away from the particulate disk. The tribo chemistry that went on between the head and the disk was always a mystery. And you kind of took it product by product and we had…

Harker: Problem by problem.

Mee: Problem by problem and they were solved specifically for whatever it was at the time. But there's no generic solution so there was always this fear that next time you'd be in trouble. And so the Advanced Development program that started in the TAD organization, aiming at sort of the end of the 1970s, was called the Apollo program, as a density of what, 12 to 15 megabits per square inch, when at the beginning of the seventies it was less than one megabit per square inch. That big jump, everybody assumed you'd have to go to the film head, film disk combination. And as it turned out I mean that objective was not reached at that time. But- and the particulate disk could be improved a lot. A lot of the incumbent technologies still could be improved a lot and it's true of the ferrite head as well when you look back on the history of how far that technology could go. But the combination of the film disk and the film head turned out in the end, of course, to be the winning technology, for that interface, for getting the head close to the disk. And it was all of the things that Jack mentioned for the head, but in addition for the disk with the film disk, you could put a protective carbon layer over it or- in the early days we had rhodium and other materials…

Harker: It was the carbon overcoat that made the film disk I think practical.

Mee: Right. And I was just looking here at one our 1970s advance recording surfaces plated cobalt nickel. I mean you could plate a big disk. We tried evaporating onto a big disk with some huge equipment from Temescal . We tried sputtering and that was done in Germany. Some of the early work on the sputter disk was done in Germany. None of those were going to be manufacturing processes for the disk. So plating was kind of chosen or selected in the early days and various overcoats and various lubricants were tried over a long period of time. And it took a long while to get to- what, to the eighties before we got the correct combination. I mean when I say we, I mean the industry, right, got to the correct combination. So it was a long drawn out process during which the particulate disk just improved and improved and improved. But it always had this problem of the tribochemistry and what went on in the interface.

Harker: Yes, there's a lot of work that went into lubricants. You had to try and find a lubricant that would be molecule thin that would actually chemically adhere to the disk, that wouldn't absorb water, that wouldn't evaporate off over a period of years. It was a tough problem.

Bajorek: And that would not be masked by the natural hydrocarbons in the drive right?

Harker: Yes. But, by the early seventies we had in place three generations of technology.

Bajorek: You created this pipeline of technology.

Harker: The 3330 with its ferrite head, ferrite core, in the alumina slider, glassed in, the Winchester head, and then the thin film head. And I don't know, maybe covering the- when we talk about product experience but I wish I had claimed that we were smart enough that we did it on purpose but, in fact, we- when we introduced Winchester it was on a low volume product and nobody in the industry paid much attention to it. You know, this enclosed disk pack. And we introduced the 3330 mod 2, mod 11, double density and the industry followed us. And then we brought out the 3350 with the Winchester head and we had it in production and we were able to ramp up. And that- for a period of time that wiped out a lot of competition on pure technical grounds.

Bajorek: Right, it gave a strong advantage to IBM.

Harker: And, in a sense, I think we did the same thing with the film head because the first film head disk drive was a 3370 which was, again, not a big…

Bajorek: Not a mainstream product.

Harker: Not a mainstream product.

Mee: So that was the 3350 technology with a film head in it.

Harker: Yes.

Mee: And they were able to double the density, again, and to about 7 megabits. So that was all going on and in parallel with that there was this Apollo project which was the film head film disk combination to get to the 3380 in 1980.

Harker: So, all in all it was pretty successful.

Mee: But we were- I mean we were all running scared about that interface every time. We were talking about the 3350 had a media interface problem that we ran into. We had another one with the 3380 so it was- we got to the end of the seventies, I mean I say there was a lot of trepidation about the technology and a lot of optimism at the same time and that kind of gets us to move on to the next stage of what happened in the eighties…

Harker: Yes, before you do that, talk about your challenges.

Mee: Oh, yes, the 3350 was my first experience of working closer to the product in Product Engineering and I entered that area about six months before the product was about to ship. And it was just before Memorial Day so it's- this was 1975.

Harker: Yes, about then.

Mee: So 32 years ago, exactly, I'm suddenly involved with Product Engineering. And the interface was- I mean, it's the old Winchester interface. No problem. I mean all they had done, I was told, was take that Winchester module, bolt it into a- into the box and increase the density because all the tolerances were tightened up. And so off we go testing it and the first weekend on Memorial Day weekend, I don't know if you can see this…

Bajorek: If you hold it up he can zoom in.

Mee: This is something that somebody gave to me after the event. There's a lot of heads here stuck to the disk. And the head is normally on the suspension riding over the disk and when we came in on Memorial- Tuesday after Memorial Day what had happened was that the testing had automatically taken the machine through the temperature and humidity corners of high humidity, high temperatures, low/low, high/low, low/high, and as it went through the high temperature end, something in there came out of the disk that stuck the head to the disk because it would be- the head would be stationary and then they'd try to take off. And if it would go from high temperature, high humidity to low temperature and then started up, whatever that something was that came out stuck the head to the disk and ripped all the heads off the suspensions. So, that was my initiation into taskforces and trying to find out… It turned out that in the binder system there were some sodium salts, you know, very small amounts, uncontrolled amounts but small. Enough to wick out there and get in between the head and the disk, set solid and hold it. So, we had to set a lower limit of 0.4 micrograms of sodium per disk. I'll never forget it.

Bajorek: And what was the effect called?

Mee: Sirocco. It was named Sirocco because that's a name for one of these winds that blow in the Mediterranean in September, a hot wet wind.

Harker: No, the disk processing, you know, you took a blank for a disk and you ground it down and it polished it and you washed it and keeping sodium out of a wash process is very difficult.

Bajorek: But you set a spec and you recovered one more time, right, on that particular generation. So the product came out right, very successful.

Mee: Yes. But it also had the effect of keeping the other competing technologies going. I mean the- during the seventies the- this alternative magneto optical storage project and other beam addressable projects could well have died. I mean you're chasing magnetic recording, which is improving at 40% a year, and if you start out comfortably on order of magnitude more dense and then as the time goes by that decreases. And that was happening with the magneto optical project. So I did it keep going at IBM for a while because of the new materials that were coming into research…

Bajorek: From Yorktown.

Mee: From Yorktown.

Bajorek: The amorphous chalcogenide type materials right?

Mee: Yes. Plus it got picked up in a big way by the Japanese labs and they took it and developed it into products early in the 1980s. So it had a- kind of a variable life and I was actually back into it even later again but my point is that this worry about this interface was always there, and this was becoming such a big business now, all depending on the reliability of this head media interface. And to think that today we make, what, a million disks a day and we don't seem to have too much trouble. It's just mind-boggling.

Harker: We always kept predicting what the limits were.

Bajorek: So, but then along the ways we were sometimes hedging with magneto optical recording like magneto optical recording.

Mee: Or bubbles.

Bajorek: Or bubbles, were they really aimed at drive replacement or a buffer? I guess we wanted to create a new level in the hierarchy right?

Mee: Well I don't think we knew- I mean I will admit that I started that program as well. But I did get out early.

Bajorek: Was it under TAD's auspices? How long did TAD last as an organization?

Mee: Yes, it was.

Bajorek: It started under TAD okay.

Mee: It started in 1970. Bell Labs had published a lot around the early seventies and if Bell Labs thought it was good, it was good, right, because we, you remember, in those days had several corporate committees for people from outside IBM as well as inside IBM to give us advice on what areas were looking good. And this looked good. It looked good because it looked like a more powerful way of reducing the cost of static magnetic memory, magnetic storage. Instead of having a read write element for one bit, with bubbles you could have it for hundreds of bits. So you could start to amortize the cost of the storage bits over fewer transducers. So that was its basic attraction.

Harker: It was the first concept of a shift register wasn't it?

Mee: Some- it was a shift register, yes.

Harker: Well, and I think the semiconductor shift register was invented…

Mee: Afterwards based on that…

Harker: After yes, because if you can do that with bubbles we can do it with semiconductors.

Bajorek: Yes, I guess it came with CCDs right.

Harker: Yes.

Bajorek: Or similar concepts right.

Mee: Yes. Right.

Bajorek: And how you handled the data.

Mee: Right, exactly.

Bajorek: And then we had the lattice.

<overlapping conversation>

Mee: I mean the only interest in the disk drive business would be if you could really get the cost down. And the problem with the pattern directed by bubbles, which was the main technology, a magnetic pattern on top of the material, which could direct- is the density of the bubbles in the pattern was very low. And so it didn't really lend itself to very high-density storage. Whereas this other idea of corralling a bunch of bubbles into a lattice and then moving rows of those bubbles sort of- it's interesting that self-organized memory devices are back again. But in those days it was a pretty way out idea and we had, again, some excellent people from Yorktown working on that and some excellent people from San Jose Research. So the effort was given an excellent support but it was just too difficult. I mean it was just the technology that was way off in the future. So we did not…

Harker: In both semiconductors and magnetic recording the densities were still continuing…

Bajorek: Continuing to march on, yes. They're following their Moore's law. Now, so bubbles were stopped consciously and were you able to utilize that resource. And that created a great resource of applied magneticians, process people.

Mee: Yes. And you got- and it was just time- lucky timing, again, in that by the end of the seventies we had gone through the 3350 with its head media interface problems. The 3380 was in the middle of those problems in 1980 and so there were- as I said earlier, there- it was a period where there was quite a lot of trepidation in the industry and in IBM about the future for magnetic disk drives. Again, since the technology was- seemed to be so difficult. In fact, I think we got to a spacing of about 12 micro-inches with the 3380 and we stayed at that level for another six or seven years. I don't know, the density was probably tripled beyond the 3380 but it was tripled by increasing the track density and not the bit density because of that spacing.

<overlapping conversation>

Mee: And we're talking about a combination of a particulate disk and a film head. However, on the optimistic side of the technology at that point there had been a substantial amount of work done on magneto resistance heads, which were invented in 1970 at Ampex and picked up as part of the thin film head project, the advanced part of that project.

Harker: Right, the magnetic tape business. They had implemented them.

Mee: So it was looking good for the magnetic tape business and the challenge was how were you going to make a disk head out of that. This is all sort of around the 1980 period so there was the need again to bring in a new resource of the type that Yorktown had and that San Jose Research had. We could tackle a problem- a magnetics problem like the magneto-resistive head. And most of those resources were actually working on the bubbles program up through 1980, I think. And that was the year it got killed. So, again, as Chris points out, resources available fortuitously and we took great advantage of it in forming another joint activity between research and the development division.

Bajorek: It was called a Magnetic Recording Institute.

Mee: And this was mainly Research, it was not little efforts all over the place, it was the Research Division joining forces with the Development Division.

Harker: This was really a contribution, Denis, and he was able to make these connections.

Bajorek: His roots in Research probably helped.

Mee: But also I think the crisis of the 3380 was the opportunity because we had new management that was ready to pick up some major push. Art Anderson really wanted to do something in the way of getting- pushing new technology. It's very similar to what Jack said about 1970 in a way. Things were kind of going along in a rather difficult way and you needed a new approach. And once again, it was putting this together with Research which just made a huge difference and I think you also agree that without that organization we would not have gotten the magnetic resistance head when we got it. It took almost another decade to get it but we did in the end.

Bajorek: I think must have accelerated the ability to commercialize it by a significant amount, compared to what would have happened had we not had that bubble resource to draw from and had we not formed the Magnetic Recording Institute, this inter divisional lab.

Mee: The other ingredient in 1980, which we were very concerned about in IBM, was the competition from Japan. Through the seventies a number of Japanese companies had developed- well, they had got into a leadership position in most of the other magnetic recording businesses. I mean they conquered the video recording business with the rotary head and so on, they conquered the audio recording business, that was all new, and the tape recording was really being led by Japan. And they were starting to get much more interested in the disk business. So we paid more attention to them. We went to visit them and maybe you want to say something about that visit, I don't know.

Bajorek: But before you go there we're about to end another tape segment so this would be, I think, a good transition point for the next tape.

Bajorek: So we pick up at the stage, early '80s, right?

Harker: It was 1980.

Bajorek: Concern about Japan.

Harker: Concern about Japan. There was a lot known about Japan's activities with semi-conductors. We really didn't know a lot about what the Japanese industries were doing as far as our disk recording business. We knew they were working. So we put an activity in place, and you Chris led a group that did a patent search and we found, to our surprise, a great number of patents of the Japanese. So we put a group together Denis, and I, Mike Warner, several others and went over to Japan. And fortunately the way Japan's industry works if we were willing talk a little bit about what we were doing they would be willing to let us visit their laboratories and tell us something about what they were doing. And so we did this. This was at the time the thin film head was just been introduced. So what we took was a set of slides that described the film head and how it was built. And we visited Hitachi...

Bajorek: Matsushita.

Harker: NEC, Matsushita and Fujitsu.

Bajorek: Yep.

Harker: Fujitsu was the most-- they didn't want us there.

Mee: And TDK. I went to TDK.

Harker: TDK, yes. And what we learned was that they had a lot of very aggressive programs. The other thing we learned from work that was done by people in IBM Japan we got a pretty good idea of what their organizations were, and they were doing these projects with fewer people. And when we did cost analysis of their products they were a lot cheaper than our products. So it really set a new set of goals for us.

Mee: Now the other thing they had about that time was fairly substantial government support for joint projects in the Japanese industry. And one was managed through NTT called the Patty File [ph] in which they were able to develop the same prototype drive in different companies but using different components. So they could put a film head, sorry a disk of one company and film head film disk of another and so on. So they were able to try all the various combinations. I think at that time they were putting a lot more emphasis on the film disk than we were and they were behind in the film head. That was the combination.

Harker: When we were at Hitachi, they asked us why did we solve the wrong problem.

Bajorek: Because they thought the film disk was more important than the film head.

Harker: Yes.

Mee: Yeah.

Harker: And from a short term point of view they were probably right, but not from a long term.

Bajorek: Yeah. Right. Right.

Mee: So I think it was a turning point for the relationships with the Japanese companies. There was a lot more interaction with them from then on because IBM was also doing a lot of development in Japan in the '80s. So there was a lot more presence and activity over there.

Bajorek: I imagine there was also one more input that stimulated this formation, or augmentation, of advanced technology through the Magnetic Recording Institute. Right?

Mee: Yes definitely.

Bajorek: Because we were concerned. IBM must have been concerned about its future competitiveness given that capability in Japan.

Mee: And in addition the universities in Japan were getting more active. And especially Tohoku where Iwasaki had already proposed the perpendicular recording approach. And, I mean, it took a long while to become the mainstream approach, what it is today, but he is really the man brought that to the front...

Bajorek: That modern reincarnation of it. Yeah.

Mee: That's right. And so that was a motivation for MRI because we wanted to have the film disk, we wanted to have the film head, we wanted to have a successful interface, we wanted to reduce the spacing and we wanted to do longitudinal and perpendicular recording. That was kind of the scope of what we were trying to do in the 1980s. So fortunately, as they say, there was agreement to put the groups together but also agreement to add the bulk of the bubbles resource into that group. And so it took off from there.

Bajorek: And I think as we talked earlier it did lead to the success, acceleration, of completion of all the magneto resistive head work. I remember, if I'm not mistaken, there were some surprises along the way, right, which we had to deal with MRI, you know, discovery of thermal asperities, molten films, charge transfer and so on. But I remember, if I'm not mistaken you, Jack, you were not actively involved in MRI per se.

Harker: No.

Bajorek: You started another group focused on prototyping high performance 5 1/4 inch file which became the Sawmill File. Could you tell us about that a bit because that ended up being the file that launched the first MR head, right?

Harker: Well there was a group in-- it was actually in manufacturing that was a Manufacturing Research group that was sort of looking for a mission. So when Jack Hildebrand came back from Japan I proposed to the management that he be given that group and that they should focus on, how do we build a really reliable drive? Because up to that time 5 1/4 inch files were a commodity item for PCs. And there were proposals, rate proposals, can't we put an array of these things. And the kicker to that was reliability. You can't have the drives failing frequently. So I thought it was a worthwhile project to see if we could build a truly reliable 5 1/4 inch file. It started out with Jack Hildebrand, but then he got-- IBM Japan asked him to come back there for a magneto optic program. Oh, the cat's got my tongue. I'm sorry. I have a senior moment. Took over the program and we did, we built sort of a bullet proof drive. It had a linear actuator, very substantial frame. It's the first time we brought a drive in with a product cost that was $1.00 a megabyte.

Bajorek: It broke that barrier.

Harker: It broke that barrier. And it became a somewhat successful product. It was used in rack mounts. I believe it lived up to its reliability.

Bajorek: But I also thought significant, superimposed on that, was the first carrier of MR heads.

Harker: First carrier of the MR Head.

Bajorek: It gave us a learning experience that later on gave us, gave IBM the courage to propagate it, right, into its mainstream product lines.

Harker: See I think one of the things we had achieved was that technology should have its timeline. And the products should use the technology when the time was right not have a product and try and develop the technology for it. And I think that was what, why it-- it was a convenient point to enter.

Bajorek: I don't know whether this is related to the learning about Japan's capability in disk drives that we talked about earlier, but how did IBM decide to start this small drive development effort in Yamato and then what became Fujisawa. I think both of you were involved in that. At least you were involved, Jack.

Harker: Well I'll tell you. This was Jack Hildebrand. At various times we had looked at and using the development, let me call it, mentality. Could you build the 5 1/4 inch drive cheaper than you could build a bigger drive? And if you start with that premise you wind up saying, "No you can't." And the first reaction to the 5 1/4 hard drives within IBM was, "Well those are just-- okay, we don't...

Bajorek: Toys, they're toys.

Harker: Toys. Jack Hildebrand didn't feel that way. He felt that, "Look, if we don't get in that business, at their level, we're not going to learn." And so he had the idea that maybe IBM Japan would be interested in this project like that. And Jack and I went to see Jerry Harries. Jerry Harries, when he was in Raleigh, had been involved in the establishment of the Fujisawa laboratory under Nobuo Mii and they'd maintained a close relationship. And it turns out that he was going to go over to Japan and he'd discuss it. He came back and said, "Look, they'd love to do this," because IBM Japan was under pressure from the corporation. You're operating like an American company not a Japanese company and they wanted a project that they could run...

Bajorek: As a Japanese company

Harker: As a Japanese. So Jack Hildebrand, Jerry Harries set this program up. Jack went over. He recruited out of the manufacturing engineering group a dozen good bright young engineers. He brought them back to Rochester for about two or three months where they learned all they could about disk drive development. Then they went back to Japan and they operated as a closed unit, sort of an independent unit to design such a disk and put it in production. And it was very successful. It wasn't technically anything of great achievement. It was more or less a copy of the Seagate drive, but we learned how to create it at that cost.

Bajorek: And create, and manufacture and we tested, I guess, all the sources for componentry for that kind of drive.

Harker: Yes. Yes. It was totally outsourced from IBM Japan.

Bajorek: But I think it laid the foundation because later on the IBM Japan teams became very successful at developing and took over the leadership of all the small drives that IBM created including the notebook computer drives, right? Including the micro drive, all of those came...

Harker: Micro drive. No.

Bajorek: Well they manufactured it.

Harker: Oh they manufactured it. Yes.

Bajorek: But they laid the foundation that could then accept the micro drive, right, and commercialize it.

Harker: Yes they did.

Bajorek: The other initiatives I think you guys were involved in were spearheading some establishment of interest in magnetic recording in U.S. universities.

Harker: Ah, that was Denis' field.

Bajorek: What triggered that and was it...

Mee: That tees of the visits to Japan.

Bajorek: Where you saw this academic involvement.

Mee: You could see that academic involvement, but also we were seeing a new generation of Japanese engineers. I mean, the older generation, I mean they had quite a bit of trouble with the language, and communicating, and coming to the conferences and so on. But we were seeing a new generation of younger people that were fluent in English, giving presentations at the conferences, you know, getting into sort of the leadership position with regard to their publication of their activities and could see that the universities were really quite active at that time. So , this goes back, again, to when MRI was formed, we felt that we needed to beef up the U.S. university work partially because of that, but mainly because we could see we needed a lot of new trained people in the future. I mean the industry was growing rapidly. We needed trained students. And the connection with the universities up to that point was from individual companies to universities sponsoring specific research projects. So fortunately, at that point, Art Anderson was interested in funding the formation of a couple of university centers for magnetic recording, one in San Diego and one at Carnegie Mellon for three years. And I think there was probably eight companies that joined IBM in that endeavor. Some were in the tape business and some were in the disk business, but they got together and they did fund university research centers which were set up. There were two set up then, and by the end of the decade there were six more added to that. So it did work quite successfully for a while to get-- I think by then we were getting something like 40 graduate students a year. And there was probably 150 or so in the pipeline. So it was looking good. But by the end of the '80s-- I don't want to go too much closer than that, but it was working well. But what was not happening is that the total technology coverage that we wanted to get was not evenly distributed amongst the university efforts. Some areas there was overlap, and in some areas there were holes. And so we wanted to form a more close interaction, somehow, between industry and the university in a way that is acceptable to the universities. So this means mentoring, advice, and so on. But if you want to go a step further than that then it meant forming some kind of consortium, industry consortium that would fund university projects from the supporting companies. And that did lead, in the early '90s, to the formation of a industry consortium that I was very interested in and that I continued to-- I helped found that and I also continued to work with that after I had retired from IBM.

Bajorek: That's the INSIC organization?

Mee: INSIC organization, yeah.

Bajorek: And eventually-- it was first a U.S. organization and then it became global, right, international organization.

Mee: Yes. It's interesting how the INSIC consortium got formed because the companies involved had no interest in sitting around a table together and cooperating.

Bajorek: They were arch competitors.

Mee: They were. And there was also a concern about anti-trust considerations. But fortunately, at that time in 1990, the government did start a program called Advanced Technology Program where they would fund projects of this kind, and so it enabled us to have a project to work on together to go after the government funding. It made it legitimate and the government would fund it. And we got one of the first advanced technology project grants. So when INSIC was first formed it was like probably 70 percent government funding and 30 percent industry. Today it is all industry.

Bajorek: A hundred percent industry, right?

Mee: Yeah. Although the ATP program, which has had its ups and downs, has now been revived recently and INSIC is again bidding on some ATP projects. So it's back again. But today there are about 30 companies in INSIC and supporting work at 45 to 50 universities.

Bajorek: Extraordinary.

Mee: And labs. You mentioned the internationalization which occurred in the middle of the '90s. It was pretty clear, as things were progressing, that making this strictly an American supported and university activity was not going to last. So internationalization took place at that time very easily. So we now have the meetings of INSIC today are held in the U.S. and in Japan and in Singapore. So it has truly become an international organization.

Bajorek: Extraordinary program. And it's created a steady stream of students.

Mee: Yes.

Bajorek: Who are more easily trainable, who can become contributors in the industry much faster than in the absence of those academic efforts.

Mee: Right. Right.

Bajorek: Both of you earned the honor of being named IBM fellows. I'm curious, how did that influence your ability to work at IBM? Did that make it easier or harder or was it neutral? First of all, congratulations on your fellowships, but...

Harker: I think IBM decided I'd done enough damage managing things.

Bajorek: So they wanted you out of the way.

Harker: Well frankly Chris, by that time I'd been managing large organizations and it's stressful, and I appreciated the opportunity not to have to.

Bajorek: Not to have to do it.

Harker: I still stayed around and made trouble for people. And I started several things of my own, but it was an easier life.

Bajorek: How long did your fellow program last?

Harker: It never really had a formal end.

Mee: No, they don't.

Bajorek: But I think your Sawmill program, right, was under your fellowship, right?

Harker: No, my Sawmill?

Bajorek: No, your Sawmill.

Harker: Yes. I covered that under a fellow...

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Bajorek: You sponsored that under your...

Harker: Yeah. I sponsored it as a fellow.

Bajorek: You were a fellow by then, right? And Jim Makiyama was the head of the file program, right?

Harker: Yes. But it quickly became a product program. So no, I was able-- in fact the 3370 program started in a fellowship group I had that I inherited from Walt Buslik when he retired and that group eventually became part of the 3370.

Bajorek: Dennis did you-- how did it influence you, make life harder or easier?

Mee: Oh, it made a big difference to me because I think the IBM Fellow program has got a lot of different aspects to it. It's different for different people. There are some people who are already, in a way, running their own program very successfully and IBM would use the fellow program to support that program over a longer period of time. There are others like Jack, and also myself, that were in managerial positions where getting a fellow program would make a bigger change if you got into it completely. And I had made it known in the early '80s, that's when I was talking about this university activity, that I really did want to spend more time doing that. And I was in the middle of the MRI program and the MRI Institute. And so, I kept making it known that I would love to do more than just that. And the idea of providing a series of books for magnetic recording, for the industry and for the universities, was one of the things that I also wanted to do. So I think, again it came to the stage where they thought, they said probably, "Okay, let him do it." So I started that in 1984. Actually I was made a fellow in '83. When I was told that I was going to be a Fellow I was also told that I would continue doing the same job for a while.

Harker: Likewise.

Mee: But I started the fellow program in '84 and then I started doing all those books. Three years later there was that other conversation with the man who headed the division at the time who said, "Denis, it's time to get back to work," so I started another, yet another joint activity between research and the development division, I think it was my fourth activity at that time, for optical storage.

Bajorek: Again.

Mee: Again.

Bajorek: It just couldn't go away.

Mee: Some people never learn.

Bajorek: This was post MRI, right? This was between research and Tucson because optical storage by then, the interest in a potential product had moved to Tucson.

Mee: Yes. Yes it had.

Bajorek: So that was a bridge between Almaden and Tucson.

Mee: Yeah. Yeah there was an excellent group in Almaden. And optical storage had been through several major innovations both in holographic storage and in multifilm optical storage. Again, a wonderful group of people suddenly coming to help the development of the program so it did work. I was in that for a couple of years and then back to the fellow program after that.

Bajorek: As you look back, both of you now these illustrious careers, is there any particular highlight that stands out, the most significant contribution, the high point or was it that the complete career was a roller coaster experience for you?

Harker: I started out the interview saying I was very lucky. There's lucky in where I was, the job I got, particularly I was lucky in the people I worked with. Years after I retired I'm still close friends with many of the people we worked with.

Bajorek: You made lifetime friendships.

Harker: And to me that's a real reward to be able to say that you really liked the people you worked with. And along the way, yeah I-- certainly putting the low cost file together was fun, a challenge but fun. When we formed-- integrated the technology that was fun because we thought we could do something. Those are really the things that stood out. A lot of other things were fine too, but...

Bajorek: Those were the highlights.

Harker: Yep.

Bajorek: How about you Denis?

Mee: Well, I mean likewise with the people, but my situation was a bit different. I had three jobs before I joined IBM so there was a considerable period of time working with other companies. And I'd always had this desire to end up in a lab like Bell Labs, or IBM, or GE or one of the big labs. Never could really see how I would ever get there. In fact I'd say one of the motivations for writing that first book was I kind of tried to make a mark with that. And it did help. It got me into IBM. I mean it helped get me in that job with IBM for sure. So I think I was able to realize the dream and join the big successful company. And I guess the second highlight for me was really moving to the West Coast. For many reasons it was the right thing to do, and I'm glad I did it and I'd like to stay here.

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Bajorek: It got you into the middle of the action.

Mee: Yeah.

Bajorek: And to capture completely, how many books did you write or edit? Could you recap? I know we talked about the Physics of Magnetic Recording, your first book. You did at least two more, right, in terms of editor or writer?

Mee: Yeah. I think there were seven all together.

Bajorek: I knew some were multi volume books, but I lost track. If you could, just tell me about your books.

Mee: Well the first one-- I only wrote one book. I mean I authored that Physics of Magnetic Recording. And after that I said, "There's a terrific way to learn something and I'll never do it again, ever."

Bajorek: Not even as an editor?

Mee: Well, editor is a different proposition. I was lucky. I wanted to do these books on magnetic recording in the 1980s and got the opportunity when I got into that fellow program. And I was starting to put it all together realizing such a vast subject. I'm not going to write this. I'm going to have 20 authors do it. Editing is harder than writing. That's for sure. No doubt about that. So I got five university authors and five from industry on the first set of books which were three books. And the first person I asked to write a chapter was Eric Daniel, who I'd known for many years, and he refused. And he said, "I don't want to write a chapter for you. I want to do the books with you." So that was my lucky break. And so we did all those books together. It came out as a three volume. One was one technology and the other two were on applications, computer applications and analog applications video and audio. Then that went through several stages of getting new authors in and expanding the scope. It became a McGraw-Hill handbook, which was putting the whole thing together in something. Then it ended up as a two volume thing. So that whole piece of work went on from 1984 through to '95. It was a long period of time. In 1998 it was the 100th anniversary of the invention of magnetic recording and Eric, and I and another author got together and we authored and edited a book on the history of magnetic recording which was a lot of fun. That was a great way to end up with it, and I said, "I'll never do it again." But I won't because I won't live another 100 years.

Bajorek: Let me ask you though, are you working on another book?

Mee: No.

Bajorek: So the title of that one was Magnetic Recording the First 100 Years.

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Mee: Yeah.

Bajorek: And the title of the series on technology and applications is Magnetic Recording?

Mee: Magnetic Recording. Volume one was Technology. Volume two was Computer Data Storage. And Volume three was Video Audio and Instrumentation Recording. They were all the linear recording, you know, technologies.

Bajorek: Well look, it's been fascinating to reminisce about your wonderful careers and contributions to this industry. And you're both retired now. A couple things happened since then. IBM got out of this business and sold it Hitachi. How do you feel about that?

Mee: At this point I thought it was brilliant considering what's happened to the industry and the difficulty that any of those companies are having in making it a profitable business.

Bajorek: These are substantially worst than the ones...

Mee: And I just, again I guess I just feel so lucky that I rode this one when it was good, all of us.

Harker: Yep. We had the golden age.

Bajorek: Well, I think you not only had it but you also shaped it as such. So I recommend we end at this point.

Harker: Good.

Bajorek: And I want to thank you very much for your time...

Harker: Thank you Chris for...

Bajorek: And for sharing these histories with us for this recording. Thank you very much.

Mee: Thank you.

Harker: Thank you.

END OF MAY 30, 2007 INTERVIEW

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Tom Gardner: Good afternoon. It's Tuesday, July 10, 2007. We're here at the Computer History Museum in Mountain View, California. With me is Jack Harker who has a long and distinguished career at IBM and is along with me a volunteer at the Computer History Museum. I'm Tom Gardner. I'm a member of the Oral History Committee of the Computer History Museum and we're here today to discuss Jack's perspective on the disk drive industry products and technologies, mainly focusing on the '70s and '80s with a brief segue into some earlier RAMAC stuff. Also in the room is Chris Bajorek, another member of the Computer History Museum volunteer cadre. Chris worked with Jack for many years and may from time to time help Jack or me with a follow-up question. It'll be a bit of a disembodied voice from the side. At that point we'll take a quick break. Jack, you've already given an oral history for us and covered your early part of your career but to sum it up you started IBM in—

Jack Harker: In 1952.

Gardner: You retired from IBM—

Harker: In 1987.

Gardner: But I'm told you didn't retire.

Harker: Well, I worked for a few years more.

Gardner: Now you're—

Harker: I'm fully retired.

Gardner: But giving us a lot of time at the Computer History Museum. I have a couple of follow-up questions for you on the RAMAC era if you don't mind. Tell us a little bit about what Don Johnson did on the RAMAC.

Harker: Don Johnson was the mechanical engineer who designed the basic structure of the file, the base, the motor, the mounting of the disks. He was involved with the disk process itself, with the overall structure of the file.

Gardner: Did he do the access mechanism?

Harker: No.

Gardner: Was it part of the access mechanism too or—

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Harker: No. As I think I've said earlier, John Lynott designed the carriage with the arms that held the heads. I designed the rail and the drive to move the carriage.

Gardner: Who put the motor inside the disk stack? Was it Don?

Harker: My memory of those days is rather dim and I would not swear that there was an inside motor but if there was I would expect that Don did it.

Gardner: I'm pretty sure the first seven RAMACs, including the one that's out here, had a gear drive. The motor was cantilevered on the side and there was a gear that drove a larger gear and about serial #8 they moved to put an AC motor inside the disk stack.

Harker: Well, see, I was off the project by then so I- my knowledge doesn't cover that.

Gardner: How about Trigg Noyes?

Harker: Trigg Noyes managed the file group. Trigg came from Food Machinery. He and John Lynott both came from Food Machinery and I can't out of my head tell you what Trigg's career there was but he was a good guy, a good manager. He managed the file project from the time that we were- started designing a product until- as far as I know until it was released.

Gardner: What do you mean when you say "file product"?

Harker: Well, the configuration that became the 350, the vertical shaft, a stack of 50 disks, the servo mechanism, etc.

Gardner: I ask because that's a term that probably is not used a lot today. I know what file product meant and you know but it's a term we don't currently use in the disk drive industry so if someone listening to this might not have understood. I will ask questions like that because IBM did have its own peculiar terminology which has sort of drifted into nonexistence today.

Harker: No. No. The rest of the industry just didn't keep up with us.

Gardner: That's true. You and I know what a DASD!

Harker: Yes, and also was RAMP at one time.

Gardner: RAMP standing for?

Harker: Random access machine processing or something.

Gardner: Memory product?

Harker: Memory product maybe except it wasn't memory.

Gardner: Did you guys talk about the RAMP conferences at any time?

Harker: I doubt it. I only participated marginally in one or two of them.

Gardner: How about Raymond R. Bowdle

Harker: Ray worked on the first embodiment of the disk technology which was the file to card machine. As I recall, he did the electric circuits to transfer information from a card punch to the file and from the file to the card punch.

Gardner: Did he go as far as a read channel?

Harker: I can't tell you that. I don't know.

Gardner: How about James H. Davis?

Harker: Jim Davis designed the servo to move the carriage and the arms between the disks. I think the read/write circuitry was probably Len Seader.

Gardner: David W. Keene.?

Harker: Dave was sort of general purpose-- I don't recall specifically what part of the machine he contributed to. Perhaps the logic.

Gardner: How did the RAMAC go from horizontal in the file to card machine to vertical disks in the ultimate product?

Harker: There are two stories. One is that Rey Johnson thought we should be able to put a multiplicity of access mechanisms around the file and if you had it horizontal you might get two access mechanisms but it would be very difficult to do more. With the shaft vertical, the original design of the access mechanism that I did I think I was limited to an 18-degree segment.

Gardner: I'm not a mathematician. That's 20 actuators?

Harker: Something like that. The other thing is that Lou Stevens thought it was a better way of doing it because you could change disks more easily.

Gardner: Did they ever do a multiple actuator version?

Harker: Yes. There was actually a three-actuator version I believe done for the 650 system and I don't think all three of them ever worked at the same time.

Gardner: Did it ship or was it a laboratory device?

Harker: I can't tell you.

Gardner: Anything else you'd like to tell us about your recollection on because we're about to move on?

Harker: No. That's fine.

Gardner: In November 1970, you became the disk file product manager, I think direct access storage product manager might have been the specific title.

Harker: Could be.

Gardner: I have a peculiar ability to remember strange facts—

Harker: Okay. Good.

Gardner: I think that was the official title for the businessperson responsible for disk storage at IBM.

Harker: Yes.

Gardner: Interesting period of time—

Harker: Oh, it was.

Gardner: Would you care to tell us about it?

Harker: Well, I had been responsible for the integrated technology group in the laboratory and I was asked if I would take the product manager job. Aside from my Cypress experience, photo digital, I had never managed a product through the business cycle but I was willing to give it a try. When I came in to the job we were under very heavy competitive pressure.

The 2314 DASF products had been priced to give a very good return because when they were announced there was nothing competitive but this had attracted a number of competitors who were seriously undercutting our prices. To date our response had been a series of reuse programs where we would take returned 2314 hardware, we would turn it around, refurbish it, maybe make some small changes, but basically then reinstall it with a new product number on it, at a price that was justified by the book value. This was not a new thing. Back when punch cards were going out and computers were coming in there was a re-pricing of the card equipment. They'd bring it back to the factory, put a different pulley so it wouldn't run so fast and it was called Series 50 and 2319 program was much like that. It was a holding action. The real hope was the 3330, which had been announced, would take over and would swamp the competition but at that point we weren't getting the orders that we thought we should. Basically, the large systems people were very focused on access mechanisms and they were concerned that the 3330 had too much capacity per arm and that their high-performance customers wouldn't want to buy it.

Gardner: For the record, that's 100 megabyte disk pack with 19 arms. Today we have a 160 gigabyte drive with two arms.

Harker: It was a long-standing argument between Poughkeepsie and San Jose but- probably the more serious problem was the intermediate systems because that was a high-volume market ones. Those systems were attaching through integrated attachments, 2314 spindles or 2319 spindles, and for them to take a 3830 and 3330s, was such a leap in expense that it just didn't make sense. There were performance issues, and that came back to that arm problem. I If you replaced two or three strings of 2314's the performance would suffer when you went to one string of 3830's. Well, we did a number of things. Harry Hill had a group running simulations, Steve Goldstein, Ira Oldham.[ph?] They did good work but the thing people had overlooked was that the data rate of the 3330, 3830 combination was so much higher that it swamped any competition from the 2314 era systems so we did get over that hurdle.

Gardner: I think they also rotated faster if I recall.

Harker: Yes. The latency and access times were faster so the overall performance just could be shown to be superior for equivalent or similar capacities.

Gardner: To put it in perspective, I think the faster data rate was 300 kilobytes a second or something-like that. --which today is standing still.

Harker: But the other thing: In order to solve the problem on the intermediate systems, Mod 40, Mod 30, the mid-range systems, we had to get some sort of an integrated attachment. Now this evolved in to what we called the attachment strategy.

Gardner: Was the 2319 integrated file adapter a precursor to the attachment strategy or a part of the attachment strategy.

Harker: No. It was a precursor. The systems had done it themselves. These were gates that were housed within the system and the systems didn't want to buy a 2841 Controller. So they designed their own integrated attachment. Tom, from our prior conversations you know all this, that there were a number of functions in the controller that were actually drive functions. The clocking of the data was done in the controller, not in the drive. I think some of the address buffering, things like that, was in the controller, not in the drive. I came in to the job and I really didn't know these things. Fortunately, there was a guy who had an office across from mine, who had come out a month or two earlier from Poughkeepsie on assignment to- as a assistant to the prior DASD manager. Late one afternoon I was in my office and I thought gee, I've never gone over and introduced myself, so I did, Bob Jones, and we wound up talking about this and he explained all of this to me and as I understood this it seemed to me this was-- Why in the world did we have those functions in the controller when they were drive functions? They were drive dependent functions. Another problem we had was a very serious morale problem with the people who designed the control unit. In earlier days when Hal Eden was there, the control unit group was a very, very proud group of guys who did the 2841 and what had happened was they had all been shifted and assigned to be part of the drive groups so that each drive group was developing its own controller. The 3330 had the 3830 but the 2305 had its own controller. The Winchester was coming along and they had a group to do their controller. This fragmenting of that group was creating real morale problems. They felt put down so I put all these things together and I tried to come up- say "Let's rationalize this." Somehow we ought to associate with a string of drives the functions that are unique to that drive and we ought to have a controller that does the function of interfacing that string of drives to the systems and this is what we called the attachment strategy. By doing this we could essentially kill all these independent controller developments, which means I had a significant resource and we used that resource, one, to do- implement the attachments and a director as we called it to provide the control functions but I was also able to go to each of the systems managers in the intermediate systems, intermediate low-end systems, and say, "I will send you people to do an integrated attachment." And we did that. George Ahearn went to Hursley for the Mod 30. I've forgotten what we did with Endicott but we were able to solve several problems. The other thing was when you had these fixed strings of 8 drives and a controller when a customer began to top off on capacity he had to take a big jump to increase. By allowing multiple strings of drives to attach to this director, all he had to do was buy a drive.

Gardner: With a controller in the A box.

Harker: Yeah, a drive with an A box, which was the attachment part of it, and then he could add B boxes but it significantly reduced that hurdle of capacity so as far as I know it was totally successful.

Gardner: Do you know whether the spindles per control unit ratio changed?

Harker: Oh, yes. Yes, they increased. Yes. I could never get forecasting to give me any credit for additional drives but I'm sure we sold a lot more drives.

Gardner: Yeah. I can tell you from Memorex's perspective it maxed out at about less than nine spindles per path and that was probably overstated because many of the Memorex spindles wound up on the IBM integrated attachments so from Memorex's perspective it didn't look like the number of spindles per path went much above the eight limitation that existed in 2314 but no one knows what the whole industry ratio was.

Harker: I don't remember the specifics of it.

Gardner: The first IFAs were done by the systems houses—

Harker: Yes.

Gardner: I think you meant to say the 145 and 135. San Jose provided some of the people who did the integrated attachments.

Harker: Yeah. It was my carrot to the systems managers. This was a very turbulent time in IBM. Up to this point, systems managers had been sort of kings of the domain. They were the ones who said what they wanted and it was up to the device people to provide those. None of the systems managers would have signed up voluntarily for this change of attachment strategy but I had Bob Evans' very strong support and he essentially edicted it. I think it really ended the era of the systems managers. I think they lost credibility 'cause I know Evans' views that they were really supposed to be managing for the benefit of the business, not their systems., So I think it changed.

Gardner: In the high-end systems you didn't have an integrated file adapter. You had an integrated storage control unit.

Harker: Yes. That was not my doing. That was negotiated back East.

Gardner: How so?

Harker: I think Evans wanted it done. And Bob Evans did not run a democracy.

Gardner: You and I know the integrated storage control unit was the same gate as the 3830 Model 2 mounted in a systems chassis.

Harker: Yes the 3830 Model 2 gate was mounted in the system.

Gardner: The 3330, 3830 with the attachment strategy and the double density turned out to be a huge success.

Harker: Oh, it was huge. Look. The person who deserves the credit for 3830, 3330 success is Carman Rosatto. Probably the most important thing I did the day I was named as product manager was I called Carman in from vacation and told him he was running that program. I don't think he ever forgave me. I did it because I knew Carman was the best program manager I have ever known and I knew that he would run it without my help and I knew I had an awful lot of other things I had to do.

Gardner: Were there any technical issues on that class of product that come to mind you'd like to tell us about, interesting problems found and solved?

Harker: No. I don't remember it having a lot of problems once it went into production. It had a long, convoluted development history -- it had its own new technology with the track following servo.

Gardner: Was it first—

Harker: Yes, first to follow a servo track.

Gardner: Yesterday I found out the inventor of servo track following is Al Hoagland

Harker: Yeah, probably, on the single disk file.

Gardner: That was about '58.

Harker: Yes.

Gardner: The 3330 then shipped as the first product embodying that technology in 1970, so that's 12 years later.

Harker: And that foolish little hydraulic actuator that I jimmy'ed up with Bob Pattison was just too attractive for people to want to change.

Gardner: Inexpensive and reliable. As an aside, I don't know if it's a true story or not but the story is the reason Memorex got in to the disk drive business is that the folks were developing the key to disk drive product and they went to IBM, who was the only seller of disk drives at the time, and wanted to buy 2311's from IBM and IBM said, "That's great. The price is $26,000." And the folks from Memorex said, "Well, no. We want a hundred." And the IBM salesman said, "No. That's $26,000 times a hundred." I think they cost about $3,000.

Harker: I have-- I can't comment on this. No comment.

Gardner: That was I believe led to Memorex then deciding to make its own disk drives. Who knows what history changed after that? We sort of jumped a bit ahead. There are a couple of other products that were on your plate when you took over in 1970. I guess the 2305 had just shipped.

Harker: Yeah. Again Carman had run that program. My impression was it was done-- I don't think there were any significant problems that I can recall that I ever had to deal with as a product manager. We didn't make very many of them. Poughkeepsie said, "Do this," and we did it.

Gardner: It sort of got replaced by either caching or solid-state disks or both.

Harker: Yes, or VM.

Gardner: It was the first taper flat air-bearing.

Harker: Oh, yes and that was Eric Solyst's contribution.

Gardner: Of course, I'm an electrical engineer by background so I don't understand this mechanic stuff but I believe there were nine recording elements on one head.

Harker: Yes. You had to press on it with about a pound of force to get it close enough to the surface. It was a taper flat and you could lap it flat. And the disks were thick disks as I recall too.

Gardner: And I think it spun up at 5,000 RPM. It was also a very high-speed device.

Harker: Yes. Yes. Yes, but it was well designed.

Gardner: How about the floppy?

Harker: Oh. Well, Dave Noble and group, Herb Thompson and others had developed the Minnow, the read-only floppy disk to be used for IPL for Series 360 with a semiconductor memory. There was interest afterwards in our group to make a follow-on, a read/write, low-capacity device. It was designed. It went through several generations of design and we had no takers within the data systems division and the- finally the program fell out of funding and we were going to close it down. Fortunately, one day Don Stephenson, who was the site manager at Rochester, General Systems Division, stopped by my office because he and I had worked together. He was complaining that they needed a product- they wanted a product to compete with Mohawk key to tape system and that they'd been pushing on Boulder to come up with a low-end tape drive for them that they could integrate with a keyboard. He was frustrated and I said, "Well, gee. Maybe we've got something for you." And Hal Hester, who had been looking at applications, came up, put together a presentation, gave it to Don that afternoon showing how you could have a cluster of these stations that would create this floppy disk from a keyboard and then you could take the floppy disks and put them into a reader and enter them into a system. And Don was impressed and it went from there.

Gardner: So that became the 3740?

Harker: Yes, which was first to be produced in Boulder and we had it half released to Boulder and then GSD decided they wanted to do it themselves so then we turned around and released it to Rochester and the guy that made that happen was Lou Blenderman, a wonderful man, patience of Job.

Gardner: There's a guy out there, a Dr. Nakamatsu, who claims he invented floppies and that IBM actually took licenses from him.

Harker: I have no knowledge.

Gardner: Never heard of the guy?

Harker: No. Dave Noble went around and looked at it all. There have been a number of floppy disks proposed. One of them was an inside-out disk where you stretched a membrane over a hoop and cut the circle out of it and you put the access on the inside. 3M wound up later on trying to do something like that.

Gardner: Stretched surface recording, SSR.

Harker: Okay.

Gardner: I looked at one of them one time—

Harker: Yep, but there were several . The credit that Dave gets is that he came up with something so simple and the key to it was a piece of wipe material that would collect the debris off the surface. When you were running in contact you would generate debris and it was a use of the wipe surface and unfortunately what he used was Kim wipes. One of the problems we had along the way was somehow those wipes had changed. That's when we found out we were working with the waste product division of Scott Paper and they had no specifications.

Gardner: That sounds like a great story. Can you tell me some more about it?

Harker: No. That's my- the end of my recollection. That's why Lou Blenderman was such a patient man.

Gardner: But you got to admit that something in a waste product's going to be inexpensive. I think the inventors- the patent on that is held by-- Of course, IBM is the assignee but Herb Thompson and Ralph Flores are the two guys who got the credit for the wipe part of the floppy.

Harker: Well, okay.

Gardner: I never met Ralph. I know Herb. He's a great guy.

Harker: Yes.

Gardner: There was a rumor that at one time IBM believed the 3330 was going to be the most profitable product in the history of commerce.

Harker: No. I'm surprised at that because the Mod 11, the double density, was the kicker to it but we had our future already planned on the Winchester technology and I'd like to claim that we were smart enough to plan it this way but in fact it worked out that the rest of the industry followed us on the 3330 technology and sort of poofed when we brought out the 3340 which was a low-end product and never did have a very high volume but it wasn't until we got to the 3350 and the rest of the industry found out they were behind.

Gardner: The 3330- 3830, were in production for 13 years, by today's standards, an enormous lifetime and I think it was actually the longest produced product until the 3380 family.

Harker: Yes

Gardner: I think IBM actually produced 3330—

Harker: You may be right. I have nothing to contradict you. My impression is we produced a lot more 3380- 3350's than we ever produced 3330's because the 3350 was the first machine I remember going into machine rooms and seeing a floor of disk drives but recognize this wasn't just us. The systems had changed. System 360 had changed the way people used storage. Tapes were out. Disks were in—

Gardner: It could be. This is a good point to break and then we'll pick up on a new tape and we'll move off 3330 on to more interesting stuff.?

Gardner: It's probably a great segue into the Winchester Technology in the 3340.

Harker: Okay. Well, we talked, I think, a little about this earlier when I was working with Chris Bajorek. The program has started with Ken Haughton and I think it was Dick Mulvany and Rudolf Lissner that came up with a concept of putting the heads into the disk pack because then you could have two heads per arm and that cuts stroke of the actuator. And the magnet for the actuator got smaller and that was an expensive piece of hardware. And the whole idea, sort of, took off. And it came to be called Winchester because the first version of it was designed to have two 30 megabytes spindles in a box, which was a 30/30 drive-- a Winchester rifle. It was our introduction of a lower mass, lower load suspension system that started and stopped in contact with the disk-- a lubricated disk. This had a whole set of technology implications with it.

It had had predecessors. The RAND buffer that Joe Ma did in ASDD that used the tri-pad slider-- it's what R.J. Miller had developed. A buffer-- I don't remember the name or the model number that was integrated into a control processor in the communications business—it used tri-pad heads on a lubricated disk but this was the first time we tried it with on a large volume product. The problems were legion. The serious problem was getting the right lubricant. You wanted something that would be only a few molecules thick on the surface and yet would not leave the surface over a period of years. And these were hydrocarbons so we succeeded in getting a very, very narrow cut of hydrocarbons that had reasonable adherence to the disk. We also had to learn a lot about surface chemistry. I'd wish we'd learn more than we did at that time but we-- of what it is that makes the lubricant adhere to the disk, what makes other things not adhere preferentially. So it brought on a whole new range of technical skills that we really hadn't had to develop before. Fortunate we have a very competent group of material analysis people-- Irmela Barlow and Ed Barrall, who did yeoman work in this area. The servo design was novel, far less expensive than the 3330. It was a well-designed product. The group that was the core of the development were a half dozen people who we'd been sent over to Hursley at an earlier time to help bail them out on a problem with a single disk file that they had-- Gulliver. They came back and were integrated into Ken's group and would up pretty much running it. Before I became product manager, we had already transferred the program out of technology into the product area and Ken was running it. Bob Friesen was running the engineering design. And in the early days at product management, it was not something I had a lot of focus on. But as it became the next upcoming project, it had a lot of hurdles to overcome; probably the biggest one was the cost of that integrated disk pack. And we had a cost target of $2000 for it. It was very difficult.

Gardner: Is that cost or price?

Harker: Cost. We had lots of problems. I think when Ken was interviewed, he talked about a number of them. The fact that the corporation in its wisdom had assigned the sale of disk packs to the Office Products Division so the salesmen for the drive products didn't get commission on the disk packs. And they weren't real eager about selling this disk pack because there was a different ratio between the cost of the pack and the cost of the drive than had been the case in the 3330. The packs were much cheaper as a part of the total purchase cost whereas on the Winchester, the data modules were a significant cost to the user. What we were counting on was that people weren't buying many packs per disk drive. When the 2311 came out, we sold something like ten packs per drive. On the 3330, I doubt if we sold two per drive.

Gardner: Is that counting the pack compatible manufacturers? Or is that just IBM sales?

Harker: I can't tell -- the reason was operating systems. They weren't being used for data. They were being used to store the system's operating system. And a systems administrator doesn't want you coming in and taking his system apart to change packs. So the only real reason the packs were ever changed was if they were debugging a program upgrade. They keep the program update on one set of packs and off shift they'd bring it in and transfer them and then only install the software when it was solid. And that was really the only use that I know or even recall. So we were counting on that with Winchester. But it was still a very significant part of the product cost-- the cost of the pack. Joe Sheredy had the responsibility in manufacturing. And I remember he and Ken and I had a long meeting once. I told him that I had to meet a $2000 target. Joe pulled out his engineering notebook and said, "Look. If we make $2000, will you agree to walk across the waiting pond in front of the cafeteria?" I said, "I sure will." So he wrote it down in his book and I signed it. Well, an upshot of that one is it was several years later and we were at some offsite function in Tucson. And somebody started kidding me, "You've never walked across the waiting pond." And I said, "Well, when Sheridy gives me marker, I'll walk." Joe had misplaced the engineering notebook and he never was able to produce.

Gardner: Was there ever any consideration of a short stack Iceberg type product as opposed to Winchester?

Harker: It was, in fact, in plan when we came up with Winchester product. And we killed it with Winchester.

Gardner: Because?

Harker: It was not a cost-effective solution. We would have had to functionally price it to try and get the price down to where it would be attractive. When I killed it, I got a pat on the back from all the business people. They didn't want it. The low-end systems managers were peeved.

Gardner: What do you mean by functionally pricing?

Harker: We would have had to find a way of pricing it based on what the function it provided rather than what our normal costing methods would produce.

Gardner: Okay. So you were selling a 200 megabyte disk pack for "X" bucks. When you have a 40 megabyte disk pack, you'd have to be forty two hundredths of X and the cost issues would not give you the margins you wanted.

Harker: Probably true -- we just thought it was technically a bad solution.

Gardner: But of course, that's the way the rest of the world went.

Harker: I know.

Gardner: And they were very successful.

Harker: Yes.

Gardner: More successful than Winchester.

Harker: My belief by that time was that we competed with technology. We had to have technology-- we could invest in it. We had the revenue base that would support a development technology effort and that was what we had to do. And these compromises along the way just detracted from it. Sometimes we had to make them.

Gardner: But looking back today-- there's no question Winchester in the 3350 was a hugely successful product. But Winchester in the 3340 embodiment --

Harker: We never had a high forecast for it. I think 20,000 units was the forecast and I don't think we ever made it.

Gardner: I think, for example, SMD shipped over 100,000 units in their 40 and 80 megabyte version which was short stack Merlin.

Harker: IBM's short stack Merlin was intended to fill a specific system's requirement for the German systems, Mod 20s or whatever it was in those days.

Gardner: So you're feeling is the Winchester volume didn't come because the system volume wasn't there?

Harker: Yes. The systems that it was attached to just didn't have that kind of volume. It wasn't designed for the intermediate systems.

Gardner: It was a 115,125 small systems product.

Harker: They finally did get GSD to attach it but it was late in the day.

Gardner: But it did lead to the 3350? You're smiling.

Harker: Yes.

Gardner: Why?

Harker: Because 3350 was very profitable.

Gardner: And to set the record straight, actually it was in production for quite a while.

Harker: Okay.

Gardner: Anything you want to add?

Harker: It's a technology base that lasted over a decade.

Gardner: Was there ever a double density 3350?

Harker: Our competitors did. We didn't which was a mistake.

Gardner: Was it considered?

Harker: It was considered but the 3380 was expected to displace it. And in fact, if the 3380 had been on its original schedule, it would have. But the 3380 slipped because of problems. And therefore, there was a gap which hurt.

Gardner: Having been on the other side of that gap, I have to say from both Memorex's and StorageTek's perspective, that was a nice period of time.

Harker: It was an opportunity for them. It kept them in business for a few years more.

Gardner: Yes, there was a lot of business in the early 80s in the 635 megabyte double density 3350 because of the delays on the 3380. Although I've lately learned from some folks that perhaps some of the people making 3350 double densities had really serious technical problems - lots of head crashes, lots of issues pushing the track density up.

Harker: 3350 is a good machine but it was not designed with the margins that either the 3330 or the 3830 were designed with.

Gardner: During that period, perhaps even while you were product manager, you started some work on fixed block architecture-- the product was the 3310?

Harker: We made lots of effort. We wanted to get rid of the count-key-data architecture.

Gardner: Why?

Harker: It was complex. The programming support that we had to provide our controllers for it was excessive. It didn't help performance. It was introduced on the 1301 is my recollection-- I think it was Jim Applequist -- to allow customers to have variable records. But the systems world had moved on -- everything except our count-key-data was fixed block. But the trouble was the programming investment to convert all was what stopped us, not just our program but the systems programming stopped us. So we were never successful.

Gardner: In fact, today on IBM equivalent to mainframes, they still emulate count-key-data on top of fixed block because the applications and the data depended upon the variable record length, so it lives on. Although nobody makes any count-key-data disk drives anymore. They emulate it.

Harker: I know.

Gardner: One of the big reasons I'm told was, as you pushed the bit density up, the channel time, turnaround time was constant because of the system's demands. That meant you were throwing away more and more of the disk, which is what you're selling.

Harker: Yes, we once proposed overwriting, in those gaps, additional records-- scrolling. It wasn't done.

Gardner: Today, we have eliminated those gaps.

Harker: I'd been a product manager, I guess, for about two or three years. Bill McDonnal had come on as my business manager. Bill was came out of the sales force. He'd been a district manager and was brought to San Jose to run the BART fare collection system. He'd worked with Bob Evans as a planner for some years and Evans thought highly of him. He did an outstanding job with the collection system-- getting it on track, delivering it, and making the customer satisfied. I had a bad situation. I had to replace the business manager. And we persuaded Jack Kuehler who was the lab director that Bill could come to work for me starting part-time until he'd get BART all done. And then he would run the business part of our operation. It started a partnership that went on for years-- a wonderful guy. So after a couple of years, I had sort of had enough of this product manager stuff. And he and I got together and decided we'd split the area. He would take over the business. He would become the product manager and he would take over the management of all the released products, and I would continue to manage the technology and unreleased products. And we split it up that way. We went down and saw our boss, Kuehler, told him this is what we wanted to do, and that's what we did. So I went back more to being a technology manager. I still had Winchester. I kept Winchester until it was released.

Gardner: And the next pair of products are the 3370 and 3380.

Harker: Yes. Okay, in between that time, I went from being, again, technology manager. I was named lab director in probably 71 or 72? Maybe you've got cheat sheet there.

Gardner: The cheat sheet says September 72.

Harker: Okay-- became lab director. Bill was product manager and George Santana was running the technology. And I was lab director then until I think about mid-74. I'd been named an IBM Fellow and Jerry Harries took the lab over.

So my involvement changed very much over that period of time. I was a lot less involved with the specific products-- more with the management of the laboratory. I did get involved later in the development of the 3830 and 3880 when it was being delayed. At one point, I was put in as a soft of a czar to get the thing on track. We had a lot of very substantial problems. It's a very difficult machine to build - it had been designed sort of by perfectionists. The carriage was dynamically balanced, voice coil actuator, -- this was the first digital servo design of an actuator. There was a lot of new technology in that machine.

Gardner: Dual actuators?

Harker: It was dual actuator. We stuck with dual actuator for a long time. In retrospect, it was a mistake but we could never justify that it didn't make good cost sense to share a drive with two actuators-- the spindle with two actuators.

Gardner: Really?

Harker: In hindsight, we should have been able to justify it but we didn't because we caused ourselves more grief with dual actuators. Because when you're reading and writing with one, had the other one moves, it's very hard to avoid. The problem-- you can get it into accessing patterns that set up vibrations in the machine that will affect the other actuator. We had a lot of those problems. We had a lot of contamination problems.

Gardner: The argument would be you solve the problems and you have lower cost.

Harker: Yes. And we did. We solved the problems, the machine went out, it was extraordinarily reliable. It was very, very great success. I think it, at its time, was perhaps the most profitable product program in industry.

Gardner: When was it withdrawn? I was researching that and I can't find out that it when it was withdrawn.

Harker: I don't know. After I retired-- long after, I retired.

Gardner: So it probably has the record for the longest production product line in the history of the disk drive industry. [Tom Gardner note: The 3380 family was “Withdrawn From Marketing” by IBM effective December 31, 1992, see IBM Announcement Letter 191-168, so that it’s production life, while long, was comparable to and may have been exceeded by the 3350 family (announced July 1975 and withdrawn from marketing effective September 21, 1988, see Announcement Letter 188-100.]

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Harker: Oh, it went through about four different upgrades.

Gardner: I know of at least three. The last announcement was the J, K and CJ Models, in September 1987. [Tom Gardner note: 0 & A models announced June 1980, D & E models announced February 1985]

Harker: We'd gone to a thicker disk. I once got a very impassioned and very well done piece of work saying, "You really didn't need to go to a thicker disk to meet the specs of the first 3380." And the only answer I had for him was, "Yes, but we want to upgrade it and we want to get closer to the disk. And we want the thicker disk." I'm sure I disappointed someone who had a neat job of analysis.

Gardner: That would have been a fairly significant savings-- a thinner disk.

Harker: It probably would've been.

Gardner: But you probably couldn't have gotten to the "K" model.

Harker: That's right.

Gardner: Any other aspects of the 3380?

Harker: No, not that I really recall.

Gardner: Why the opposed actuators? In the next product, the actuators were side by side.

Harker: Designer's choice. I-- no more rationale than that. The next product was the 3390. I did have a fair amount to do with the start of that program.

Gardner: It was dual actuator side by side.

Harker: Yes, it was Rick Davis-- ran it. It was a successful program but it was sort of the last of the big disk drives.

Gardner: Why ten-and-a-half inches?

Harker: The only thing I can recall, we had a product in Rochester that had had a dual actuator that used two zones, an inner and outer, and what that ten-and-a-half was, was a mapping of an eight inch format into two bands. And when you mapped it in, you would up with a ten-and-a-half inch disk -- that's my recollection. And I suspect just because that disk was available, I think we wanted to go to a higher RPM so it made sense to go to a smaller disk. That's all I remember about setting those specs.

Gardner: Again, the rest of the industry stayed with single actuators. I think Fujitsu Eagle had a lot of success in the same market.

Harker: Fujitsu Eagle was a very interesting drive. It got us to realize we had real competition from across the Pacific. In 1980 Chris Bajorek led a patent search -- we then came to realize the Japanese had a lot of patents in this area, significant ones, and I led a group of people where we actually visited our competitors over in Japan-- a very interesting way of doing business.

Gardner: At that same time period, the president of Memorex was pushing co-developments so I spent a lot time visiting Japan, particularly Fujitsu and Hitachi on joint projects. It never went anyplace but it was always a great place to visit.

Harker: Well, what was clear was it was a focused effort of Japanese industry. MITI was pushing it. The PATTY file was developed in NTT. Kaneko-san had very nice piece of design. NTT was designing disk files and sharing that information with Fujitsu and others.

Gardner: At least three drive makers, Hitachi, NEC, and Fujitsu were part of that consortium?

Harker: Yes.

Gardner: I was pretty heavily involved with the Nippon Peripherals side which was the Fujitsu-Hitachi joint venture that did, first, a Winchester and then a Madrid and follow on products. An interesting set of folks.

Would you like to tell us anything about the Sawmill and it's genesis.

Harker: There was a group in manufacturing called AME, Advanced Manufacturing Engineering, that was supposed to be developing new manufacturing systems. It was a talented group of people but it wasn't clear that they really had a role somehow in manufacturing. It just didn't seem to be very productive. So I brought a guy, Jim Makiyama, to lead the group to develop a low-end file, rack mounted disk file. And at that time, we were being pushed very hard for reliability, the mean time to failure sort of stuff. So my instructions to Jim was, "I want a really reliable file." And I think he delivered one. It was too conservative to be a big success financially or volume-wise. But as far as I know in the applications it was used in, it was totally successful.

Gardner: What did you do to make it so reliable?

Harker: It had a linear actuator that was well designed. Again, lots of margin?

Gardner: It is all about margin, isn't it?

Harker: Ah, yes. You make tradeoffs when you design hardware.

Bajorek: But there were some risks taken, right?

Harker: Oh, yes. It was used to introduce the MR head. But again, that was a technology driven not a product driven decision. After the Winchester, the next head was to be the film head and the 3370 carried that. Not a high volume product. When the MR head came out, the product that looked like it was in the right place was the Sawmill. So it got an MR head.

Gardner: It was also the first negative pressure air bearing head.

Harker: Yes--

Gardner: My experience suggests that high reliability and new technologies are usually mutually exclusive.

Harker: Again, it's margins. If you apply the technology right and you aren't pushing both the limits of the technology and the product, you can often introduce new technology and have it very successful.

Gardner: Correct me I'm wrong, but I would expect those kind of combination of technologies would be new, lower flying heights, which would mean potentially problems with the air bearing stability, et cetera. It could cost you in reliability.

Harker: Maybe. Except with the small disk-- and I can't tell you want the thickness of the disk were-- but as I recall, they were a very flat disk.

Gardner: Probably standard five-and-a-quarters but--

Harker: I don’t know. They may have been bigger. I do recall that the choice of the MR head actually allowed for relief of fly height.

Gardner: Yes. Chris Bajorek points out that the MR head might have been used actually to fly higher than in the earlier products so that even though it was negative pressure air bearing, it was flying physically higher which would improve the reliability.

Harker: It could. I can't tell you those details.

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Gardner: I can sympathize with that. Memorex in its double density 3330-- used manganese zinc heads instead of nickel zinc which allowed the Memorex 3330 to fly about five micro-inches higher than the IBM and therefore arguably not as many head crashes. So, I can sympathize with that argument. That would be a very clever way to do it. You know, back off on the flying height and use the MR transducer to get back your recording margin. Any other disk drive developed programs?

Harker: No, I think pretty well exhausted that subject.

Gardner: I still got a few more things to cover and we'll pick it up after we change this tape.

Harker: Okay.

Gardner: In your experience at IBM, you were involved in other products and other technologies besides disk drives, or maybe magnetic bubbles, or disk drive replacement. What can you tell us about bubbles?

Harker: After I was made a fellow and was no longer the lab director, there were a lot of people in IBM working on magnetic bubbles: I think there was an activity in Rochester; I don't know if there was activity in Fishkill or not; there were a group under Dennis Mee that was working on them in San Jose; probably the Almaden group had some involvement. And it was very fractured, and I was asked to pull the thing together, which I proceeded to try and do. It was on the surface a very attractive technology.

Gardner: This would have been early '80s?

Harker: Yes, it was in the early '80s. And it was a lot of outside activity. And a lot of people thought this was going to be a successor product. Either to semi-conductors or to disk files, depending on how you wanted to choose it. As a matter of fact, I think one of the first things that was implemented in bubbles were shift registers. And I don't know if it's apocryphal or not, but my memory is that the first semi-conductor shift memory was made by a fellow in Yorktown to emulate a bubble shift register. And the history of that is obvious. [laughs] You couldn't get densities that were being achieved in semi-conductors. It's one of these things that when you look at a new technology, you tend to project what you think it can do. And then you measure it against what conventional technologies are doing. It's very hard to understand that those conventional technologies are going to continue to improve. And within a fairly short period of time, it became obvious that the bubbles was not a competitive technology. There were a few military applications where it was attractive because it was, it was not affected by radiation, missile kind of things. But I don't know of any application ever succeeded in.

Now the only other program was the 3800 printer. Back in the days, back in the late '60s when we were finishing up Cyprus, IBM wanted, the printer product group, wanted to develop a high speed, xerographic, photoconductive printer. They came to us and asked Jack Hildebrand, who had been leading part of the program on Cyprus, if he would take that job to manage it. And he did. He formed a group, looked at all the various technologies available, concluded that the only viable one of those at that time, was a gas laser, with a high speed rotating mirror to scan a photoconductor. Because of Xerox's patents, IBM had to develop a different photoconductor technology, based on a plastic, which was essentially a consumable. You have roll of the photoconductor and you would put it on a drum, and then you would expose it, and then after a number of exposures, you'd have to replace it. And that was the technology put together for the 3800. Unfortunately, the result was a very complex machine. But when we finally did get it in production, and I did get pulled in for a period of time to manage that program [laughs] into production, it was a fantastically successful product. IBM had two products: one was 3800 printer, the other was the check sorter printer, out of Charlotte. They both were exceedingly difficult machines to maintain in the field. They were expensive; however, they sold systems. If you were in the banking business, you needed that check sorter, and it only worked with IBM systems. If you were in the utility business, billing, you needed that high speed printer, and the 3800 filled the bill. I once had the dubious task of going back to try and persuade our CFO, Paul Rizzo, that we shouldn't raise our prices on the maintenance, because it wasn't really fair to the customer. And he looked at me and he said, "You know, I ride home," he lives up in Westchester, and he rides home, "One of my companions is the vice president of Con Edison. And I asked him one day, 'What would happen if we raised, doubled the prices of your 3800.' He said, 'We'd be very unhappy, but we wouldn't have a choice '" [laughs] End of my presentation. Now, I wound up, I did a lot of things in later days, but finally I retired.

Gardner: Would you care to share with us your views on what happened with RAID and IBM and the, you know --

Harker: Back in the -- golly, I have a hard time putting it in context. It must have been back in the, sometime in the '70s. There were several people in IBM -- Ken Ouchi, Alex Malaccorto -- who had the concept of a parallel redundancy on a set of drives. And we actually built a test system, I think it was 3370s. And they built such a system, and it worked. By that time, our focus of our, the control unit people -- Dale Pilgeram, others -- the focus was on high end systems, particularly-- and it was very performance oriented. And I think we were more concerned with performance. And I think reliability of our products was good enough so that the failure rate was not that serious a problem. There had been discussion, particularly in research, about using small drives in parallel to be a cost effective solution against the cost of our big drives. The trouble was their reliability wasn't that good. And that's what led people to RAID. It just wasn't the focus of our division. That is the only reason I can give you. We had an early inventor -- Ken Ouchi. We certainly had the talent. We just never did it.

Gardner: Because by 1995, I think, EMC had about half the storage business, which happened in five years and was an incredible erosion of market share.

Harker: Yes., EMC did. STK tried, broke their pick on Iceberg. These staged high end systems were a real bear; and really, the whole, since the mid-'80s is where there's been real progress in storage management, as opposed to data management. Prior to that, all of the focus that I can recall was on data management.

Gardner: Tell us what you mean by the difference between data management and storage management.

Harker: Well, data management is being able to associate data in different dimensions. This is Oracle, this is Google [laughs], if you will, Yahoo! Storage management is how you have an array of disk products, and how you can manage and stage data to balance activity to be able to sustain very high data rates to-- or hit against the storage facility; to be able to back up data, to be able to maintain the integrity of the file. It's become a whole field of itself.

Gardner: Now there's a chicken and egg question for you. Is it RAID that caused that to become, or did that cause RAID? Or is RAID a precursor or an outcome? Or are they two separate axes?

Harker: It was a useful tool. I don't, no, see, storage management was coming without RAID. Iceberg was storage management. It was staging data. When you updated a file, you essentially obviated the prior copy and would manage the storage to know where the data was.

Gardner: Wasn't Cypress, or the 2321, storage management?

Harker: Not to today's sophistication. Obviously, any system managed its data.

Gardner: How about, was it Oak?

Harker: Yes, Oak was intended to work as a staging system. Oak subsystem data was moved from Oak to disk for activity and then automatically staged back as the activity changed. This is what the storage management does.

Gardner: But by the way for those who listen to this in the future, Oak is the 3850.

Harker: Yes, it was 3850, a tape cartridge to disk staging system.

Gardner: And an interesting product in and of itself. I guess my last question, again, is along the lines of IBM's technology. So many of the technologies that IBM led in the disk storage industry, but somehow they were late to metal media. Do you have any view on how that worked out? Or didn't?

Harker: [laughs] I think part of it was we were late to the small disk. And I think the metal media was easier in the smaller formats.

Bajorek: Also the fact that, as I remember, and this was true inside and outside, was that we had a great difficulty achieving adequate reliability in the early plated metal media.

Harker: We did.

Bajorek: Compared to particulate disks, they were very difficult to make.

Harker: My recollection is the breakthrough was the carbon overcoat.

Gardner: Chris had pointed out that the early metal media, mainly plated, was very unreliable.

Harker: Well, and if you're making 14 inch disks in a sputtering system, you have one disk per pass, through your system.

Gardner: In plating, it's also really hard to get a uniform depositing across a 14 inch disk.

Harker: Your defect rates on a large disk are substantial. Now, it's just, I don't think there's any one thing.

Gardner: Maybe it was staying with large disks.

Harker: I think our focus on the large disk sort of dictated where we went and how long we stayed.

Gardner: It did take carbon overcoating and sputtering to make metal media reliable, and those both work better on smaller disks.

Harker: Yes. And you put a lot of small disks into a sputterer or evaporator and you can only put a very few large disks in.

Gardner: The economies of scale of sputtering units definitely favor small disks.

Harker: Yes. So.

Gardner: Okay, that was sort of my last question.

Harker: Well, thank you, Tom.

Gardner: Is there anything else you want to mention.

Harker: Nope.

Gardner: I forgot I was going to note that the last time you and I had this sort of experience was 30 years ago.

Harker: [laughs]. Across the table.

Gardner: Sitting across a table much like this. Jack was testifying for IBM in the Memorex anti-trust matters, and I was working as a paralegal helping the Memorex attorney take Jack's deposition. This was a much more pleasant experience.

Harker: Good.

Gardner: I enjoyed it very much.

Harker: I enjoyed it more. Thanks.

Gardner: Thanks, Jack.

END OF INTERVIEW

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