Oral History Panel on HDD Transition for Personal Computers

Interviewed by:
Jim Porter

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Jim Porter: We're here today to discuss the transition in the disk drive industry from those big disks that were used for all kinds of things from mainframes to mini-computers to what we call small business systems the size of a desk, etcetera, which were there in the 1960s and up into the 1970s, that transitioned to those smaller disk drives. It started by going down a little bit to 8-inch disk drives, which are not that big a deal. But we're here today basically to talk about that transition to 5-1/4 inch hard disk drives. Why it happened, how it happened, and its significance to the industry. But to start, I'd like to ask each of these very interesting people we have here on the panel today to give us a little bit of background on each of them. Let's start with you Terry Johnson.

Terry Johnson: Okay, basically, just to give you a little background, I basically got a...

Porter: Oh, you dropped your mike. You dropped your sound system. <laughs>

Johnson: I got a Masters degree at UC Berkeley in about 1982. And, excuse me. 1962.

Porter: You only lost two decades.

Johnson: Yeah, right. And went to work for IBM in 1963, and I worked at IBM at the San Jose facility at Monterey and Cottle Roads. I was there for actually seven years, and basically worked on various disk drives, and a few other things like electron [beam thermoplastic] memories, and some other things along that line. But, at any rate, the final thing that I worked on at IBM was the 3330, and you know, that was in the fairly early development stages, the IBM 3330. Basically I did analog circuit design and some servo circuitry basically, development basically is what I did. And in 1970 I went to work for Memorex. This was like after the original 100 people that had gone over there with Al Shugart. I think I was the last one that they hired out of IBM. Anyway, I went to work at Memorex, and we worked on a product that would be competitive with the IBM 3330. And there I worked on the servo system, the electronics, the servo system, and the IBM 3330. And from there I went to a start-up that was funded by Storage Technology Corporation [Louisville, CO, hereinafter StorageTek] here in the Bay area as well. And the name of the company was Disk Systems Corporation. And they developed what was called the super disk, which was an 800 MB disk drive with -- interestingly it had 64 disks and 128 heads. <laughs> By today's standards that's fairly interesting. But anyway, after two years it turned out that StorageTek acquired the stock of Disk Systems Corporation, and moved some of those of us that were willing to Colorado. And I spent another five years at Storage Technology. And after the Super Disk, I was kind of the Program Manager on the 8650 drive, which was a double density [IBM 3350] equivalent product. And then I worked up to where I was the Director of Engineering for the Disk Division. And somewhere along the line they had a reorganization in the management, and I'd been working for Juan Rodriguez up until that time. And anyway, I went to work for somebody else, and I didn't have much respect for him, and he didn't have any

respect for me, and they ended up putting me in a staff position, which in the corporate world is the equivalent of being basically put out to pasture, you know? Just short of being fired. So, in effect, I left there with -- I figured whatever it was in life I was looking for wasn't there anymore. And I left StorageTek with no idea what I was going to do or anything. And it turned out that shortly after I left there, one of the guys I'd worked with there said, "If you wanna start something, well, why don't you put something together and we'll join you." And I kind of looked around like, "You couldn't be talking to me." You know? So any rate, to make a long story short, I founded a company that was called MiniScribe Corporation, and was CEO there for four years. And once again, I kind of sensed that the board was -- that the job had outgrown me, and...

Porter: One of those early companies to do a 5-1/4 inch drive.

Johnson: An any rate, I decided that basically that the job had outgrown me, so I left there, and about six months after that, fundamentally, it turns out that John Squires had left MiniScribe, and I called him up and said, "You made me a lot of money, if you'd like to start a company, I'll give you a hand." So he started a company called Co-Data [Co-Data Memory Corporation, Longmont CO, hereinafter "Co-Data"], and it turned out that a few months after that we ended up bringing Finis Conner into the company, and he wanted his name on the door, so he changed it to Conner Peripherals, which became one of the fastest growing corporations in computer history. Kind of when Finis came in the front door, I went out the back, and had nothing really to do with the company after that time. And then I started a couple of companies after that that were much less successful. One of which was Prairie Tech. Anyway, that's kind of...

Porter: We might note it was the first company to do a 2-1/2 inch.

Johnson: 2-1/2, right. So that's kind of my role in this.

Porter: A very colorful history. Thank you. Scott Holt.

Scott Holt: Thank you. [My history] isn't as colorful as Terry's, but I started in '71 with Control Data Corporation as a salesman in the peripherals [products] division. They had decided to start selling their peripherals that were being manufactured for large computers to other computer manufacturers. At that time [there] was a very limited landscape of customers, because it was for large systems. And I think at that time there were only seven or eight major customers. I did learn about disk drives at that time. The first drive we were building was similar to the RAMAC. It was about six feet high, eight feet long, and four feet wide, and was 5 MB. And 36-inch disk or something. It was huge. Monster. And then we progressed on to do the 1311 and 2314 devices. That was also fun to learn. From there, I left and went with another company, Century Data, for a while, which was a division of Xerox. And a friend of mine

was over there and he decided he wanted to bring all these different peripheral companies together like Shugart Associates and Century Data. There were two or three others in the printer business. I think Daisy was one of them. Tried to replicate what Tom Kamp had done at Control Data. So I went over there for a couple of years, but then decided that this new thing that was coming on, the 5-1/4 inch disk drive that Al Shugart and Finis had started in Scotts Valley looked really exciting and challenging, so I joined them in '81 after they'd announced their product early in the year. I think I was employee 100 or something like that. It was very exciting times, as we know. And I think we'll get into how that really influenced the PC world, and had a big impact on how storage became such a viable part of the computing industry. And I had similar stance that you did, Terry, where Tom Mitchell was there as COO, and Tom and I didn't see eye-to-eye on some things, and so he asked me to leave, and so I left there. And, fortunately, I was good friends with Finis, and after he worked with you and put together CoData--was it CoData?

Johnson: Well, CoData that...

Holt: That you had.

Johnson: Finis picked up basically. Or you know, acquired.

Holt: And then Conner Peripherals, and so I started there and I think I was employee number 25 or something here in San Jose, with the development being in Longmont. And it was a great experience. Met some absolutely top talented people in development, John Squires being one of them. That was a great opportunity to see how we could take the whole business of the 3-1/2 inch and make it a viable product, where before when people had tried to do 3-1/2 it was just putting a 3-1/2 inch drive in a 5-1/4 inch enclosure, and that wasn't really viable.

Porter: And didn't you run all the sales and marketing for that group?

Holt: I ran all the sales and marketing for Conner at the time. So I did that for about ten years. Had a great run. And since then I've done other things. Since then I've done other things, but not nearly as exciting. They were multimedia area, Diamond Multimedia, and then Cornice, which was doing a one-inch HDD product. The real exciting time was at Seagate and at Conner.

Johnson: Well, Conner, I think was the fastest growing.

Porter: Fastest growing company in the industry in the States.

Johnson: That's true.

<overlapping conversation>

Holt: It was unbelievable.

Porter: Let's move on to Dave Brown.

Dave Brown: Well, let's see, my first job in the computer industry was at a company called Peripheral Data Machines, which was in Santa Ana, California. And there I learned the technology and the application of stepper motors. So my first job was I was hired into Memorex in 1970 by Brent Nilsson to work on the 8-inch floppy and convert it from what as then was a Leadex stepper motor on the end of a lead screw to a modern stepper motor that didn't have the wear characteristics of solenoids. And so I worked on the 8-inch floppy at Memorex. I forget the number of it.

Tom Gardner: Probably the 650, perhaps the 651.

Brown: Which was the initial program load device for the large disk system. And before I left Memorex, I started working in magnetic recording with Herb Thompson there. And then when Herb and other -- and Al Shugart, and the folks left to found Shugart, I was hired by Herb to design and put into production the magnetic heads for the floppy disk, the 8-inch floppy disk at Shugart Associates. And I stayed at Shugart and became a manager, and left there as the Director of Floppy Disk Engineering. And left under some negative motivation, <laughs> and some positive motivation, and started Quantum Corporation in 1980, February of 1980 with five other fellows. And retired from the Board in 2003. And Quantum is still a viable company today, but no longer in the disk drive business. And while at Quantum I played several roles, Founder and Vice President of Engineering. And Chief Operating Officer, and President, and Founder of Plus Development, which I guess we'll get into later, another Quantum company. And one of the main, I think, something that talks to what you want to talk to about today, Jim, is that we also saw -- went down and saw the ST 506, or whatever it was designated at the time, and we were also working to found Quantum on a 5-1/4 inch disk drive and went to see Norm Dion at Dysan, and realized that he had already done a deal with Al Shugart, and it would've been futile to try to grow two companies with the limited supply of disks at the time, 5-1/4 inch, which were only available from Dysan at the time. So we decided to do an 8-inch hard disk, offer something much greater than what Shugart Associates was offering at the time. And from there we did all the soup-to-nuts hard disks and the small frame form factor at Quantum.

Porter: Good! Tom Gardner.

Gardner: In ’65, I got out of the army and went to work in the aerospace industry on the East Coast. Got my Masters degree in servo theory. Along the way, a good friend of mine went to work for Digital, and wound up in the Disk Drive Acquisition Group in Digital. He wanted me to work for him at Digital, but it was the “summer of love,” as I recall, and I wanted to go to California. Digital was negotiating with Memorex at the time over acquisition of what was the equivalent of a 2311 disk drive. So my buddy set me up with an interview in California. They liked me, I liked them, and in August of ’68, I went to work at Memorex as the fourth engineer, I think, in the disk drive group. At least the fourth engineer with a college degee. For the record, the other three were Roy Applequist, who did the mechanics; Dave Jebson, who did the recording electronics; and, John Richards who split the rest of the electronics with me. I actually stayed at Memorex for 14 years, starting as a working development engineer, and got to be the chief engineer of the disk drive division. Memorex then sent me off to Stanford to get my Masters in management. I came back and took over Operations for two years. That was an interesting experience for an engineer. <laughs> You probably had the same experience, Dave. I can give you some incredibly interesting statistics about yield and costs. I got my job in Operations, because the guy before me had a yield problem with heads, and was putting them in a closet. The closet had $10 million worth of inventory, which they wrote off. So I figured I’d never make that mistake in Operations. I made other mistakes, but I sure learned how to control material. In ’82, Memorex-- by the way, we competed with Terry [at StorageTek], and our version was the 3652, which was the double-density version of the IBM 3350. I think your double-density was the 8650.

Johnson: 8650, yeah.

Gardner: And IBM didn’t do that product. They never did a double-density. They tried to leap directly to the 3380, and that was a painful leap, so both StorageTek, with Terry’s product, and Memorex, with my product, did very, very well in the late ’70s and early ’80s. But in ’82 Memorex was making a transition to the next generation, a 3380 class product. I was afraid it wasn’t going to work. I turned out to be prescient. But I didn’t make the greatest career decision. I went then to Shugart Associates, which soon changed its name to Shugart Corp. From ’82 to ’85, I was the Vice President and General Manager of the Hard Disk Drive Division of Shugart Corp., responsible for their 8-inch, 5-1/4, half-high 5-1/4, we even started a 3-1/2. I was also responsible for their SCSI, SASI organization. Had some interesting experiences there, too. But by ’84, Shugart was in trouble, and the management of Shugart made what is probably the biggest strategic error of the management team in a company – that is, is you never piss off your board or your banker. Shugart Management had managed to get Xerox Management quite upset with them. So when Shugart Corp. got in a little trouble, Xerox decided to shut it down and exit the business. I shut down the division and exited in the middle of ’85. Since then, I’ve been consulting in the industry, consulting for lots of different companies. Probably the most interesting aspect of that is I’ve done several stints with Syed Iftikar at SyQuest. I’m part of the decision making at SyQuest to go SCSI instead of ATA [or IDE] . That turned out to be the right decision for the wrong reason, and maybe we’ll talk about that later. After that I also got involved in doing 2-1/2 cartridge drives with SyQuest. Since I left SyQuest in the late or mid-’90s, I’ve been consulting around the disk drive industry.

Porter: Thank you. Well, I think we should take note that the fact that the 5-1/4 inch hard disk drive came along as a copy of the form factor of the 5-1/4 inch floppy. And a company that's been mentioned a few times here, Shugart Associates, had become a significant maker of floppy drives, which were 8-inch. And then in '76, I guess driven by some demand from a company called Wang Laboratories there was a desire to make a drive small enough to go onto this computer that Wang proposed to do. Instead of making a computer the size of a desk, the revolutionary idea, putting a computer on the top of a desk. And they wanted something, as a memory product, smaller than the 8-inch floppy. So out of that discussion came a reduced size from Shugart Associates, which turned out to be 5-1/4 inch, and it was, as I recall, 3-1/4 inches high by 5.75 inches wide, 8 inches deep. Those became very significant dimensions in the industry, of course. And then when Finis Conner and Al Shugart decided to start their company to make a hard disk drive company, to make a small hard drive to use with this new thing called the Personal Computer, they very cleverly decided to make their hard disk drive the same physical size as that floppy drive from Shugart Associates. So the ST506, which was announced at a computer conference in what? Orange County, I guess, in the middle of 1980, became the pathfinder for this whole 5-1/4 inch disk drive area we're discussing today. Tom, do we have a sample of that 5-1/4 inch ST506?

Gardner: We have an ST506.

Porter: Good! Let's take a look at that.

Johnson: And that ST506 was used in the IBM XT computer.

Gardner: Well, actually the ST412, the next generation of the ST506.

Johnson: That's right, okay.

Porter: So that, for reference, is the size of the 5-1/4 inch hard drive. Now just so that we have it on the table before we get started, there was later a transition both from the floppy drives and the hard disk drives to this thing called a half-high. Merely making it half as high when they wanted to save a little space as they were doing things. And then, of course, before we finish this there'll be some mention of the 3-1/2 inch floppy, and the 3-1/2 inch hard drive. And that merely became cutting that dimension of eight inches across, and that was four inches, etcetera. So these dimensions that were here became very, very significant as they were cut in half for the other products which followed. And Dave, you worked on some of these products, huh?

Brown: Jim, I would like to add that, as you mentioned, the floppy drives were really the predecessors of all of these products. In fact, the half-inch high came out of the half-inch floppy form factor. And backing

up the 8-inch hard drive came out of the 8-inch form factor. So floppy drives really drove. There were a lot of computer products that had -- that in the late ’70s, early ’80s became multiprocessor, desktop-like units. There were dedicated word processors, and Altos Computers, and things like that, that needed small form factors. And at that time the leading small memories were floppy disks. So the 8-inch brought the 8-inch hard drive; 5-1/4, 5-1/4; and 3-1/2, and so on and so forth down the line. And the half-height, I just wanted to add, was also a flexible disk form factor.

Gardner: Further elaborating, Dave and I both know about it, the [Tandy] Trash 80-- TRS 80 Model 2, which first Shugart sold to, and then Quantum sold to. It was a desktop computer with an internal hard drive. The Trash 80 Model 2 had-- excuse me, TRS 80 Model 2-- I suspect Tandy would be very upset with me for calling it such.

Brown: I was struggling with what that meant, too. <laughter>

Gardner: It was the TRS 80 Model 2. It was a desktop computer with initially two full-height 8-inch hard drives side-by-side. And in ’79 they announced a version of it that had the Shugart SA1000, which plugged into it. Later, due to Shugart’s incompetence, Quantum replaced Shugart as the purveyor of 8-inch hard drives that fit into the 8-inch form factor. So really form factor competition in desktop really started a generation before in the 8-inch, but clearly because of cost and size, the industry quickly moved to the 5-1/4.

Brown: And also a strong implication for how these products were designed as their interfaces and power requirements also were dictated by what the floppies used.

Johnson: And just to kind of set the stage for this, what was the capacity of the biggest floppy disk drive at that time that this ST506 came out? Do you remember?

Gardner: 1.2 MB, megabytes, that is million of bytes unformatted, with the formatted capacity depending upon your controller.

Brown: Was that a double-density 8-inch?

Gardner: That’s a double-sided, double-density 8-inch.

Porter: And of course, the ST506 hard drive had 5 MB in its initial version.

Johnson: You're comparing an 8-inch. What was the...

Gardner: The 5-1/4 was-- the initial one was...

Brown: 120 K.

Gardner: 110, actually. Then they added the five tracks.

Holt: Was that at the time the 506...??????

Gardner: No, by that time you've gone to double-sided, double-density, and so you were probably 440 KB or something like that.

Johnson: So it's 440 KB to...

Gardner: To 5 MB.

Johnson: To 5 MB, so it was like...

Gardner: 10:1.

Porter: More than ten times the capacity.

Gardner: That was the TRS 80.

Brown: And the industry was having a very difficult time making double-density, double-sided floppies work viably in the 5-1/4 inch form factor.

Johnson: That's actually 20 times from 500 KB to...

Gardner: Yes, unformatted [500kB] to unformatted [6+MB].

Johnson: Maybe it's ten. I don't know. Yeah, it's ten.

Porter: So the impact -- if we think of the kinds of software that was being used in those days, much less complex than it is today. But using floppies only, just the software that they wanted to have resident on the computer, this had become a real burden. So that hard disk drive was very well received, and immediately had a flood of other companies making "me, too" imitation products. So for example, on the 5-1/4 inch drive, considering that the Shugart technology, or later Seagate Technology drive, introduced in 1980, by the next year, 1981, the drive's less than 30 GB in 5-1/4. There were 17 company's announced products. And the year after that, there were 30. So we had a landslide of competitors in the United States, Japan, Korea and Europe that followed to make 5-1/4 inch drives that box size with that same controller that could be used in those computers. So it became quite a competitive jungle, didn't it?

Brown: Yes, one of the things that was going through my mind when you were saying that is that one of the reasons it was relatively easy to get into this business was the components were already readily available from many different sources. So people that had worked in the drive business, no matter what they worked on, it was a fairly easy thing to buy a disk, a head, a stepper motor, a casting. And there were a lot of products that looked like mirror images of each other. And that's why the number of companies flourished for that brief period of time.

Johnson: Well, we followed Seagate with our first product at MiniScribe. And Seagate had done a 5 MB version, the ST506, and so you know, I had come out of StorageTek at that time. At any rate, the last product, and I think that the ST506 had a -- I think it was like 100 tracks per inch, or something like that. But anyway, the interesting thing about this is the last product I'd done at StorageTek was the 850 track per inch per product, the 8650. And so we looked at this, and basically all we really did is we basically took the technologies from these much larger disk drives, these 14-inch drives and we repackaged it in -- I think our first drive at MiniScribe was like 200 tracks. I forget whether it was 200 or 400 tracks per inch, but it was like a real -- almost a step backwards in technology, but it was repackaged into a very small package that could be used in a desktop computer.

Porter: But it had to be sold very cheaply, didn't it?

Johnson: Well, that's right. But I mean, technologically, somebody -- one of my daughter's friends worked at IBM said, "Well, you really didn't do anything technologically at MiniScribe. All you did was just repackage stuff." And I remember at the time I was offended. But the more I thought about it, it was truly that we had just basically taken this technology and repackaged it into a smaller drive.

Brown: Well, there's an important distinction now, Terry, in that all these products, your first, and ours, these products, these early ones, were all open loop. So you took complex closed loop densities, and the value added was knowing how far you could go on an open loop system.

Gardner: I think the real technical problem was thermal off-track. That was the killer for a number of companies, and in the end, even a killer for Seagate. I worked on a lawsuit against Seagate over the 251, which was 600 tracks per inch. And you know, thermally operating open loop at 600 tracks per inch is just really, really difficult. I think you're right, Terry, it was about 200 tracks per inch for 10 MB. The Seagate ST506 then became the ST412, which was a 12 MB unformatted, 10 MB formatted. And then it was your, MiniScribe's 2012, the Seagate 412, and a CMI product that won the IBM contract, and in my view sort of -- there may have been 37 companies trying to do a low-end product, but if you didn't have IBM or Apple, you didn't survive.

Porter: Let's talk about those companies doing the PCs that really constituted that immediate market, then come back here for a second. The initial PC announcement by IBM was in August of 1981. And of course, that used only floppies as I understood. It.

Brown: That's right.

Porter: Then they announced the PCXT in March of '83, which was the first IBM PC to use the hard drive, the 5-1/4. And then the big event of that decade was when the IBM announced the PCAT in August of 1984, moving on in each case. And IBM bought all these disk drives from other people, didn't they?

Brown: Yes, and they always had, I think, three sources. And to win one of those contracts really put you on the map in the early days of the 5-1/4 inch. You know, that was a real powerful change in the industry, IBM announcing the first personal computer that didn't have a hard disk. It had one mini-floppy. But it had one mini-floppy, it had two bays. And what a huge opportunity that was to stuff a hard disk. Because everybody in the business knew you weren't going to have much of a computer with a floppy alone. So that was really the watershed for the small form factor hard disk. A major computer manufacturer shipping a computer without a hard disk. Instant opportunity.

Porter: How do you think IBM made their selection of their source with those 5-1/4 inch hard drives?

Brown: You know, I don't remember the algorithms.

Johnson: Was an interesting...

Brown: I was...

Johnson: Go ahead, because you were basically the first one with the Seagate.

Gardner: Well, we have those three drives here.

Holt: I think we also need to go back-- Dave brought up a very good point about the supply of components being available so that you could have 17 companies within a year developing new HDD products. But what's more important is that there were hundreds of small companies doing CPM machines that adapted these things immediately. The Vector Graphics, and the Commodores and all those that had used floppies, realized they'd need more storage. They started using disk drives, and we sold a lot of drives to those kinds of companies before IBM ever got into it. And so that's what launched Seagate was the other companies, and positioned us in a way that we knew we had to get cost down, which meant we had to go to Singapore. So we had two or three years of positioning the company prior to this onslaught of an IBM who was going to be extremely difficult from a technology and qualification standpoint. And lo and behold, obviously, pricing was the big name of the game. But the volume was huge. And so we had already gotten ourselves pretty well positioned.

Porter: As you point out, IBM didn't start doing the PCXT thing until early '83, and Seagate had announced the ST506 in the middle of '80.

Holt: Right, and then with Terry driving the technology, and driving the capacities up, we announced the 412, which was one that really captured the business at Digital Equipment, and at IBM. But it's a tough business at IBM

Porter: But you did sell IBM, did you not?

Holt: Yes, we did. Yeah.

Porter: With the ST506?

Holt: No. The 412.

Johnson: Yeah, what was interesting, was just to illustrate how much activity there was going on in the industry before IBM got into it with their XT, was that we started MiniScribe based upon basically Seagate's 506, and we thought well, you know, there's no point in us trying to compete with them at a 5 MB level, so we'll go to a 10 MB level. And there were actually people at that time that said, "You know, do you really need 10 MB?"

Holt: They didn't know what to do with it.

Johnson: I mean, you know, it was like, you know, because all these things were really used for at that time was primarily word processing. Well, what was very interesting, we developed what we called the MiniScribe 1, and it had two disks in it, you know. And I remember John Squires one time went down on a sales visit down to Tandy, who was basically buying, who was talking to all of the vendors out there. And it turns out that John came into my office one Saturday after he'd got back from this Friday meeting with Tandy, and he came in there and he says, "Well, we went in...," and I forget the guy's name at Tandy in Ft. Worth that he talked to, but anyway, it was really a tough guy. And so he kind of marched the salesman and John into the office and said, "Hey, you guys are just wasting my time and yours trying to sell this MiniScribe 1 product." And he listed, he says, "You don't have an onboard microprocessor, you don't have onboard diagnostics. You're not using [manganese] zinc heads, and you're using two PCBs. You're just wasting your time and mine selling this thing." So you know, obviously he'd seen other people's products, and knew that we were not going to cut it. And so at that time I told John, I said, "Well, you know, all right. Do it!"

Porter: We might point out that Tandy wasn't ignorant about disk drives, in that at Ft. Worth they actually did manufacture floppy drives. So they knew what the basis was.

Johnson: Well, this guy, I forget his name, he was really tough guy, but anyway, and then he just in effect dismissed them, you know. So fundamentally, we just turned over -- John just basically got set aside, and he did the onboard microprocessor, and the diagnostics. And we went to the manganese zinc heads, and went to 1 PCB instead of 2. And that was the drive basically. That was the MiniScribe 2, which we sold to IBM for their XT. And allowed MiniScribe to make an IPO, which basically did our funding. So you know, and so that basically put us on the map, you know. And we were -- I think, we and Seagate, I think were kind of the co-producers of the earliest product in that XT. You know, that was MiniScribe's hour of glory. So. That's right, we had our hour of infamy shortly after that. About six months after that when IBM announced that they were going to cut back our order, and basically, I was traveling at the time. I was out here, and you know, that was before the time of cell phones and everything, and fundamentally, you know, I found out the next morning that they'd got the word that IBM had cut back the order. And they'd actually suspended trading in our stock. And I think our stock fell about 50 percent in the market when they finally opened it up the next day.

Holt: Bad.

Johnson: I remember I talked to a venture capitalist later and he said, "Johnson, there's one thing about it. You never get a second chance to make a first impression." <laughter> And our first impression was...

Gardner: The Tandy guy? I have an anecdote about that Tandy guy, whose name also escapes me. It's our good friend, Don Massaro, apparently there was a production shortage on the SA400 floppies in the late '70s. Massaro went to this guy and basically told him that he's going to limit the amount of drives he gets shipped for the next six months or a year, because he's trying to be "fair." And the guy basically said, "Well, I'm not going to let any SOB limit my business." He went to Jugi Tandon, and put Tandon in the floppy business, as a way of assuring that he had multiple suppliers. He's one tough guy.

Porter: As a footnote, I think you're probably talking at Tandy about Jon Shirley.

Gardner: That's who it was. <laughter>

Porter: Who happened to be the CEO of the company. And later in his career, of course, was among other things, President of Microsoft. But I visited with Jon about his floppy drive business at Ft. Worth at their headquarters. It was Jon Shirley, I think, that you're discussing.

Gardner: One comment about IBM procurement., I fought very hard in '84 to get into IBM and knock out one of the three, or become a fourth supplier. And it was absolutely not going to happen at any price. But then they went sole-sourced on the AT with CMI. And that's another story we might get into. But on the XT, my understanding -- you guys correct me if I'm wrong -- is that it was split, not necessarily equally, but split between CMI, Seagate and MiniScribe.

Johnson: Yeah, Seagate had the lion's share. We had the largest volume of it at that time. Seagate always was the market leader. And today is the largest manufacturer in the world of...

Holt: We had the production volume in place, and we had probably the toughest operation guy, Tom Mitchell driving prices on material. And he was -- I learned a lot from Tom. He was an expert at getting the price he wanted, when he wanted it.

Porter: Okay, let's hold there while we change the film.

Porter: Okay, we were talking about the manufacturing setup at Seagate and how it was managed. And I think Scott you mentioned Tom Mitchell. This was quite a manufacturing arrangement, was it? Where was all this manufacturing?

Holt: Well, I think the thing that was very important was that Tom had worked for Commodore, and I can't recall the guy's name that was there. But anyway, he called Tom in the middle of the night, and told

Tom, “We gotta stop building computers here. We’ve gotta go build them over in Asia, ’cause it’s gonna be cheaper.” And so while we were at Seagate, the same thing to happened to Tom. He woke up one day and said, “We aren’t going to be able to support the cost, and really drive the market and do what IBM and these other people want if I don’t go to Singapore, or go offshore.” So I immediately went to Singapore and set up an operation there with the Singaporean government, which was very beneficial for us, the use of the [English] language, and there were also vendors starting to move their production into Asia. So Tom was way ahead of that, and he was driving him them very hard to go into Singapore. And at that time, there was unemployment in Singapore, there was space available in Singapore, and the government was very much in line of trying to bring in more companies. And so the timing was perfect for Seagate. And that established our Asian base, and that’s where we ended up moving all the production from Scott’s Valley. We had three buildings there and we moved it all over into Singapore.

Porter: So you were the earliest, I think, in offshore movement of disk drives for the smaller stuff.

Holt: I believe we were.

Porter: IBM, of course, had some overseas factories already making disk drives, but you were the ones that took the smaller diameters overseas.

Holt: Yes.

Porter: MiniScribe, what did they do?

Johnson: We had plants. We opened plants. We had also a Vice-President of Engineering, Jess Parker who had worked for, I think it was Mattel. And they had plants -- they had a plant in Hong Kong and in Singapore. And when we hired Jess as our Vice-President of Manufacturing, it turned out that Mattel was closing up in Hong Kong and Singapore, and we had the good fortune that we -- like the day they walked out the door, we walked in, and we picked up the same manufacturing people. The same staff and everything. And the same buildings in both Hong Kong and Singapore. And so we very quickly followed Seagate into these locations. And you know, it was a wonderful place to do manufacturing. It was beautiful, you know.

Porter: I know when Seagate first introduced their ST506, 5 MB drive in 1980, the price was over $1,000, I think, wasn’t it?

Holt: I think, yes, I think.

Porter: Now a couple of years later when there 30 other manufacturers, what was the typical price for one of these small drives?

Holt: I think at that time we were in the $400/$500 range. Something like that. I'd have to go back and think more about that.

Gardner: My recollection is [Seagate] Shugart, I think the SA1000 was the first drive over under 1,000 [dollars]. And at that time the ST506 came out., and so I think maybe the ST506, it may have started quoting at $1,000, but I think it was under $1,000 pretty quickly.

Porter: Oh, yeah.

Holt: It was a zoo out there pricing. And it was crazy, you know. Salespeople would come in and said, "Well, Jugi Tandon is offering this thing at price X." And it was, "Well, Jugi didn't have a product." And I wanted to tell the salesman, "Well, tell him to buy it from Jugi, then." Because he didn't have anything, but he was kind of setting the price of the industry. But it was a firefight, you know? It was...

Gardner: Mitchell did have a serious impact upon pricing in the industry with his distribution policies. Maybe that's later than what we're talking about now, but he would stuff the channel big time, and then the channel would dump the product, and I mean, it was like buying fresh fish on the pier. It was whatever today's price was.

Holt: That was later in time. The distribution channel opened up, and when Tom opened up his European distribution...

Gardner: ...and then to come back.

Brown: Well, another big factor in that period of time, which was beyond IBM was that in the early days of disk drives, no matter what their size, even if going beyond back to washing machine-sized disk drives. The computer vendors pretty much felt the responsibility, the definition of the product came from the disk drive suppliers. Whereas later as the industry matured, the actual computer companies themselves started trying to dictate capacities and what they needed and things like that. And once they -- and to try to get multiple vendors, you know, on every form factor. And so one of the other delineators became time to market and quality. And so all of us had to begin to start to turn on a dime. So fast ramps, high quality product out of the shoot. That was pretty much the name of the game in the later '80s. So being able to transfer product offshore and ramp it quickly, those became more of a delineator than just what your price was.

Porter: Oh, absolutely.

Holt: And we found the workers, though, in Singapore we could get more repetitive quality out of there than we could with the US base. But then you had all the problems of freight both ways, and managing the business. And so the way Tom managed it was everyday at 5:00, we had a video conference with Singapore for three hours, and all of us would be in the meeting, so those were long days.

Brown: I have an interesting -- I don't know how it fits into the discussion, but before we get off the IBM part, what we were talking about 5-1/4 inch disk drives, at Quantum we had a slight three or four year departure from the 5-1/4 inch frame size for the IBM PCXT. The IBM without the hard disk, and then follow-on products. And that is that also in the announcement of the PC from IBM, another standard got born, and that was the standard add-in slot dimensions, and for additional power supplies, interface boards. Help me with this. What else did we stuff in there?

Gardner: Ports. You didn't have enough...

<overlapping conversation>

Brown: Right.

Gardner: Serial ports, Parallel ports, Modems, Audio cards – the early PC's had very little motherboard integration.

Brown: And one of the benefits of not participating in an IBM contract <laughter> was Quantum decided they -- we had a board member who Bob -- I was trying to remember his last name -- he was the CEO of Qume -- at any rate, when the local retailer opened up here on Stevens Creek and Saratoga, I believe it was, the first computer retail store -- I don't remember the name of it -- started selling IBM PCs, he took all of the board members and the founders over there and we each came home with a PC that night. <laughter> And of course...

Porter: BusinessLand.

Brown: Yes! Thank you! BusinessLand. And we used to hold up the disk drive, the power supply, and the interface board. And we started a company called Plus Development, which integrated all of those into a card slot for the IBM PC called Hard Card.

Porter: Let me interrupt you. If Tom could bring over a brochure, which I gave him this morning to show.

Gardner: I'll do better than that.

Porter: Oh, okay. There's the brochure, and there's the hard card.

Gardner: The brochure's interesting.

Brown: So the reason why I bring this up is because it touches on a lot of things we've talked about, including offshore manufacturing. We thought at the time that -- so what the hard card was was actually -- I don't know if it was the first. It's a 3-1/2 inch disk drive, basically. But in a form factor to fit the IBM slot, as opposed to an OEM Bay, a floppy bay. But this was the first hard disk to integrate a full controller and microprocessor and all the electronics to control a hard disk all on one board. And we had hired various consultants to help us. This wanted to be a hard disk that you just plug into the PC, turn the power on, it self-installs and boots, and puts a little plus sign up in the upper-right-hand corner. And we knew we were going to have to make this for peanuts. And the challenges of the size and the components were new to us also. So we chose to go to Japan, as opposed to go to Singapore.

Porter: What had happened was I got a call from one of the people there, whom I knew, who asked me to recommend somebody who knew the manufacturing operations overseas, who could recommend somebody. And this individuals that I recommended to him, put together your manufacturing arrangements with Matsushita Kotobuki Electronics.

Brown: So you're the one that recommended Masa Murakami.

Porter: I recommended Masa Murakami, yeah.

Brown: Well, Masa Murakami married Quantum via Plus Development at the time, to Matsushita Kotobuki Electronics. And we went over there for our first trip. We knew that this was gonna have to have the economics of at the time, a VCR was. And we all thought, how can you make a VCR? It's got heads more complicated than disk drives, more electronics than disk drives. Many more components, much more weight. How can we sell those things from $200 in a retail store, where we're charging $300/$400/$500, and we have manufacturing costs well above $200 or $300. So we went over to MKE and we saw a production facility with nobody in it making a third of the world's VCR. All automation. And we said "That's what's gonna make the hard card!" Well, of course, you don't start out that way. You start with some manual processes. We brought MKE to our facilities. They didn't speak a lick of English. They went to night school to learn English. It took a little longer to develop. The first product was the

Hard Card 10, so we were behind the market, so we quickly jumped in and designed the Hard Card 20, which is this. This is one, which is great that you got one. At any rate, this was a very successful product. Obviously, there was a fixed market to upgrade the old computers that didn't have hard disks, and the new ones, so we tried to do follow-on products that didn't, the company didn't work out in the long run. We folded the people back into Quantum, and this 3-1/2 inch drive, which I guess is topic for another discussion someday, became the platform, if you will, for Quantum's 3-1/2 inch products.

Porter: MKE ended up making all of the Quantum disk drives in due course.

Brown: And for a period of two or three years, I think '86 to '88, somewhere in that timeframe, Quantum actually was the largest volume maker of disk drives in the world. In fact, we made 30-40,000 drives a day with nobody in the facility. It was just marvelous to behold.

Porter: You resold them.

Brown: Pardon?

Porter: MKE made them.

Brown: Yes, yes. Our arrangement was they were a contract manufacturer. And boy, sitting through those! We didn't know what was worse, managing multiple thousand people in Singapore, or once a year negotiating a new manufacturing contract with -- <laughter>-- I think the stress level was constant. Just which enemy did you want to choose? They were both difficult. But they were a wonderful supplier. They were our partner for 15 years.

Johnson: I didn't actually realize that you were bigger than Seagate at that time.

Brown: Just for about two or three years.

Holt: They had a big Apple contract that was high volume for them at that time.

Johnson: I didn't realize that. I thought Seagate was always the largest.

Brown: We actually made volumes, the same volumes that VCRs were being made at.

Porter: Well, the transition to 3-1/2 really started to come along as we pointed out starting at the very beginning of 1983. And there was a long period when both 5-1/4 and 3-1/2 inch hard disk drives were both used in the industry. But really to concentrate on the 5-1/4 inch drive at this point, with all of these sitting here in front, which are the -- all the same size, is that initial floppy drive, which they were all copied to. What was the process of modernization of the drives, improvements in cost effectiveness that led to the solution -- the selection by IBM when they brought out the PCXT of the sources they used for that? We may remember -- excuse me PCAT in '84 then, became really the pacemaker for the whole industry in establishing that ATA interface for the disk drive. And the whole industry then followed that. It became the dominant pattern for the industry. How did that transition occur? Tom?

Gardner: You might point out that these are the three XT drives that 'are sitting on the table now. One closest to Jim, in front of Terry is Terry's drive. I think it was a MiniScribe 2, or also called a 3212.

Johnson: That's correct, yeah.

Gardner: And then in front of Scott is the Seagate ST412. And in front of David is the CMI product for the XT. And as I understand it, on the AT, the only drive that IBM initially qualified is this thing, the CMI.

Johnson: Was that the 19 MB?

Gardner: That's a 20 MB drive, formatted in the IBM format. This is the [CMI] 6426, 20 MB, and I think for the first year-and-a-half it was the only drive that IBM had in the AT.

Brown: I'm sort of curious as to what we know about why sole sourced, why CMI?

Holt: Well, the things that I knew about it was the capacity, storage capacity. At that time Seagate did not have that storage capacity, and was off chasing rapidly to develop products that would fit what Seagate wanted. And that was part of the whole demise of everything kind of falling apart there. And I think that's when the Quantum's were able to capture more volume business, because Seagate was off trying to figure out how to do a 25 MB and a 40 MB devices.

Gardner: You Seagate had the 419, which was 15 MB formatted, but not a 20 MB formatted. The same thing at MIniscribe, Terry, you know, correct?

Johnson: Nothing really particularly, but you know, fundamentally one of the things that we could really go back to at least my view of the business. I was working on an 800 track per inch voice coil actuator drive at Storage Technology. And so the inevitable thing is that we needed to get away at some earliest opportunity to get away from stepper motor drives and open loop systems and everything. And so that the obvious next step in the industry was to go to where we wrote servo tracks, and we had a voice coil actuator, and that became, at least technologically, the next major step. We did some downsizing to half-height and stuff like that, but that was really a repackaging issue. That technologically, the next step, which was merely in catching up with where the disk drive industry had been years before, you know, in the large diameter drives to bring that technology into these. And that's the way I view it.

Gardner: I have a data sheet for the product here, and it says the CMI product is a 720 TPI closed loop product.

Johnson: Okay.

Gardner: All these other guys were open loop. But Quantum had 40 MB closed loop, the Q500.

Brown: But I think the subject we're still addressing is IBM, and we didn't sell to IBM

Gardner: You didn't even bid that?

Holt: But at that time the Atasi was probably a closed loop product. That was closed loop I believe.

Gardner: Atasi had one.

Holt: Because the design we ended up with was very similar to that.

Gardner: But ultimately you sold open loop 225 half-highs. I mean, the story of CMI on that product there, includes Core International was buying failed AT drives, and claiming to build a breakwater in Boca Raton out of CMI drives? <laughter> Remember that?

Holt: Yeah, very well.

Gardner: Well, that's that drive.

Holt: Yes!

Gardner: I'm looking for one of those ads to get donated to the museum., but that...

Brown: That was about the limit that an open loop gets to.

Gardner: This was closed loop., but it apparently had some...

Holt: It's closed.

Gardner: Apparently 600 TPI turned out to be the technical limit for open loop, and in this form factor, and once you got more than that, you went closed. And it was -- it took some very clever engineering to build an open loop product that ran at 400 or 500 or 600 TPI in order to get 20 MB in a two-disk product, in order to get your cost down. The anecdote I know about CMI, 'because of my work at SyQuest, is that CMI got a bad rap on this product. The real villain is Microsoft. It turns out that, I think DOS3 is the first DOS that came out with the AT, it was 2.1 and 2.2 were the prior DOSs. And somebody at Microsoft or at IBM, because it was PC-DOS, but I'm pretty sure it's the same problem that was in Microsoft, so it had to be MS-DOS and PC-DOS had the same problem with 3.0. Somebody at Microsoft changed the error recovery to turn soft errors into hard errors, if it was for a multi-sector format transfer. So if you had a record that was more than one sector, more than 512 bytes, and it got a soft error, there was a hard error, and you got the control, you know, "control/alt/delete." Well, you got the "retry" message. And iIf you retried and, it was a soft error, everything went fine. But there were a lot of those. So then they made another change to the firmware [driver], and this time, instead of recovering from the error, they turned it into a hard error. They just truncated it with causing bad information and in memory. So now instead of having hit "retry," you got the blue screen of death. And it was principally because that drive had a higher soft error rate than any of the earlier drives. When you get too many blue screens of death, you start sending your product back. And that's what led Core International to come up with the "Trade in your AT hard drive, and we'll build a breakwater at Boca." And CMI then got cut off by IBM in the middle of '85. I mean, IBM said, "You know, we're stuck with you, but after we build out this contract, you're not going to sell us any more drives."

Brown: What year was that?

Gardner: That was '85.

Brown: I was trying to think, and Jim, sticking with the IBM train of thought, I was trying to think, "Well, what were we doing if we weren't' selling to IBM?" And I remember, not only that, but DEC and other,

they were large volume. We had single contracts with DEC, and we were shipping a 40 MB 5-1/4 inch with our famous optical closed loop system. So while we never sold to IBM, we solved this problem with a closed loop system, and we were selling them to other people. DEC and others. And I can't -- DEC, Apple and others. And I don't remember who the "and others" were in that period of time. Who were some of the other large computer sellers?

Holt: At that time I think you were also doing selling to Wang Labs at the time.

Brown: But they weren't huge volume. DEC was very large volume.

Holt: Tandy? Did you have Tandy?

Brown: Yes.

Holt: Tandy was always pretty good volume.

Gardner: Al [Shugart] used to say, "There're only ten customers," Al Shugart used to say, "There're only ten customers that count, and I've got eight of them! And so the rest of you guys aren't going to survive." And he was right! Most of the rest of us didn't survive.

Holt: We didn't have all the volume to all of those eight.

Porter: So the transition during that period in 5-1/4 inch drives at some point the industry got tired of these 5-1/4 inch drives, didn't they? The full-size drives. And the transition then, when did it transition to the half-high drives really occur? Any comments on that?

Gardner: Well, clearly the floppies were moving half-high. I mean, you know, Shugart was in Comdex-- or no, At the 1982 fall NCC? The fall conference of '82, we all announced half-high 5-1/4 floppies. And they were being adopted very, very rapidly by the industry. They were less expensive, used less power, and took up a lot less space. You could put two in the same form factor as the full height. They were very...

Brown: The portable PC is what I think drove that.

Porter: And for using less space was probably the factor.

<overlapping conversation>

Holt: Space is a big deal.

Brown: I think the Compaq, the portable guys.

Holt: No, they were a little later than that.

Gardner: You could either make a slim-line desktop, because you were half the height, or you could put four in, or two hard drives. So the industry, I mean, we no-bid IBM, our product just wasn't in volume and wasn't cost competitive with Seagate or MiniScribe, so we tried to jump ahead. So we did a half-high product at Shugart. By the way, Shugart also looked at offshore manufacturing. And to us offshore was Sacramento, which was another one of our tactical errors. <laughter>

Holt: You were part of Xerox.

Brown: The River was large then.

Gardner: We built a large plant in Sacramento, which didn't turn out so well. But so we pushed very hard to do a 10 and then a 20 MB. I think we announced ours also in late -- must've been '83. And shipped in early '84. The first two companies to ship were MiniScribe and Seag-- and Shugart.

Brown: The half-high?

Gardner: The half-high, 10 MBs. Seagate had announced a 5 MB 206, which was withdrawn, and then their 212 was shipped, but very expensive and difficult to build. And so for that -- early in '84 -- actually in '83, I think Shugart shipped our first product in June of '83 as a half-height. And we started getting a lot of business from people who were moving to half-height floppies, that became real important. MiniScribe came out right about the same time with their MiniScribe 3. And I think there were three different variants on that one, Terry.

Johnson: You know, when you really -- it wasn't just, you know, one of the things is that's happened continuously in the disk drive industry is that heads were flying lower, and you know, and coatings were getting thinner. And in other words, the recording density you could do on a disk was increasing, so fundamentally, what had been a two-disk drive became a one-disk drive, and what had been basically where maybe like some of the early drives had even up to four disks in. Well, then pretty soon you could

get the same capacity with two disks, and then with one disk. And the flying height, you know, I'm not really -- I can't you know, these are not exactly the numbers, but you know, it seems to me that with the 3330, the flying height was like 50 microinches, you know? And you know, and once again, a cigarette smoke particle, if I remember correctly, was like 75 microinches, you know? And so like a fingerprint on a glass disk was like 130 microinches. So fundamentally what started out at 50 microinches would seem to be a very small number. Today there're actually flying heads at less than one microinch. And so the recording density on disk which is a whole other story. This just absolutely exploded over the years. So you know, all of the technology of all of this stuff was changing in such a deal that drives could become smaller, and even, you know, not only maintain the capacity, but you know, we were increasing capacity as the size got smaller. And so everything was working in favor of you could either have larger applications with the same size drive, or you could keep the same application with much, much smaller products, and smaller power supplies, and more compact thing. So a lot of things technologically were going on at the same time here.

Gardner: But I think most of the transition to half-high was a repackaging of motors and actuators, and not a technology -- we all started out with 5 MB per disk, two disks in a half-high. And that's, by the way, compared to what, 80 GB per disk on a disk that's half the size today? So we first repackaged, and then we upped the capacity. But the real volume market switched to the 20 MB half-high. And that was really dominated by Seagate and the ST225. That was a huge, huge product. You know, that really...

Holt: That was huge volume. And that's the one that Mitchell really drove the cost out of. In fact, we were doing other products at the same time, 3-1/2 inch products, and he just said, "There's no reason to do it." I mean, the market's not big enough, and I'll reduce the cost for the 5 ¼ product, you know, until you show me where there's a need for 3-1/2 only, inclusive of what you did in the hard card, why do it?" So he just then went on a passionate mission to drive the cost out, and he did, and it became a huge success for us. In the area of the 212, I think one of the big customers on that was Convergent Technologies.

Gardner: Yeah, Convergent was taking that. The architect, to give him credit, the architect of the 225, I'm pretty sure was Steve Kaczeus, who later went on and founded Kalok, and...

Holt: And that's when he did the split-band actuator, I believe.

Gardner: It was Totem Pole right? Isn't the 225 -- Terry's...

Holt: I can't remember.

Gardner: Terry's MiniScribe used a gear and rack...

Johnson: Rack and pinion.

Gardner: Rack and gear, or rack and pinion, which you allowed the stepper motor turn more than 360 degrees. So it allowed you to push it up. Everybody else used band-capstan type of designs, which sort of limited you to about 320 degrees before the band wrapped on itself. The totem pole was another way to turn more than 320 degrees.

Porter: Okay. So the half-highs in the '84-'85 timeframe went into high volume production probably by most the companies.

Holt: In '84/'85? Probably, yeah.

Porter: Most of the companies.

Gardner: '85/'86, I would say.

Porter: '85/'86, and then how long did it take to get rid of these full-size 5-1/4s?

Brown: Not long.

Johnson: You know, I don't think that they ever disappeared, it's just that they became voice coil actuated things that went way, way up in capacity, and so you know, the applications were changing, too, where you had very sophisticated applications that needed fast access time and that. And so the voice coil actuator cut the access time way, way down. And the track density could go up, and so once again, you know, you were getting -- basically, there was a whole, you know, explosion of applications, where you know, these desktop computers were becoming more and more powerful and doing more and more things, besides just initially it was spreadsheets, and text editing.

<overlapping conversation>

Brown: Terry, do you mean rotary actuators, as opposed to voice coil?

Johnson: Well, no, I just mean voice coil. In other words, the stepper motor was an remedy of open loop device when you really think about it. And so once you went to a voice coil actuator you could take the capacity way up. For instance, like I say, you know, way back when in 1980 when I left StorageTek, we were doing 850 tracks per inch. You know, and 30 millisecond access time. Well, there was a tremendous step backwards to the ST506, so it was like it was packaged different and it went in a small thing, and it didn't cost hundreds of thousands of dollars, you know. But it was a step backwards technologically.

Porter: Okay, so the point's been made that the full-size 5-1/4 stayed around. And, of course, for those companies that got started to do high performance drives, a company like Maxtor got started to do high performance drives, to compete with the large diameter drives for high performance applications. But we're not really discussing that application area here today. We're really talking about the market for the PCs. And did it become basically fully dominated by the half-highs for the most part, for the PCs?

Gardner: That's really a good question -- what form factor did IBM use on the later PC/ATs until we they went to 3-1/2s? The industry moved to 3-1/2 in the '90s. But at the low end in a small form factor, until you go to embedded servo, you can't afford a servo unless it is embedded, because you give up one disk. Without embedded, a servo can take one surface. If you have a disk drive that only has two disks, and you have to give up one surface, that's 25 percent of your capacity gone, which you can get back by higher track density, but then the electronics cost a lot.

Brown: The servos didn't give up disks. They were embedded.

Gardner: But they didn't go embedded until the '90s. So the question is what -- in a full high where you can get ten disks...

Brown: That's not true.

Johnson: That's not true.

Brown: The Quantum Q200 was an embedded servo for Apple. That was a half-high, wasn't it?

Gardner: It was a half-high. We have a Q280 right here.

Brown: That was an 80 MB half-high, and that was in the '80s.

Gardner: In my understanding this is the first embedded servo product in volume production, the Q200 series.

Brown: Well, it's actually that, plus the first OEM controller onboard disk drive embedded servo. But when you were saying voice coil, my vernacular that means linear actuator. And I don't think anybody was making linear actuators in the 5-1/4 inch.

Johnson: Well, we did, oh yeah.

Holt: Oh, yeah.

Brown: They were?

Johnson: I think capacity was voice coil.

Gardner: At Seagate the ST4000 series.

Holt: 4000 series was voice coil.

<overlapping conversation>

Gardner: Now that may have been in the desktop market. We're really talking desktop market. Today's terms.

Brown: But in other words, all of Quantum products were rotary actuator of some sort, of which you could say is B cross x I, or voice coil. But they were all rotary in nature. But this is a half-height sold to Apple. I don't remember when. I guess in mid-'80s.

Holt: Yeah, it had to been mid-'80s, because in '86...

<overlapping conversation>

Holt: Co-Data.

Johnson: First cut was December, ’85.

Brown: But I agree with Jim, you know, Quantum, as most companies in the ’80s, had to address all three markets. Low-cost, half-high, and high performance. And there’s no question in the mid-’80s that half-high was the dominant volume for 5-1/4 inch drives. And for people that had to have the absolute highest performance, you enjoyed the full height and packed as much bits in it as you possibly could.

<overlapping conversation>

Gardner: The ST225 also was an ST238, and ultimately went to the ST251. So that mechanism...

Brown: There was a big difference in computer applications that could afford the power required to power 8 or 16 disks at high RPM with very high access times. And the half-height guys, of course, wanted lower costs, lower power, lower weight, so that that was always a big dilemma. Much different market requirements.

Porter: So that really by the end of the ’80s, is it safe to assume that the desktop PC market was basically using half-highs?

Johnson and Brown: <in unison> And 3-1/2 inch.

Porter: And starting to go to 3-1/2. Yes.

Holt: Actually, it was really the Sun Micros of the world, and the Apollo, a bunch of them back East that were doing those computers that used the bigger drives with the higher-- high performance, high capacity.

Porter: Agreed, but we want to concentrate on the desktop application areas.

Gardner: The first 3-1/2s, MiniScribe’s first one, Seagate’s first one, were either open loop of dedicated servos. Conner, I think, was a breakthrough product. It was an embedded servo, so you didn’t give up any surface for positioning. The entire all four disks, except for the embedded sectors, were available. I’m pretty sure that was a breakthrough from the computer industry’s point of view. The entire low-end went that way. And by ’93 -- I think ’93’s the crossover. By ’93 there were as many 3-1/2 inch shipped hard drives as 5-1/4.

Porter: By that time, yeah.

Gardner: Somewhere in the early ’90s. And I suspect most of them were low-end embedded servos, displacing ST225 open loop, or maybe 238s or 251s. Or maybe...

Holt: Most of them were the embedded AT interface to IDE.

Gardner: And most people went embedded ATA instead ST506.

Porter: And the principal determinant as to whether a PC maker used a 5-1/4 or a 3-1/2 at a given price -- at a given capacity level was probably his cost.

Holt: Yes.

Porter: So at a time when the 3-1/2s at a given capacity level, whether it was 20 MB or 40 MB or whatever, at whatever point in time that at that capacity level, the 3-1/2 was cheaper, that’s what he selected, right?

Holt: But initially the 3-1/2s weren’t cheaper. That’s when Tom Mitchell said, “I’m going to keep driving the cost.” It’s only when -- we were very fortunate with Conner, we were with Compaq, who wanted space and power cut down, and the only way he could get there was 3-1/2, and that gave us the leverage to drive volume, and get other people following Compaq and be able to cut the cost.

Porter: And then at that point in time in 3-1/2s where at a given -- at the capacity level which was desired for that PC application, at the given time when the 3-1/2s were lower cost, that was the cross-over, wasn’t it? And it was the cost at a given capacity.

Brown: Well, it was the price. ’Cause some people would want to transition quicker, so they’d price it forward.

Holt: Don’t get price and cost...

Porter: Don’t get them confused. They have nothing to do with each other.

Holt: They normally don't have any relationship one to the other.

Porter: Let me just ask if there's any other specific things in the last couple of minutes to discuss about the transition to 5-1/4 inch for PCs? Have we covered it all?

Gardner: Well, we sort of missed the issue that in 1981 the dominant companies in the desktop market were Quantum and Seagate. By 1985, Shugart was going out of business, Quantum was in serious trouble. Right? Quantum, had it not been for the Hard Card, probably wouldn't have survived, and had been replaced by MiniScribe and Seagate.

Brown: Actually, this product saved the company. Between the two of them, I mean, there was a period.

Porter: Well, why did Quantum...

Gardner: Why did Quantum and Shugart fail, why did Seagate and MiniScribe succeed? I don't think, you know.

Brown: Well, Quantum, I can talk to -- what do you want to do with that?

Porter: It depends on how much time we're gonna take here. If we need to go off into any length, we'll do another tape.

Brown: I believe from the wisdom I've culled out of the disk drive business is that the reason why companies have cycles is because their leadership has cycles. And it's rarely a technological problem, and for Quantum, we put a lot of eggs in the basket for Hard Card, and the mainstream business suffered. And then when we decided to come back, because it didn't have a long future, Hard Card, the leadership got bolstered and Quantum became successful again.

Johnson: And I'd say the same thing. I think it's execution is the issue, you know. And it turns out that we pioneered kind of the 3-1/2 inch drive. We were the first ones to really make a run on it at MiniScribe, and we had IBM. We had a very rigorous schedule of stuff with IBM and the 3-1/2. And we kept missing dates and everything. And finally IBM went away. And the bottom line was is that I think IBM would've gone to 3-1/2 inch disks much earlier if we would've executed. But we just didn't execute. You know, they wanted it, and they signed up with us, and we had all these benchmark things, and then when we stated to miss them, they gave up, and decided it wasn't real, and so I think that the movement would've

occurred much faster -- you know, there was all sorts of opportunities for them to use a smaller drive with the same capacity and everything, if you execute. And you know, basically it's execution in the long run.

Porter: Good summary. Any other key thoughts at this point?

Brown: I would just say one other thing about why Quantum became a leader in the 3-1/2 inch, and that is because of all the technology and partnerships that we had from Hard Card we brought to the 3-1/2 inch arena, and we got our quality measured in parts per million, and our execution and that allowed us to have booming growth for four years in a row.

Porter: Good. Well, I'd like to thank all of you for a very interesting discussion.

Gardner: One more point, Jim, if you don't mind.

Porter: You've got 60 seconds.

Gardner: Well, I'd like to show this picture to my colleagues, and ask -- this is out of his product, that product, and if you look at today's disk drive, if you took apart a Seagate or a Maxtor, I think you'd find it looks exactly like this. And that's the earliest picture I can find of a product that looks like today's product. So it could well be that to today's point about the Q200, it was certainly a pre-cursor. The Conner CP340, you know, you scale it down, it looks just like that, as does a modern picture of a modern disk drive.

Porter: That is a good summary.

Gardner: The first modern disk drive.

Porter: Thank you very much. And it's been a pleasure to have this conversation. And I think it's been helpful to get all these facts on the table. Thank you.

END OF INTERVIEW

