Oral History Panel on the Development and Promotion of the Motorola 68000

Participants:
Jack Browne
Murray Goldman
Thomas Gunter
Van Shahan
Bill Walker

Moderated by:
Dave House

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Dave House: I'm Dave House from the Computer History Museum and its Semiconductor Special Interest Group. We're here today in Austin, Texas, at Freescale Semiconductor—the former Motorola Semiconductor—with the team that created the Motorola 68000 [microprocessor].

I'm going to ask the various members of the team to introduce themselves now, with a little bit of their background: where they're from, where they went to school, their experience before the 68K and the role that they played in the 68K development.

Murray Goldman: Go ahead, Tom.

House: You can go ahead, Murray. We'll go around the table this way.

Goldman: I'm Murray Goldman. I was born in Pittsburgh, graduated from the University of Pittsburgh in 1961. Went to Bell Telephone Laboratories and I was a member of the technical staff there for six years, working on a giant telephone system which really was a big computer. I didn't really appreciate it at the time. I didn't realize how much and how important it was to my future life, but it was a good experience. I thought I wanted to teach college, so I went back to New York University, taught as an instructor for a couple of years while I got a Ph.D., and decided I really missed industry.

And then I went to Motorola in 1969, bounced around—basically an individual contributor. I worked in computer aided design; worked in design a little bit; worked in the front–end a little bit, and then ended up in microprocessors where I was a Product Engineering Manager, and then became Operations Manager, and then titles that went all the way up to leading the entire semiconductor sector of that time. During the 68000 time I was Operations Manager and Vice-President, and the titles that followed after that.

House: Okay, Tom?

Tom Gunter: My name is Tom Gunter. I was born a Cajun, in Marksville, Louisiana. Went to Texas A&M where I got my B.S. in EE and followed that out with graduate studies in basically small-scale computing, which was the study of small 8-bit machines, 12-bit machines. This was well before anything called a microprocessor existed. I wanted to work on that, and I did that at Motorola. I came to Motorola in 1969; left for awhile and came back in 1975. Then I was team lead of the 68000 family, from 1975 until into the early 1990s, and had roles in every one of the members of the 68000 family.

Bill Walker: I am Bill Walker. I grew up in Central Texas near Waco. After high school I joined the Marine Corps for 4 years. After the tour of duty, I started school at North Texas State and worked nights at Texas Instruments. I joined Motorola in 1968 as a night shift Technician. From the mid-eighties until around 2000, I built most of Motorola's manufacturing facilities around the world. From 1999 to 2003, I served in the office of the president as Senior VP and General Manager for Semiconductor Sector.

Jack Browne: Jack Browne. I was born in Stillwater, Oklahoma and grew up in Dallas. Went to school at the University of Texas here in Austin and then joined Boeing out of school. I did system analysis on a

bunch of different programs over two years, and came to Motorola and joined as an application engineer. We launched the 68000 and I became the Marketing Manager. As we grew the business my responsibility increased. I ended up leaving Motorola in 1997, and I moved on to other roles in industry.

House: Okay. Van?

Van Shahan: My name is Van Shahan. Grew up near West Texas, in Angelo, Texas. I was an older student. Went to school at University of Texas, Austin. Came out in 1979 with a B.S. E.E. and joined Motorola Semiconductor at the time, and have been with Motorola and now Freescale since then. I actually hired in to Motorola three months after the original 68000 first silicon. My involvement was primarily with succeeding generations of the 68000 family after the original product.

House: Very good. So let's start out. How did this whole thing get started? Can you tell us a little bit about the environment that you were in, and what sparked the idea of the 68000?

Goldman: Well, let's see. First of all, I guess Motorola had somebody named Tom Bennett, who back in 1971–1972 who fought for a project to do a microprocessor. It was a hot new thing that was happening in the industry. So we had a team that was working on a microprocessor that eventually became the 6800. That was in the early 1970s when the environment of Motorola was kind of rough. We went through a recession in 1975 where Motorola wasn't doing too well. We had massive layoffs.

We weren't very good in MOS, so before the 68000 really got started we had to fix the 6800 part, the original project, and get that going. So the simple answer is it really didn't get blessed until I think around 1977. But before that we had to make the original project whole. To make it whole, first of all we had to execute. Intel was out about a year earlier and we were able to achieve in the marketplace, as you all know, we captured a big part of the market. What finally happened was when we got our act together, I'd say we were finally able to get the design correct. It was manufacturable. We were finally able to get our factories in order so we could actually build it repeatedly. Then we needed a big customer. Once we got a big customer we were able to go and commit to something like the 68000. Now in order to get there—I hope you don't mind if I go in my memory.

House: Go ahead. We have all day.

Goldman: In order to get our act together, there were some key things that happened, at least in my mind. One was that a fellow named Gary Daniels was put in charge of the design group, and he really brought order to that team. He really made some things happen.

House: Where did he move from?

Goldman: I'll let him tell you, when you meet him in the session. He is a tremendous leader, and he was for the [design] team. Bill Walker, who just introduced himself, the ex-Marine, started making things happen in the front end, in the wafer factories. Suddenly, when we started a lot of wafers we could

actually expect to have a lot of wafers to come out, and yield good product, where before we weren't always so sure. Yes, we were behind in commitments to our customers at the time, whoever was signed up to go with the 6800 families being designed. So we had a major goal of shipping 25,000 6800s by September of 1976. We did; we met that goal, which was nice, except once we did there wasn't really any more backlog. So we were in a situation where “Gee, we need a big customer.”

An opportunity came along with General Motors. Now unfortunately the first opportunity was kind of limited. It was for a program called “Trip-master.” It was a special device for Cadillacs that would tell you how far you went on your trip or what the average gas mileage was: things that you take for granted today in your automobile. It required several custom parts, so there was a big controversy inside Motorola Semiconductor over whether we should commit to that program or not. They're an awfully big customer, but that particular program required tying up our design group. We couldn't afford to have much more than what we already had for a program that only had 10,000 devices per year. Our General Manager at the time, John Wilke, made the decision that we were going to do it. The environment back then—we had these big signs up all over the place, “B-O-O-T,” which stood for—I probably can't say it in today's world.

House: No, you can say it.

Goldman: “Balls Out On Trip-master.” It was the environment inside of Motorola Semiconductor: we will execute on that program. The whole team was fired up to go make that happen. And we did, to make a long story short. Having executed on that program I think gave us an inside track to being chosen for General Motors for their engine control program. Now that was something that was significant. General Motors was shifting maybe 6,000,000 vehicles a year at the time: 500,000 vehicles a month. This was a system that used maybe four chips per system. It was a big business.

House: Was it engine control?

Goldman: It was engine control.

House: That was the application.

Goldman: Yes. It was engine control, and it finally became the whole power train later in life. Anyway, Motorola microprocessors went from sales of zero to sales of about $250,000,000 almost overnight, maybe a year to 18 months or something. And it was at good margin. It was a microprocessor-like business, in which you tend to have better gross margin in that kind of business if you're manufacturing a lot. That really gave us the confidence and the ability to start investing in other things. And the culture, as I remember it back at that timeframe, was “Okay. We survived so far, but we have one big customer.” We still had the picture where Intel was pervasive, “They're everywhere. How do you crack into that? They have all the software and everything else that goes with it. How do you crack into it?”

The culture I was going to come back with was this notion that if we're going to do something, we have to give customers a reason to say yes to us, to design us in. If we're within 10% of what Intel is offering we

don't have a chance, so we always had this goal in our mind: 2X. We want to go for that, not that we necessarily achieved anywhere near something like 2X. But it's a cultural drive: we're going to come out with something for the high end. We're shooting for 2X. But if we're coming out with something in the low end, we're shooting for half the cost. So it's twice performance or half the cost, as an ideal for when we're generating products.

But being able to have significant billings for us at the time allowed us to invest. In 1979 we came out with five families that were very, very powerful, across the board. Back in 1977, Colin Crook at the time was the Operation Manager and he had the concept with the 68000 as a 16/32 bit. And he hired Tom Gunter to run it. And Tom, in turn—if I could just make a little comment about Tom—he hired a team; he's really good at hiring people. He had the vision; he had the courage and the guts to go for something that was significant. He had the knowledge; he was smart, the work ethic, customer interaction.

He could do everything except give a pretty pink speech. There used to be a term of somebody who gives pretty speeches, but not very good, not much beef, which was that “He's all hat and no cattle.” I think Tom was kind of the opposite, he's no hat and all cattle. He's all beef. And that's how it really got started was back in that environment where Colin asked Tom to go start this family called the 68000.

House: So it was viewed as being the high-end solution?

Goldman: The high-end solution, yes.

House: Was there any feeling as to what kind of customer it would most appeal to?

Goldman: I'm going to ask Tom. Well, my own perception at the time was that we were going to replace the minicomputer, if you will. It was going to be very high-end, maybe a part that would sell for several hundred dollars, two or three hundred dollars, but it would be of great value to our customers, and have very high margins, and bring in lots of other kinds of parts. We had that kind of a design when it pulls in everything else for your customer. That was my impression of what that thing could do. Tom, you're up.

House: So Tom, was it Colin that hired you?

Gunter: I was actually brought back to Motorola in 1975 by Bill Lattin who eventually moved on to Intel. I was his choice for being hired. But Colin is the one who had the vision of what we needed to do to get on the map as a supplier of microprocessors. As Murray said we had to find major, big customers, and we did that with the 6800 family, and we were doing it with the entire family. But our goal—his goal, he first presented to a lot of us, was we are going to be the definitive leader in the next generation of architecture. And that was going to be at the time a 16-bit machine. Intel was known to be working on the 8086 ISA, Instruction Set Architecture, and Zilog was believed to be working on the Z8000. There were several others, at National and other places, but those were the big three. Colin was just enough competitive that he wanted to beat both Intel and Zilog.

At that time those two architectures had all of the what was then the low–end of computing: <inaudible> BASIC, Altair, all of that. And a small company at the time called MOS Technology, not Mostek but MOS Technology had borrowed most of the 6800 architecture to go into the Apple. Colin was never going to let that happen again so that was the goal. And we, a bunch of youngsters, were allowed to go off and take on that challenge. I remember starting building the team on the first day of 1977, and our challenge was to get that architecture out. That architecture became the 68000. When we introduced that in 1978, it was referred to as a 16/32 bit.

Goldman: 1979.

Gunter: It was sampled in 1979, but we actually started talking about it in 1978. It was introduced as a 16/32 bit, and the main reason for that, was it needed larger data types, 16-bit. The 32-bit, by that time, it was apparent that you needed a larger address space and it could be done easily with the A2 architectures and design.

And it still had to achieve the higher performance. At that time a 1 MIPS processor, one million instructions per second, was considered the de facto standard, and indeed the de facto leader. It could do that first, with the 68000. That was our goal and that's what we headed for. We could only do that if we had discipline, and I'm not the most disciplined in the world, but we had manufacturing leadership by Bill Walker and his team. In that case we only had to—we couldn't do anything about changing then but we had to tell Bill what we needed, not only for the 68000 but also, eventually, in the meetings we had for the two 32-bit versions: 68000 20 and 30 in subsequent years, in the early 1980s. That was all mapped, without question—well, maybe there were some questions—but it was always delivered to us so that it made possible the products to be delivered. Bill can tell you about more of the struggles for doing that.

The goal in the marketplace was to recapture what was then an undefined personal—take back the personal computer area, take it back inside, capture back Apple. Tandy at the time had the Z80, had products based on it. Radio Shack had computers in their actual stores. Also by that time we weren't even asked about this stuff that we were doing by the legitimate computer guys that really didn't have their own minicomputer architectures, like NCR and other companies, and AT&T. There was a need for a true, not microcomputer but a minicomputer that could be used by both groups. That was the leadership in terms of what we were designing for.

But there was also a statement, as Murray said earlier. I was told several times in the early days of the development: he said, "I don't know why we're building this, why we're investing all this money, because you'll never sell more than 50,000 of them, or 50,000 a year." Probably when we shipped our hundredth million, we were still counting them, past the 50,000.

And that was what led to the 68000, to serve that class of customers. Embedded computing has always been a space for Motorola, probably more so than personal computing or anything else, and getting our products embedded in a whole host of products. Jack Browne can refer to oddles of major customers that led us down that path. We found many applications for that class of product. That additional discipline came—the early fire was to gain back from Intel and Zilog that birthright which we had given up in the late 1970s to the Intel ISAs.

House: So Tom, can you tell us some of the early people you hired when you started the project and what their roles were. Do you recall?

Gunter: Well, in terms of the team itself we were what I would call youngsters in that none of us were 30 yet, at that time. We did have the likes of Gary Daniels and <inaudible>]—who's unfortunately not here today—that were going to do the actual circuit design. I wouldn't say I got to hire them, that was just assigned, because at some point you just can't trust your entire future to a bunch of kids. But I was able, for a lot of reasons, to attract other people like Skip Stritter [Edward Stritter], Nick Tredennick [Harry L. Tredennick], Les Cordell and others to be part of that first team.

House: What was Skip's role on the team?

Gunter: Skip's role was to make sure we really defined a computer. None of us had ever designed a computer. Skip had never designed, had never been part of a design team to design something based on semiconductors. Skip and later someone named John Zenowsky [ph?] graduated of course with their Ph.D.s from Stanford. So they had—they were the geeks. They had the education to tell us what we really were doing. But the actual architecture and stuff was defined by the entire staff teams. I got to probably design much more than I should have. But all of us had certain credentials and geek potential. All my graduate studies were in small-scale computing. At one time we had five Ph.D.s working on the 68000, which was kind of a new phenomenon. I will never do that again, because you can out–smart yourself and un–wise yourself even a lot more if you don't have the wisdom to do some of the things that you need to do. You really need experience to complement your intelligence.

House: What was the role that Nick Tredennick played on the team?

Gunter: Nick probably brought the most amount of intelligence to the project. He actually helped us design in detail many of the integral parts. This was the first microcoded designed microprocessor that I can find any little history of. He did almost all of the microcode. Remember, until there was a 68000 family there were not workstations; maybe a little bit of design stations. But the 68000 is what opened the door to have literally a computer sitting on your desk: a workstation, that can be used as an engineering workstation. In fact, Jack will probably highlight it, but at one point we were doing well enough in that market that we also had a saying—we'd refer to it as JAWS, "Just Another Work Station." But we were winning in many areas, like Xerox, Wang.

Goldman: Get back to Nick.

Gunter: Nick himself was fundamentally doing that level of design and keeping the rest of us honest.

House: I think it was pretty well acknowledged by those of us over at Intel that the 68000 had a superior architecture. The software people preferred—the programmers and customers preferred the 68K architecture over that of the 8086, which had a lot of vestiges of the 8080 and past history. The addressing mechanisms and the registry mechanisms were much more like computers and minicomputers. Can you comment at all about how you got that so right?

Gunter: Well as I said, we had these people that had much more education and had gotten their Ph.D., but it's only fair to acknowledge that we were heavily influenced by the DEC family of products. Both the PD–11 and the 11–70 at the time were kind of the definitive minicomputers in the market, in terms of performance and such. But we didn't borrow or plagiarize that exact architecture, but at least we knew what was working and not working for it, and we knew it very well.

We decided we were going to truly do an architecture that was correct and not play too much on the 6800 architecture. We were indeed designing a computer level architecture that would survive. And particularly there were some decisions that, in retrospect, were very wise, from experience, that we made. Although it was a 16–bit machine it could handle 32–bit data and addresses very well—and extended precision or double precision arithmetic; both handling addresses and data was pretty profound at the time. The addressing, the ways addresses were presented: it addressed a linear address space all the way up to the 10 <inaudible> the 32–bits, but primarily 24–bits, that were presented, which came off the chip. Those decisions were verified by the things that we could do in visiting with customers and such.

There were some that customers that weren't quite ready for it: i.e., Steve Jobs at Apple said he'd never put more than 120 Kbytes on the early Macs. And I remember thinking, “Steve you're not right on this one.” But those type things were kind of reinforced in our early definitions. It gave us a step up from what the competition was doing, and particularly not only Intel's products but also the Z8000 product family. There had been such a heavy emphasis on those products, to build an economical 16–bit machine, where we could probably do what Murray said, twice the performance and still try and achieve a cost that was competitive with any architecture. I think eventually we did that.

House: What were some of the decisions that you made doing this architecture and design that turned out to be particularly right? What ones did you later wind up wishing you'd maybe done a little bit differently?

Gunter: Well in terms of doing it right I've already mentioned that it really was a 16/32 bit architecture, which we wanted to make sure competitively we could compete with 16–bit machines. But the 32–bit capabilities were right. The fact that we made a decision to microcode the implementation allowed us to make some level of mistakes as we were implementing this machine.

We had people like Nick Tredennick who was very, very precise in his ability to do design. Has anyone told you the story of him? He had a big art <inaudible>. All of this was drawn up by him, by hand—large fill-up sheets. He would erase them at night, his actual dots. The microcoding was not done with any program: there were dots on a sheet of paper. At night he'd take all of his [eraser] sweepings—he'd put them in a little plastic box and put it in his desk. I have to admit that box became pretty full over time. We didn't know what pieces of the machine had to do. Thank goodness we microcoded it, and we just said “magic box number one, magic box number two,” and we knew what the hell we were talking about.

House: So what decisions did you later decide that maybe you could have made differently?

Gunter: Well the main thing that we did is we added complexity to the machine, especially in transitions. As we went up the chain a little bit to 68010, 68020, we created a monster in terms of all the addressing modes that we had. We thought that adding more addressing modes was the way you made a machine more powerful, totally contrary to the principle of RISC later. And the fact that we didn't add a floating point until very late in an edition of the architecture. Thank goodness Van came and showed us how to do a high performance floating point. I wish we'd have been able to do that earlier.

I don't know what we would've done differently, but the packaging for the 68000 was in a 64–pin, large, heavy–cost package. And 64 pins at the time were just terrible. Then we knew, we got from some of the later customers, we had to get that into plastic. I affectionately named what turned out to be the 64–pin plastic package as the “Texas Cockroach,” a great big thing. It was about the size of a Hershey Bar, but with a lot of legs. And it was about as ugly as a Hershey Bar with a lot of legs. It took us forever to get that thing right, in spite of all of your prowess in manufacturing, because it would bow and twist and crack the die. It's hard to say what it didn't do. You just couldn't afford to keep paying over $75.00 for ceramic packages from KSN.

House: I remember the very, very large package, with lots of pins.

Gunter: I don't know how many times I got lectures on it: “If you had to go to a large package, why didn't you go to 48 instead of all the way to 64?” But we decided not to multiplex any of the addresses. But I'm not sorry we did it the way we did it. It was very important to have that linear address space the way we addressed it because that allowed us to use almost any type of static RAM, ROMs at the time; eventually the EPROM system. It's very easy to attach the 68000s to memories, because it had all the timing pretty much built in, and we needed the link. So those were the right things, the DM. The things that were not so right: we should have gone earlier to a CMOS implementation, some manufacturing stream issues. Not that we weren't getting the recommendations, we just—

House: So it was an NMOS design?

Gunter: The 68000 was truly a single channel NMOS.

House: Was it metal gate?

Gunter: The 68000 was metal gate. And we were not even—we didn't even add a depletion load and such until late on the second—after the 68000–10s. We were slow to adopt the next generation of technology, but at the same time we were trying to deliver the highest performance of technology. That's where the inexperience of this young team, to do that, came about. I don't have any regrets, but that's—again, if that would've come about we may have been so competitive technology–wise that we would've been hard for the customers not to use this up, including—

House: Did you feel like you were at a technology disadvantage against Intel and ZiLOG at the time, or on par?

Gunter: Well if you haven't heard it in my voice so far: One of the parts of being successful is we had confidence in the team and confidence in our team–mates. I never had feelings that we were behind Intel or anything else; I just had feelings that we just needed to execute fast. But I was always proud of the team's ability to use the technology they had. Now one of the things we didn't have until late in the game was we didn't choose to have a silicon gate.

Goldman: If I can jump in just for a second, I think I mentioned earlier that up until 1979 “survival” was the keyword. We were trying to figure out how the hell do we survive against this big competitor? After 1979 when we had really five families, the 68000 came in, probably the big one, that was introduced, put silicon in the marketplace. Between that and the famous date in 1982, we were—there were always technologies that we should have done, this or that, or had trouble building packages. But we were winning customers. That's the ultimate test: “Are you getting designed in?”

It's hard to get designed in. We were flying all over the world, all the time, and a competitor would go in there and we'd have to fly back. And, it was, “This is our roadmap,” and, “What do you mean you don't?” Well, you had to make them believe, and we had to believe the roadmap as well. We were winning. So it was just almost every customer that we can identify had designed this in, even though there were things that maybe we could've done differently.

And if I could think of a word that would describe the environment then, it was “kill.” “Let's go kill the dragon or anybody else that's in our way because we're getting designed in.” We couldn't even figure out how our competitors would respond to what we had. We said to them, "If you're over there what would you do?" “I don't want to go to a new architecture. You've got the software and the one they had might be hard to improve.” There was a lot of electricity in the air, environment wise. That's the only thing I wanted to interject: even though there were things we might have done differently, we were winning big in that timeframe. Sorry to interrupt you Tom, but I—

House: Well, it might be interesting to hear from a couple of the other players here about how they first became aware of the 68K program and what was happening. We were just talking about some of the packaging and silicon issues. Maybe Bill could tell us when he first heard about this project and his early experiences with it?

Walker: I became aware of the 68K program in the late 1970’s. In the mid to late 70’s, Motorola had two 3 inch factories (later upgraded to 4 inch), one for NMOS and the other CMOS. Our manufacturing practices were pretty bad back then, low yields, long cycle times and poor productivity.

In 1978, Motorola and Hitachi entered into a technology exchange venture. I was named the Transfer Manager for Motorola, and decided I would learn as much as possible. I traveled to Hitachi about 10 to 12 times a year for about three years. Each time I went I took a couple of people with me; operators, technicians, engineers, manufacturing supervisors. I told them while they were there to just listen and observe, “see what you can see”. We had to figure out how to manufacture better. During that 3 to 4 year period, I took 60-80 people, and with their help we gained a lot of knowledge about what Hitachi and Toshiba were doing. We brought a lot back and injected it into our manufacturing and it helped greatly, especially when we built our newest factory in the early eighties. That became the factory that built most of the 68K products – a new 5 inch factory, MOS-8**.**

Before the Hitachi joint relationship we were horrible at manufacturing. We really started to change after that. In the mid to late 1980's, we became very good and hopefully was able to provide Tom and team the necessary manufacturing to produce the 68K family of products. We learned a lot from our competition. We took what we did best and combined it with what we learned from the Japanese and we become very good at manufacturing.

Gunter: Bill's honest to a fault and accurate to a fault. But to go back to my point, I don't know that people like myself ever lost confidence in what we were doing. We didn't go back and dwell on Intel stuff. We only had a metal gate, so we designed metal gate. So we did have confidence. When we needed a Texas Cockroach, one member of the team that's not here today—we put a great guy on that named Larry McDonald. He solved that problem. The things that needed to be done were in. Now, maybe there was lack of confidence somewhere else, or when we got the actual results they scared the hell out of us. But it was never one that led us to lack of confidence in what we were trying to do. I think that was the difference. We never blinked on doing some of these things. And then Murray said the famous date 1982 that I'm assuming you're talking about: the hammer throw.

House: Oh, the ad?

Gunter: Yes.

House: The famous ad.

Gunter: Yes, yes.

Goldman: No, that was the IBM PC. The hammer throw was 1984, I think.

House: Oh probably about then, yes. 1981, August 1981 was the introduction of the original IBM PC.

Gunter: Yes, I thought the ad was—I remember Apple saying, "Welcome to the game."

House: "Welcome," yes.

Gunter: That's the one. We talked about customer meetings. I was always coming from a meeting at Apple, with Steve Jobs, at the time. But we had won—we had basically won all of the 16–bit applications. I don't know that they'd have such a significant—

<Telephone rings>

House: You were saying that you'd won most of the designs and Murray had said how electrifying that was. I can tell you that at Intel it was pretty electrifying too because we saw the design loops being won by the 68000, and we talked to the customers about why, and it was terrifying to the team at Intel.

Goldman: Well, it was 1979—or when was it that Steve Jobs came in? I'll let them tell the story when he came in with his vision of what we now call the PC, and whether or not he could use the 68000. Jack, I don't know if you want to tell that or whether it'—

Browne: Tom, you ought to tell them. You were driving Steve.

Gunter: At the time, Murray mentioned earlier, there were good prices associated with microprocessors, a lot better than memories or anything else. We were literally selling 68000s at the time for $125 a piece, in volume; much more than that if you only bought a few of them. Jobs came in and he told us—talked a little bit about Lisa and he said, "But the real future is in this product that I'm personally doing," and that was what became Macintosh. He said, "If you want this business," and it was going to replace the Apple 2, not the Apple 3, and he said, "You got to commit that you'll sell it for $15." I'm sitting here, "$130, $125 here and he wants it for 15?" The only way we could get that—I said, "Well, what are you willing to commit to?" He said, "Well, we'll use a million a year." I said, " Steve, here's the deal. If you buy a million chips you will not pay more than 15 million dollars, today."

I went back to Murray and I said, "I have no earthly idea how we're going to—we're going to stagger the price. So the first ones are going to be—you had to get $35 and still break even at least. So we put together a proposal that said if you buy this many for $35; well, actually it started at $55 and the next line step was $35, and it went on down. It turned out, after we had sold the first million units—it was a lot of units—it was healthy on that end. The average price during that period had been less than $15; in fact, I remember the number pretty well: it was $14.76, not that anybody said. I don't think anyone remembers now very well. It was $14.76. I had the biggest grin.

Then I wanted to know what Steve was going to do to give us the next million. He was off and running still. It opened up another revolution in computing, which is one the reasons we're here today. I think Macintosh brought about—maybe it was all borrowed from Xerox or whatever—Mac brought about, including the ideas about the type of GUI, Graphic User Interface, that had not existed until then. Before then it had been Class CRTs at best. I still hit Control–Alternate–Delete to login, to start-up one of my computers then. You did do that. Steve's idea was, he said, "You're going to have a great out–of–the–box experience." I said, "What in the hell is that?" He said, "You take it out of the box, plug it in the wall, and you can use it right there." Now Apple made a lot of mistakes, but some of the things that they did were really the—

Eventually, simultaneously, was the fact that the 68000 family was able to underwrite the entire engineering workstation second generation. The main three customers were Apollo, Sun and HP. We won all of those applications. They didn't even exist before. Now this had to do with both the 68000-10 and the 20 and such. But we won those applications, and we used to often laugh and say, "Boy, if we only had these tools when we were designing the 68000, it would've been a little bit easier."

House: What kind of tools did you use? You talked about using mylar and writing microcode as dots on mylar.

Gunter: Well we used <inaudible> to do the logic design. No, the mylar had to go to the guys that were doing the actual layout of the circuit. All of that was done by hand. We didn't even need graphic programs to do it. At that time you drew it out in detail, on the mylar, and then you digitized it. I don't know if you guys went through the same thing. And on a bad day you would have to cut rubyliths.

House: So did you use rubyliths on this product?

Gunter: Heck no.

House: Probably on the 6800.

Gunter: 6800. There was no problem on the 68—we did it on the 6800. But I pulled a trick even on that. Gary Daniels, as Murray said, is one hell of an engineering manager, and he didn't understand why I didn't like to do more of that. I can't stay in the lines when I'm coloring, because you had to color in a drawing, so that they could cut and they would pull the areas that weren't filled and held the areas that should be solids. Gary quickly understood that if I did that kind of stuff, coloring in and filling in the lines, that I couldn't stay in between the lines, something my 3-year-old granddaughter can do very well now, but I couldn't. They'd pull the wrong things. So I got excused.

House: So how many people were on the design team during the art of the design?

Gunter: 42.

House: 42.

Gunter: Not 40: 42. That included people like senior circuit designers and the systems team. We didn't do much around software at the time. That was the real missing element. If I had something to do over, we would have figured out how to have a common software base that could've been shared among the customers. But everybody thought anyone could prove that they had the best implementation of software. That was unlike how the PC came about. There was not a shared system software base that was shared among the customers.

House: What computer systems did you use in the design? Were you using VAXs?

Gunter: Oh, we bought 11–780s. <inaudible> VAX. And one of the things Van always reminds me of is that we did a lot of the design, again too smart for out own good, because Pascal was going to be the next language. It was not going to be FORTRAN, it was not going to be COBOL. Pascal was going to be the solution, not C. We put a lot of features into the 68000–20 particularly to have modes of operation

that would underwrite Pascal. I don't think we ever sold more than 10,000 to the entire Pascal community. But of mistakes made, that was one of the big ones. Then we had people that understood all that. But what we really used was the 11-780 and using DEC's native operating system.

House: What software tools? Can you remember the tools that you used?

Gunter: I've said this three times: we didn't. Are you talking about the software for the customers?

House: Well, the software tools like Spice or any of those tools?

Gunter: Oh. We had internal to Motorola, we had a program called M-Time. That we used a lot of. But again that was done almost—

Shahan: But that was the proprietary version of Spice.

House: Okay, I see.

Gunter: We were designing individual inverters at the time, and then—

Shahan: There was a gate level or transistor level—I was new to the place—called LOG CAP, I think. It was the only simulation tool available.

Goldman: It was <inaudible>.

House: A simulation?

Shahan: IBM mainframes with 32/70 terminals on engineers desks.

House: Was this logic simulation or circuit simulation?

Shahan: Yes, logic.

House: Logic simulation.

Shahan: LOG CAP was, correct me if I'm wrong.

Gunter: No, I think that's true.

House: Any layout tools?

Shahan: CALMA for digitizing.

Goldman: Yes, we used CALMA for digitizing.

Shahan: Paper schematics, hand–drawing layout.

Gunter: Tell them how we really did logic simulation.

Shahan: Breadboards

Gunter: Breadboards. Les Cordell had that: he was the project lead on that. That's when I learned what the definition, not of a mythical man–month but of what a mythical day was. Because Jamie Schreiber who did all the circuit designing thought you came in late. Two minute, if you came in after 6:30. And Les Cordell thought you were early if you came in before 10 in the morning.

House: 6:30 am?

Gunter: Maybe it was Les Cordell who asked, “Why don't you give me a call when you're leaving?” And we would get a phone call about 10:30 at night. I'd been there at 6:30 in the morning to meet with Schreiber—and then we would get a phone call about 10:30 at night, about the time I was going to bed. And my wife said, "Do we have to?" Burning this candle at both ends of this thing.

House: Okay, why don't we take a break at this point and change the tape?

Gunter: I'm hoping somebody else will pick up the conversation.

<Break in recording>

House: Okay, Jack Browne, you had the marketing job as I understand. Can you tell us a little bit about how you first heard of the 68K and got involved in it, maybe what led up to that, and some of your experiences with the 68000 program, what went well, what didn't go well, your stories?

Browne: I joined Motorola in 1978, and as Murray said we had a whole lot of different microprocessor products coming. We had a narrow customer base, and the first activity I was involved in was putting together seminars; we called them “Systems on Silicon” seminars. We talked to several thousand people in the 1978 timeframe.

Then we started working on some of the key design ones. We had some programs going on with Tandy, who was a customer we were trying to get going. And I got involved because of the good results we had at Tandy, I was actually following up with the 68000 there. That work progressed on to a lot of other customers. We had some changes in the organization. In 1981 I ended up running the marketing team.

Murray would always challenge us on how to get more customers and Murray would keep us true to the customers. He always—I remember he'd say, "How are you going to make sure you take care of all the customers you have? Because if you can't take care of the ones you got, never believe that that next one's going to solve all the problems."

So we spent a lot of time understanding what the customers needed; understanding their benchmarks. We spent a lot of time trying to understand their value proposition: what was our play in the value proposition and how could we work with them? We had a lot of customers with all kinds of different volumes, and the different volume customers would come to market at different points. I think we did an exceptional job of—it didn't feel like it at the time—but we did an exceptional job of maximizing the revenue out of the mix.

We'd get started with the customers. They gave a leadership product that had better price performance. We couldn't have the whole mix of products, go do that, and we'd get some ground rules on it. We'd work back with Bill's team. It didn't matter what speed we were doing, we always wanted another 20%. We'd always get started with the customers and then we'd get it down to where it was rock solid. We ended up being very critical to a number of customers, the workstation guys, who you talked about already: Apollo, Sun and HP. There were whole other ranges of business. I remember Stratus and Non Stop Computing—all the guys who were building multi-user systems. NCR was probably one of our more successful customers in that space, but also Unisys and just a whole lot of people.

And then we even actually—because the nice thing about selling this kind of processor is that it was such a major undertaking for the customers, the really up–level relationship from <inaudible> selling silicon that you designed in to, really, you were building a systems business and you had a lot of insight. We spent a lot of time trying to teach the sales force and the distribution channel why you didn't want to just go to purchasing and get the DRAM order, why you wanted to do another couple years of experience in order for the customer to really get the architecture designed in. We did a lot of those things, all in parallel. We didn't understand how hard it was. Like Tom says, the thing that would've been better if we'd had the foresight to have more discipline in the software space. But everybody was differentiated in software and everybody's problems were different there.

House: Were you doing much software development inside Motorola?

Browne: We had the tools, the assemblers, the compilers. We had a development system environment. We were starting to work with Green Hills and Wind River and the other software companies at the time. It was always fragmented because this customer had this partner, and this other customer had another partner, and we probably weren't as deep as we could have been in leveraging those.

House: Were you involved with the compilers different through various languages or was that largely done by your customers?

Browne: We were partnered with the systems side of our business, which at times reported to Murray and at other times didn't report to Murray. We were always trying to manage getting all the pieces together, of the programs. By and large, across multiple organizations, we managed to get the schedules pretty well going, yes.

House: What customer were you closest to in the early days? Was it Tandy?

Browne: Well, in the early days it was Tandy. Then the IBM PC happened. Different people ended up in different spaces. Tom, because of the impact on the business, and because of Steve's style, was pretty much negotiating with Apple. Van and I over the course ran the workstation segment and we ran the—

Gunter: Which was basically, “Yes sir, yes sir, yes sir.”

Browne: There were a lot of gulps in between.

House: Do you have a recollection of interfaces with IBM in Boca Raton and what became the IBM PC?

Browne: Yes I do. I remember after that decision IBM and a lot of other customers trying to go back in and change those decisions. The IBM Boca one was probably the most difficult because you could never—we could never really figure out who was a decision maker that we could get access to.

Compared to the rest of IBM at the time they were not as well organized. I remember going down there multiple times and not getting past the lobby, with trips set up in advance and you're supposed to meet with somebody and you get down and they'd say, "Oh, you guys here today?" But the IBM one was probably the toughest thing for us to stomach because we'd done well in the rest of IBM.

Gunter: I don't think we really understood that it was really that significant. I think we spent almost as much time, or even more time, trying to get Intel replaced in page writer, whatever it—

House: Display Writer.

Gunter: Display Writer.

House: From my experience at Intel I know that the 68000 was our primary competition and it started out that we were looking at the Z80 and decided we had to have a 16–bit machine. And ZiLog was kind of dismissed because of Exxon's role in office products and their stated objective to be strong in office

products and stuff. I'd be interested in hearing what the experiences were. I think probably we were able to get in because of our success with the Display Writer, to get into that design group and we maybe had better access to them. It was really done at the design engineer level. You just couldn't get to talk to those people.

Gunter: No. You could probably answer a million questions for Jack and I on that. We were constantly told that the real decision at IBM was they wanted to make sure that we were going to have a competitive product from a cost perspective; and the fact that you had the 8088, an 8–bit implementation. And we didn't. That gave you the option to build—IBM at that time didn't have the PC

House: Oh yes.

Gunter: We refused to do the 8–bit version of the 68000. In retrospect, it would take one person less than a month to do the conversion. We basically didn't do that until after the fact. That would even have fit in a 48–pin package.

House: Well, of course this is all part of the 8086 story as opposed to the 68K story but the design team at Intel, they'd done an optional 8-bit bus, but it was on the die. We never bonded it down, never tested it at the time that we proposed that. And the bigger damage was that it could use the 8–bit peripherals from the 8085. They were all second sourced by AMD at the time and very low priced, which provided an advantage. But clearly the 68000, with its register structure and addressing modes, had a significant architectural advantage. Our feeling was that we had to take a cost approach. I had certainly assumed that you had better access to the design engineers, because they clearly talked to us about the 68000 multiple times. They were looking at it closely.

Browne: We had better access before the decision was made.

House: Exactly. That's the time I'm talking about, before the decision was made.

Browne: The challenge was the cost.

House: The cost objection.

Gunter: And they wanted peripherals that they knew would work.

Shahan: Plus Jack, say a few words about—I was a junior design engineer. I was hearing there were other parts of IBM that we were strategically engaged with, at the same timeframe, 1980 to 1981, who were telling us, "Don't worry about this PC thing, it's not going to go anywhere. What you're doing with me, on my side of IBM, is the most important part."

House: In fact you had an agreement with them where you—didn't you re-microcode one of the 68000 products to run the 360 instruction set?

Gunter: Actually worse than that. We did a—I think it was called Cascadilla—and we basically did pretty much a customized version using the internal architecture of the 68000; we re-microcoded it in fact. The only thing that was fortunate about it at all was that you had a “big endian, little endian” argument. The 68000 and the IBM 360 are the same.

House: Same <inaudible>.

Gunter: Yes. Maybe it would've been better not to have it because then we could've done that; we could just tell IBM—I think they were the 500 pound or 800 pound gorilla.

House: Absolutely.

Gunter: You didn't want to tell IBM you weren't going to do it.

House: Well, they asked us and we said “No.”

Gunter: That's what I said: wisdom was needed.

Shahan: But that was a good size program at the time.

Gunter: It was represented to be a good size program.

House: Did they buy anything?

Gunter: They bought some stuff. They probably bought a significant amount by the then standards. But the thing that always had us behind was that it wasn't replacing a 360 wherever there was a glass CRT. You mentioned earlier—

Browne: 3270.

Gunter: Yes, 3270. Now they're going to move that out to the engineers’ or peoples’ desks instead of—you didn't have to run timeshare or whatever it was called.

House: It would've done great computing, distributed computing.

Gunter: Yes, at that point it would've been.

House: Somehow it didn't happen.

Browne: But you look at that program, and you look at what happened with the rest of the customers, and what really didn't happen with that program is it didn't spawn the follow ons. We had the generation of the technology, and what really happened is the disruptive event was—we did it in two chips, and that let them emulate—the hard instructions were on one and everything else was emulated in a standard 68000 with some extra address space. Then we did virtual memory right after that. We had Apollo that used two processors to implement virtual memory with the 68000, and then we did a virtual memory machine and that's what—

Shahan: 68010.

Browne: 68010.

House: Okay, that was when you—

Browne: That's what really got us to the—at that point the mythical point was one meg for performance, one meg of memory and one mega pixel of black and white.

House: Sun made a big deal of that didn't they?

Browne: A $10,000.00 workstation. I think that's what Cascadilla didn't really follow on to that space.

Gunter: Little did we know that IBM was not going to push the 360 down into the minicomputer and even superminicomptuer space, because they had other architectures that were going to go. The 801?

Browne: 801, yes. Of course that was the precursor to the R6000.

House: Oh, okay.

Gunter: Yes. But in reality it was they didn't mislead us because if they were misleading they were misleading their own people. Everybody had their own theory about what this next generation of computing was all about.

House: At Intel we were quite concerned that was going to be the direction. So Van, can you do the same, can you tell us about how you first got involved in the 68000 and some of your stories about it?

Shahan: Yes. As I said earlier I was hired in three months after the 68000 had seen first silicon. I was lucky enough to have heard Nick Tredennick, who Tom mentioned was the microcoder on the 68000, as a guest speaker two or three times in classes I was taking at University of Texas, and also was lucky enough to have taken a microprocessor design class focused around the 6800 and its family of peripherals.

And my opinion, in having a design background, what interested me, and looking back with the benefit of hindsight, is to appreciate the emotions that drove not only semiconductor companies but also the customers that we ultimately developed to have such a sense of excitement and creativity in the early 1980s timeframe. With the benefit of hindsight, as I was thinking about doing this, I was thinking we all went to school where we had to stand in line for the stupid punch card machine. It was annoying. It was frustrating. If we were lucky or went to a good school we got exposed to a DEC minicomputer with a line editor and thought we had died and gone to heaven.

I think we really emotionally, without realizing it at the time, considered—we loved computers and yet we felt that computing was a feudal system and we were the serfs. And it was incredibly exciting to be able to contemplate, “Hey, I can be part of breaking the stranglehold on computing that IBM, corporate MIS, rationing computing and restricting computing to the one flavor, one size fits all.” I don't know what it was like, whether this was true at Intel. But I don't think people today can understand the sense of excitement daily; it was palpable, in the halls. And the 1979 through 1985 timeframe, and the sense of empowerment that it created, at least in the design community, and at our customers—of people getting excited, “Hey, this means that life as we know it with mainframes and minicomputers is on the way out.” And that opens up totally new vistas.

So even though I was a junior engineer at the time, my recollection of customers—who in many cases contacted us, we didn't have to contact them, once the 68000 was out there—they had the same sense of excitement of, ”Let's do something together,” and requesting partnership and requesting co-development. The other thought connected to that, again with the benefit of hindsight, is I think that Mac commercial in 1984 with the Orwellian setting and the runner coming down the aisle and throwing the hammer through the screen and crashing it, really represented the whole industry, both semiconductor side and customer side. It was the sentiment of “We have changed computing.” My hunch—I wasn't at Intel, didn't know anybody at Intel at the time—is it wasn't restricted to Macintosh, it was the entire industry had that sense of “We are making a substantive difference.” Earlier you asked some questions about design tools and methodologies. I joined the company in June 1979. The 68000 was already out. I considered having access to the schematics and all the internal documentation to be a graduate course in microprocessor design, of which there were none at the time.

House: What were you doing immediately before that?

Shahan: I got out of school in spring 1979, came right into Motorola, worked on a few—I was a rotational engineer and took all three rotations in the same organization. Worked on a couple of microcontroller activities, and then migrated into floating point, first for the 6809 and then on the 68000; what became the 68881 floating–point coprocessor to the 68020.

House: Okay. Was there a floating point offered on the 68000?

Shahan: No.

House: Okay, so the first time you had a floating point—

Shahan: The first hardware floating point was a companion chip to the 68020.

Browne: The customers pushed us, particularly the engineering workstation guys, to get a floating point. Weitek came into being as a company and was doing a very high performance floating point, and the workstation guys were telling us if we did a good job they'd do 100% utilization.

Shahan: Intel had the 8087 at the time. And we were in the IEEE 754 floating point standard activity with Intel, Dr. Kahan out of Berkley was the key driver for that. We really wanted to be able to, as Murray said earlier, with the 020 and the 881 and a memory management unit called the 851, be able to 2X the performance or half the price; we got to leapfrog to offer a compelling alternative to what the 286 and 287 from Intel was offering at that same timeframe.

House: When did the floating point unit from Motorola come out, relative to the 8087 or 287 or 387?

Shahan: My memory, we—

Browne: December.

Shahan: Hold it. We sampled 020 and floating point in 1984? That was when—

Browne: We introduced them in May. We had the 020 in September. We had the 881 in December of 1983.

Shahan: Right.

Goldman: Hardware in 1984.

Gunther: That's right.

Shahan: And Intel had already been out, I think, two years with the 8087, the original 8087. And you know better than I: when did the 286, 287 come out? My memory—

Browne: It was before the 020.

Shahan: It was before the 020.

House: Yes, it was in 1982 I think. It was introduced in the IBM PC AT, or PS2 I guess it was, in 1984, August of 1984. It was September of 1985 that the Compaq 386 came out. I remember those dates.

Shahan: So on the geeky side of design tools, people that are in our business nowadays would be amazed and appalled by what we didn't have. Schematics were all on paper.

Browne: Manually—

Shahan: Manually done. There was no synthesized placement, none at all. As was touched upon earlier, the most powerful simulation capability was a TTL-equivalent breadboard.

Browne: Wire wrapped breadboard.

Shahan: Well, big cards, 12 cards in a card cage. Logic simulation at the time, even on the biggest IBM mainframes, was dog slow and you couldn't get enough cycles for the 68000, which had never been debugged with software simulation.

House: I assume you only built certain blocks in discrete logic. Did you build the whole thing at the—

Shahan: The whole thing.

Browne: The whole thing.

House: The whole 68000 and the whole floating point unit?

Browne: It was up through the 20 frame.

Shahan: The 68000, I think, was the first TTL–equivalent breadboard. No, it was not. There was—

Gunter: There was a 6809.

Shahan: A 6809 breadboard, yes. From the 68000, we continued breadboarding both integer and floating point all the way through the end of the 1980s. The 68040 was our first design that had no breadboard and depended upon Verilog.

House: There was a hardware product—Quick Time I think it was called—and it came out at one point in time.

Shahan: That was the early 1990s, and our 68060 was the first device that went into three of the gigantic Quick Time FPGA boxes, strapped together with big cables.

Gunter: But if you look at the real time performance that we could get to emulate with that, we measured that in instructions per minute. When you looked at what was available with simulation, it was instruction per minute, it was just—we could've never gone through the process. By the time we got to the 20 and the 30, we had large amounts of software that had to be precise.

House: So Van, do you remember any early customer interactions?

Shahan: I was still quite junior. I think it was 1983. It was before the Mac was introduced. It was a68000 and there was Steve Jobs—Apple came to our <inaudible> facility, and it was the first time I'd ever been in a meeting with them. Steve Jobs went around the room and asked each person from Motorola to identify what job they did, which everyone did. Then he said, "Okay, you, you and you, marketing guys get out." He was really serious. I think he let you stay.

Browne: Yeah.

Shahan: But junior marking and—

House: Had no use for them, huh?

Shahan: I think he was very concerned about leaks—always has been. In his opinion, marketing guys are more likely to leak than design guys, I guess.

Gunter: We now know the sort of 50–year–olds–plus are more likely to leak it.

Shahan: Then of course as we got into the later generations, I really got more involved with customers in the 68020 and 68881 generation. Workstation people: we were intimately involved with HP's workstation people, intimately involved with the Apollo workstation people. I personally was just barely involved with Sun at the time. But if you like computers, you love UNIX, you love C, and you love workstations. It gave you the power to be in control of your own creativity instead of being dependent upon what the management information system gods allowed you to run on the mainframe. So the era of software tools blossomed in the design area.

House: Now wasn't the Lisa also on the 68000?

Shahan: Yes.

Goldman: Yes. The Lisa came before the Mac. This just wasn't the right product for Apple, I could say. They replaced it with the Mac.

Browne: It was the first order of vision that, if anything else, it breadboarded the space and he basically said, "You've got to have a different price performance model."

House: That must have been a critical win for Motorola at the time.

Gunter: We actually won them at the same time. The difference was the professional designers, the computer designers, headed up by a fellow named Wayne Rosing.

House: Sure.

Gunter: Had come from—

House: I know him.

Gunter: They got assigned the task of designing the Lisa and they were testing out all these ideas. But the pet project, the poster child, was going to be Macintosh, Steve was going to personally orchestrate that one, operating out of an old Texaco service station there. But Steve was great at building things. I can't tell you how many times I went there and got lectured there. That was his pet project.

House: My perception was the Lisa predated Macintosh, but during the Lisa development Macintosh was started—was that correct or is that not your perception?

Gunter: No, they were going on simultaneously, but they weren't ready to come out with everything. Steve <inaudible> In fact it predated it but—

House: Yes, it was announced before the Mac.

Gunther: Yes.

House: Maybe that's why I assumed it was started—

Gunter: It was out, basically, but Macintosh, if you stop and think of all the things that Macintosh brought, not the least of which an embedded mini–floppy disc. Remember the floppies up to that time had been 5¼ inch, big floppies, and they used—

House: 8 inch before that.

Shahan: That's right.

Gunter: They used the smaller Sony form factor. As Jack said, Steve had this requirement that they could handle a million pixels. It was those kind of decisions. But he totally ignored the need for color. It had become the standard for graphics processing for as long as Macintosh ran. It's kind of amazing where it could go to, in a machine. They also ignored the need for a lot of memory. They were convinced that they'd never need more than 256 kilobits of memory.

Goldman: They were trying to keep their costs down.

Shahan: Yes.

House: Of course memory was more expensive then.

Goldman: Yes it was.

Gunter: It was more expensive, but for all the great visions they had, they were very short sighted in terms of certain things. Cost was always a driving factor. You couldn't negotiate down to Steve. He always succeeded in negotiations, but he'd throw out such large numbers; and they had that by virtue of Apple 2 and 3; that they were going to sell it. You couldn't afford to ignore those large volume numbers. But Lisa was the—to this day I still don't know what the term Lisa really means. There's all kinds of rumors about that.

House: Well, the rumors were that there was a woman by the name of Lisa that was a friend of Steve's.

Gunter: To this day I actually don't know. It's named after somebody, and that's as far as I'm going to go. Obviously it had to be a female, I think.

Shahan: I don't know where it fits in this discussion, but when you think back to 1980 through 1990, most of our customers were migrating to something that was related to UNIX. The UNIX community was highly fragmented. Every single customer had a different flavor. From a history of computing perspective you had the IBM PC that became everyone's PC, with a shrink-wrapped software industry that fed it. We were wining almost every workstation socket, but there was no shrink-wrapped software capable between multiple workstations. I think that's what created the ultimate demise of the workstations—with apologies to Sun and others that are still in the business. They stayed very nichey while X86-based PCs grew into X86 servers grew into X86 based workstations.

Gunter: With a little help from Linus and his friends.

Shahan: Yes.

House: Yes.

Gunter: If you don't know this already, Linus worked for Murray.

House: Oh, is that right?

Goldman: For awhile.

Gunther: No, that's your story. Well, when we talk about the history of computing, it's the way in which this all cast itself together at some point in time.

House: So was there an effort to try to unify the APIs, the application program interfaces, or to standardize UNIX?

Gunter: We were constantly doing it.

House: At Intel I was very active in trying to get the UNIXs on Intel to have a single API so that any application would work on anybody's version of UNIX, and I was totally unsuccessful until Linux basically came along, much, much, much, much later, after I'd left. It created that standard.

Gunter: Everybody agreed with the principle of it, as long as the standard was theirs.

Shahan: That's right.

Browne: We couldn't coalesce around the 68000. We did follow on products in computing space where there was much more willingness on a clean slate, to have a clear set of APIs.

Gunter: You asked about some of the driving factors. If you look back at a Macintosh or at least Mac, the concept of a mouse being associated with that class of products came about because of Macintosh. The concept of bit–oriented graphics was before there was Paint—is that it, Paint?

House: Paint was a program on the Mac that—

Gunter: Yes, that came with it. And the other thing that happened at the same time, and that turned out to be truly based on the 68000, was laser printing came about. Before then you'd always had large character printing and you wouldn't even dream of doing it, dot-o-ing it.

House: Dot matrix or chain printers were before that.

Goldman: Do you remember a meeting that was called the “Hamilton Avenue Meeting,” where AT&T was going to drive UNIX towards Sun?

House: Yes.

Goldman: The whole rest of the meeting really erupted, and the meeting was on Hamilton Avenue. I don't want to talk about that too long. It just emphasized the difficulty of trying to establish a standard in UNIX, period.

House: Didn't you go back to AT&T and meet with Bill O'Shea, or meet with people at that time?

Goldman: We were in on all of that.

House: Try to standardize UNIX.

Goldman: We went to that Hamilton Avenue meeting, by the way. Actually we were asked to be the speaker on behalf of everybody else, the others—

Browne: That's right.

Goldman: Sun and AT&T: it was difficult, it wasn't a pleasant experience. It just emphasizes the times. I wanted to bring it back a little bit too. We came out with the 68000, to lots of elation and so on. The IBM PC happened in around 1982.

House: Yes, August 1981 it was introduced.

Goldman: August 1981, It really grew big and suddenly.

House: In the first couple of years.

Goldman: Suddenly everybody and their uncle was riding <inaudible>. We had the 20 in design. That was another kind of critical decision: What technology is it? I don't know whether somebody could comment on that, but we ended up CMOS, to make a long story shot. I remember going to the introduction, I think with you, Jack, where we hadn't even decided what it was going to be and how we were going to position it.

House: But you knew it was a 68020?

Goldman: We knew the number. Exactly what is this—

Browne: They weren't sure whether it was CMOS or not.

Gunter: We'd designed it already. It was heavily depleted. There was a P and an N [channel] transistor. But what we were going to call it, how we were going to introduce it—"Only a fool would have introduced a CMOS," quote–unquote, at that time. Because CMOS was always thought to be four times more expensive.

Shahan: Metal gate CMOS, and a poison in people's minds that "CMOS equals bad."

House: Well, it was the 386 that was our first Intel CMOS implementation. So that would've been what, 68020 timeframe?

Gunter: Yes.

House: It was about then.

<Participants speak over one another>

Shahan: We beat the 386 out.

Gunter: 386 I think would be closer to 1985 wouldn't it?

Shahan: Yes.

Gunter: Maybe that was the 286.

Goldman: I remember the 68020 was introduced. It was a huge success. However, we called it CMOS. It performed well, it did everything we kind of hoped it would do, and you're getting customers coming from everywhere. Then we ran into this little problem of making it. Isn't that the part we had the silicide problem with?

Gunther: Absolutely, yes

Goldman: Where suddenly we had all this demand and all these customers and so on. We were <inaudible>

House: A real problem.

Gunther: It was a problem for them.

Goldman: But none of them gave up on it. Bill, maybe you can just tell us what happened on that?

Walker: Well, I think that started in 1984, with MOS-8 (5 inch factory) trying to get 68K product to yield good die. . I was running MOS-2, an older 4 inch factory, when I received a call in early 1985 from Gary Johnson saying, 'we would like you to take over MOS-8 and run the factory.' At the time he called the factory was yielding zero die per wafer.

Goldman: Yes, zero is not a good number.

Walker: They were really struggling. I told Gary sure I would be happy to run MOS-8. You all remember how good Gary was about communicating with people. He told me to go over and change jobs with Tom Felesi on July 5th. So on July 5th, I walked over and said I am here to replace you. Gary Johnson told me we are switching factories. As I stood at his door and said "I am here to switch with you", he looked at me and said "screw you, I am not going anywhere!" I called Gary Johnson and he said, "Oh yeah, I forgot to tell Tom". Tom and I finally worked out the factory switch. I can remember taking my first tour of MOS-8. It had originally been equipped and started up by Al Tash (came out of TI R&D). As I toured I noticed the factory looked more like a lab than a factory. Every tool in the factory was different. The Steppers were an off brand that no one else had ever purchased. Al had built a good R&D facility, but a really poor manufacturing factory. The Engineers were really struggling with lack of back-up equipment, bad equipment and a new process that was yet to be proven and qualified. The new process used silicide based on a Genius silicide machine. The process didn't work, and most of the time neither did the equipment. We were really struggling in many ways. I remember one of my first biggest challenges was to figure out how to get any yield at all. Up until now one or two die per wafer was the max we could yield. Tom and team were really on us because they needed parts to sample customers. I scheduled a meeting with the CEO of Genius in California. At the meeting he was giving me excuse after excuse, as to why his machine wouldn't run. I finally slammed my hand on the conference table, at which time my watchband broke and flew across the table and hit him in the chest, and I said 'no more excuses!' I looked him straight in the eye and told him "I want this thing fixed now, today!" From that meeting we had the entire Genius team focused on fixing our problems. Bottom line, they fixed their machine, we improved the process and started seeing better yields. Later the Genius CEO sent me a watch in commemoration of that meeting. It was a very interesting time and both Motorola and Genius were better for that meeting. That was the beginning of MOS-8 becoming a factory we essentially re-equipped and in some areas re-built. MOS-8 was probably the factory that produced most of the 68K family of products and did so for a very long time. But, as I look back it got off on a pretty rocky start…that July 5th 1985 morning.

Goldman: Was that MOS 8? You said it was MOS 8.

Gunter: The other significant thing in terms of being late with technology is see we didn't use multi-level, multi-metal until I don't remember.

House: It was about 1986, 1987.

Gunter: So we had to have the silicide because without it you couldn't use the left or right or north and south..

House: So the 68000 was single level metal?

Walker: Yes.

House: 68010?

Gunter: Yes.

House: 68020?

Walker: 20 is the one I think we moved to double level then, but it started out single with silicide.

Gunter: That's right, but it was silicide. We had to have—

Shahan: No, it was single metal with silicide on poly to get it down to 10 ohms per square.

House: Something like that, yes.

Shahan: Most people in the business today would go, “Single metal, are you out of your mind?”

House: Yes, right.

Shahan: Can't be done.

Gunter: It can be done.

Shahan: With lots of creativity, because in those days we would say, “Hey, sometimes transistors are free because the routing—“

House: Covers them up.

Shahan: Covers them up. But routing is never free. It wasn't until in the 68000 family, the 68040 was the first two-layer metal design, still with silicide on the poly. We never did a 68000 that was triple metal.

House: Is that right?

Shahan: Our first triple metal design was the 88110.

House: So you must have had die sizes that were quite a bit larger than Intel's.

Gunter: I think so. All I remember is when the 68000 came out it was as much a fluke as anything, and I used to tell people we planned it that way. When the 68000 came out, it came out at 68000 square mills. At the time Motorola as a corporation had 68,000 people working for them. Was that kind of a fluke. I was trying to put that back into microns and so on. We didn't even have microns that'd go—we had motrons. We had our own definition of a micron.

Goldman: I remember that, yes.

Gunter: Instead of dividing by 2.54 and multiply, Motorola had its own way of converting.

House: Mo for Motorola.

Gunter: No, we just—

Goldman: That was the 881 with the 020?

Gunter: Yes.

Goldman: It came out about the same time.

Shahan: Yes. Jack's memory was better than mine.

Browne: The summer of 1983 is when we had silicon.

Shahan: So five or six months after the 020, this was. Instantly we had people at Apollo, HP and Sun workstations giving us feedback. They already had pre-built boards for the 020—881.

House: So Tom I understand that Friday night there was a tradition: you went to the bar, is that right?

Gunter: Yes. If you worked with Gene Schrieber and the fat guy—his name was Wayne Bosco. I learned there is a lot of wisdom in the people that were the old men then, and they hadn't hit 40 yet.

House: But they were the old men.

Gunter: They were the old men. What they did have is that they understood—there was a bar not too far from where we all lived called the Red Dog, and we could buy pitchers of beer for a dollar. Even I could afford it. The three of us would meet on the way home. That was the one time Schrieber would stay up late. We were not the most politically correct, nor did we have a lot of commonsense. We drank more than one or two pitchers. Every now and then somebody else would stop in, but it basically turned out it was—it was a way to relive the stress.

House: I assume you were there.

Gunter: Yes, I was there. I was more than there sometimes. On one of my birthdays, my wife was going to make a surprise birthday party. It was on a Friday. I stopped by the Red Dog—what was it we called it, the Dead Dog, because we buried a lot of beer there—and I stopped by, and I didn't get home until probably all the way to eight o'clock. And my wife was steamed, just absolutely. I get in the house and there were probably 30 people inside my house, and she had planned a surprise birthday party.

House: You almost missed it.

Gunter: Not only was I late, I was not in control of all my facilities.

Browne: There were some of us who were supposed to get you out of there after an hour, and you kept going "One more pitcher." We couldn't get it done.

Gunter: Thank you to the man upstairs for forgiving us of our—

Browne: Yes.

House: Murray, you probably know how to get some of the stories out of these guys because you know some of the questions to ask that I don't know.

Shahan: Well, let me slip another geeky comment in. For people who weren't in our business in that timeframe, today it's standard practice that computers do logic to layout verification, computers do physical design rule verification. In the era that the 68000 was born, those computer aided design tools did not exist. From human beings took paper plots of the different layers of the device, colored them with colored pencils and then had parties on light tables where human beings read the logic off the layout and talked to a guy next to him, looking at the schematic. Human beings did the physical design rule verification. And obviously the industry would never have grown the way it did between 1980 and today

had not the very CAD tools that the products both companies created in the late 1970s, early 1980s, created workstations which created CAD tools that let us design the kinds of things we do today.

House: If we'd only had those—the product of our work—we could've made our work easier.

Shahan: Yes.

Gunter: And we talked about the history of computing. The fact that we could bring computers right to the desktop and we could interact with them, no matter what—it was just as Van said. We got around at least part of the feudal system. The fact that Sun and Apollo and HP all were UNIX–based, even though they weren't binary compatible, you began to make things available on workstations that we didn't think were available before. Just think what today they do. You can network together tens of hundreds of workstations or PCs, and do what could only be done with a Cray at the time, or a CDC machine—they just kept getting bigger and bigger machines.You still had problems that can only be solved that way. I don't even know what—solutions that enable and go ahead and still drive off multiple workstations when nobody's working on them, to solve problems like that.

Browne: No, we did that on simulator models, steal cycles to—

Shahan: Oh yes, I presume all companies are the same way.

Browne: But it was a big deal when we started—they were huge.

Shahan: One anecdote I recall that highlights the feudal system comment is even though the DEC minicomputer that the design team had access to was initially a PDP 11–70, and I was told that after I came onboard that the only way that the microprocessor group's management, was able to get that past the computer cops at sector levels was to call it a "test system." The stranglehold on computing in our own design organization was such that if you had really revealed, "We're going to get a minicomputer in here which will allow us to offload things from your mainframes," they would've vetoed that. I would think that to people who came into the industry, whether semiconductor or customer, since that timeframe they would go, "What? That can't possibly be true." They just don't understand how mainframe computing was stifling innovation across our business and our customers' business.

Gunter: There was certainly no interaction that was timely.

Goldman: I think he's looking for personal stories that we have.

Gunther: Personal stories.

House: I think it's great to get as many of these personal stories. The Red Dog, or the Dead Dog, or whatever your experiences are: to get the personal stories out.

Shahan: So many of mine aren't appropriate.

Gunter: We won't go any further with a lot of the things that happened. But what I guess I should've added is the comment that although we were known to be playful, a number of problems that got solved there and being able to talk to each other and we got away from a confrontational standpoint.

House: And that's an important part.

Gunter: But it was a mess because we weren't always—because they were the older generation, at 40; we were the young. I was in the younger generation at 30. We weren't always ready to communicate. And Schrieber almost insisted that if you wanted to get any work done you had to be there at 6:30 in the morning, you had to be prepared. You'd have coffee and breakfast with him, because that's when he worked best. Cordell: like I said, I don't know that he was ever in before 10 o'clock in the morning.

Browne: Well again, he didn't call me at ten o'clock at night.

Gunter: I'll give him a lot more credit than that. But in such a way that most people on the project couldn't understand, because he was instrumental—

Walker: Our normal daily staff meetings started at 6:30 in the morning.

House: Oh is that right?

Walker: As a matter of fact, when I was turning MOS-8 around in 1985 my normal staff meeting time was 6:30 am. If the team wasn't executing the way I thought they should I would move the meeting to 5:30 am. If there was still an issue, we would meet at 4:30 am. I used this tactic effectively in bringing up or turning around a factory. The team usually responded to tough challenges with a little help.

Gunter: But I don't think you were still there at—

Walker: No.

Gunter: You didn't go to 10:00 at night.

Walker: No, we got home about 7:30 or so.

Gunter: There's a different type of discipline.

Walker: Yes but 10 until—coming in at 10.

House: Well we ought to get all this—this is all part of the lore. I love the story about the 6:30 staff meetings, and moving them up.

Walker: A lot of motivation.

House: At Intel we didn't have that 6:30. We had an 8:00 deal when Grove had this sign in sheet, and if you came in at 8:05—it gave you five minutes. If you came in after 8:05 you had to sign in, sign your name. In the early days he'd monitor that list himself and then as we got bigger he'd take the senior executive in every building and make him be the building czar, as we called it, and he had the responsibility for two things. One was the sign in list and the other was the Mr. Clean tour. Once a month we had a Mr. Clean tour and the senior executives—Grove would do it at first, but then we got too many buildings, and the senior executive of the building would go around, with a facilities manager, and inspect all the offices and the hallways and the conference rooms and write up the people that were messy and had things on top of their cabinets and all this kind of stuff.

<Participants speak over one another>

Gunter: This man demands that your desk be organized. He's exactly—

Goldman: How Mr. Grove was.

Gunter: Exactly.

House: But Grove was not out of TI. Grove managed a lot of Fairchild, and Fairchild wasn't particularly disciplined. Grove was just naturally disciplined I think. He used to go to the executive staff—once a month he would show the tardy statistics for each building. I was the senior guy in my building so I was responsible for the percent tardy in my building, and it was ranked against the other executives who were responsible for different buildings. And so I'm like, “How am I going to deal with this problem?” I used to send out a memo once a month that says “To the three most tardy—<Break in recording> So let's get back to this now. Murray, I understand you have something to tell us.

Goldman: Well Dave, as you well know, if you're in the microprocessor business you have to do everything; you have to be on the leading edge. You got to do your own process development. You need a leading edge package; you need design tools that don't exist yet so you either have to get them or do them yourself. You need testers that you can't—they're on the leading edge or bleeding edge. And I always, personally, when I walked around—and by the way, you also had to have a roadmap. You could never just sell "Look what I have here Mr. Customer." They'll go, "Yes, but what'll you have 18 months from now?" Because you had to have a roadmap that was competitive to whatever they perceived your competition was doing. There was just so much work and so much investment. I personally used to walk around feeling like that I had this thousand foot wave over my head, at all times, there was just so much to do.

Gunter: Stomach ache.

Goldman: And I would try to delegate everything I knew how to delegate. I always felt that everybody that worked under me had this thousand foot wave over their head. We were just kind of running a 4 minute mile every 5 minutes trying to keep up with what the world was doing, and so on.

One of the requirements of the job is that whoever would design us in, it was a big decision at that company. It was a company—a "bet your company" kind of decision on whatever they designed in for the next generation of microprocessors. So the top guy—I don't care what company it was—had to be involved. He had to talk to whoever was running the business on our side and feel comfortable that he's making the right decision and if anything went wrong he would get supported, and so on and so forth; and that really you're going to do what you say you're going to do.

That meant that I had to go visit all the top customers with Tom. Tom is not the kind of guy—Tom is brilliant. This was a situation where he knew all the kind of stuff you heard about today, and all these Ph.D.s worked for him, and all the schedules and everything. But one thing Tom cannot do is tell you what he's going to talk about at the customer site. He'd say, "I'll tell you on the airplane." "Tom, give me some material. We're going to make this trip to visit customer A, B." "I'll tell you on the airplane." But Tom and I would get on the airplane and as soon as the airplane took off he would fall asleep. I'd sit there wondering, "Gee, I wonder what I'm going to do with the customer." It's like no pre-information whatsoever; although Tom did wake up in time to eat, whenever they served some food or something like that. But we just learned to work with each other, to where we liked each other and trusted each other and we kind of knew what each other was going to say, and even without the kind of preparation that you'd really like to get. But that was working with Mr. Gunter, on a customer trip. Sorry Tom, but that was the way it was.

House: So when you got there I'm sure there was not any printed material, it was just—

Gunter: Sure there was printed material. I just put it in the back of the room. I asked people, "Do you have a slide?" And literally you would do your presentations on each slide as they're walking from the back of the room to the front—when you didn't have to plug it all into the projector.

Goldman: Well, we made it work. It felt like running a four minute mile every five minutes. Bill, what is something you remember?

Walker: I have a couple of things. Murray came to Austin in 1975. I had moved to Austin in 1974 under the previous team. The factory was in big trouble (yield and reliability) and the old team just bailed out and left for RCA. Dave Turcotte was the new operations manager and he brought with him his new team which included Murray Goldman as Device Engineering manager. Those of us that were between the old team and the new team wondered if we would survive the change. It was 1975 and the industry was in a bad downturn. I can remember after a few weeks I was going to lunch with Murray. Motorola did not have a cafeteria, therefore, we drove to the Tracor cafeteria. I was behind Murray in line and the serving lady ask what he wanted. Murray pointed at a dish and the lady said 'hominy'? Murray said, 'I don't know how many'. Again, she said, 'no, hominy'? and Murray said, 'I really don't know. How many does

everyone else get'? I could tell Murray was getting frustrated. I broke in and explained to him what hominy was. He told me he had never heard of or eaten hominy before that day. That was the beginning of a long, good relationship between Murray and I.

Goldman: That was embarrassing.

Walker: That was when I first met Murray back in 1975 or so when he came down.

Goldman: You had to go tell it. When I walked back to the plant that day every single person came up to me and they said—

Walker: How many?

Goldman: "That really wasn't true, that was a joke wasn't it." It was embarrassing, yes. It's not the kind of deli that I was used to seeing in New York City.

Walker: It wasn't a New York deli, that's for sure.

Gunter: I've probably been on the other side of that, in terms of embarrassing moments. He tried to take me, in downtown New York, to a true New York deli. Older people were there. I actually just waited, but what do you get when you order?" A pastrami sandwich or corned beef or a Reuben. They're about that tall and they must be 25 bucks now, or more. I had no idea how to order a sandwich.

House: Didn't ever have them.

Gunter: Like that, no. He did.

House: You probably knew how to eat it though.

Goldman: Oh, I'm going to tell you another story. I was traveling with Tom and somebody named Russell Stanfield. We were at the San Jose Airport. I don't remember the details; it's like we had a 4:30 flight. It was the last one out, and they cancelled it. We had to leave on the 3:30 flight. Russell was sick or something; he went somewhere else to try to get better. But we got tickets to the 3:30 flight and if we didn't get on there we were stuck there all night. I said to Tom, "Don't let them close the door on the airplane. I'll go find Russell." So I went upstairs, I was running around looking for Russell. When I came back there were police down there, because Tom physically was not going to let them close the door on the airplane.

Gunter: This was before 9/11.

Goldman: Now we did get on, by the way. We almost got arrested.

Gunter: The cops had a nice place for us to stay that night.

House: That was local jail.

Goldman: He tried to accomplish that though, as I was coming back.

Gunter: To this day I think either one of us, neither one of us, liked to travel America West.

Goldman: Yes, that's all right, we don't.

House: I'm sure there's a different story.

Gunter: I'm sure you have thousands of them. Are there questions you would like us to address?

House: Yes. Before we go on Jack had a story he told a little bit earlier about going to HP and going to the airport—as long as we're on airport stories you can tell us Jack.

Browne: Van was telling that one.

House: Oh, Van was telling it.

Browne: When we visited all the customers we would talk about the products and we would get so excited about the products that—you went so many places so much, you always knew the next airplane schedule and you believed there'd be one more flight. I don't know how many planes I missed, because you had to stay 15 minutes longer and really make sure we answered their questions. It was really hectic.

I remember when we were trying to get started on a new product one of the most important things was to make sure we seeded as many customers as possible. With all the schedules and goals and everything else, you always got—the samples would come out at the end of the month, end of the quarter, and so you'd want to go ship two parts to a bunch of customers. The warehouse would be trying to make their number. You'd have big orders. They'd put them all in a box to ship them to one customer. He's really happy and everybody else is mad. So we were shipping, for a while, through FedEx: product out of the conference room, two parts in a box. I remember talking to Murray's controller and he's going, "Jack, you can't ship a million dollars a month out of a conference room. It just doesn't work this way." But we did a lot of work to make sure we got all the customers started.

Gunter: I'd like to ask you a couple of questions.

House: Yes.

Gunter: You guys, somehow or other, hit your schedule. You said you pretty much were able to hit your goals at Intel, with the 8080, what we tended to call it, Intel ISA. How did you get your team to achieve that? Because I remember, that was the biggest curse we had against us.

House: First of all, I had tremendous support from the factory and the process development teams—a phenomenal job on process and reproducible process, having a process that was responsive to our design needs and producible right out of the shoot.

Beyond that I think it was a case of enough resources, putting in adequate resources. I came out of product development myself and the thing that I've learned through the school of hard knocks is projects always take longer than engineers think and they always are more complex than they think and they always take more resources than they think. Most managers are trying to get development teams to do more with less people. When you do that you wind up being late and you wind up having low quality and you wind up having bugs and you wind up missing key features that customers want.

One of the things I tried to emphasize doing is “Let's make sure we've got enough resources on each project and that we've really thought out all aspects of it, that we know how we're going to test the product and we know how we're going to layout the product, we know how we're going to verify the product, we know how we're going to validate the product from a systems standpoint when it gets done.” All of that takes a tremendous amount of resource.

It wound up being a battle inside of Intel between basically the memory group and the microprocessor group, back in 1985. Andy Grove wrote a book about it called *Only the Paranoid Survive*, about that battle, inside the company. It was all driven by the philosophy of make sure that the engineers have everything that they need, all the resources they need. You had more Ph.D.s than we had. In talking, in hearing the story here, you had some smart guys. We probably just had—

Gunter: More or less, less wise guys.

House: We had probably less Ph.D.s but we had a strong group of people that—I think it was the team that did it. I don't think there were so many superstars.

Gunter: But Bill always did probably the best, to me, of the senior managers or team managers, or Murray's managers, in terms of being disciplined and making the commitments. I never had to worry about his commitment. He had to worry all the time whether we'd ever get them a mask set.

Goldman: Well, I don't want to use the word “correct” you, but I'm going to remind you, as we said earlier, you always needed the leading edge. If you're building a new factory in our industry you're either

staring with DRAM where you can fill it up with big volume quickly; or you'd better have a microprocessor that you're winning with, where you have a huge market share and you can fill it up with. But we had, I would say, a slightly different situation where we had good volume on the microprocessor, but for the leading edge, the next generation, we would need them—we might need a new factory for it. Maybe we'd just reached the end of the last factory we were running in, and for the next generation we're going to need a new factory. So we hit that situation in about—

Walker: 1989.

Goldman: 1989. So we decided as a staff and as a team, we needed a new factory, that we have to call MOS-11, and we just numbered them. It was, I don't know, 6 to 8 hundred million dollars, at least initially.

Walker: 1.5 billion.

Goldman: Now it's 1.5 billiion, yes, but an initial investment, whatever.

Walker: 800 million was the initial estimate.

Goldman: Yes, initial estimate.

House: Cost you probably 1.5 billion.

Goldman: 1.5, yes. So an 800 million dollar. Bill was bringing that up. Bill reported to me. I had to go fight for that factory. And so I'm paranoid about everything. Is that factory going to come up on time? Is it going to work? Is it 6 inch or is it 8 inch? Who's going to run in it initially?

I know I'm going to need some of the 68000 family to run it, and I'm going to need some of the memory guys' stuff. Memory was run by Jim George, it was static RAMs, need it to run in there initially until we're building up the volume; hopefully fill it up with high-end microprocessor. That was our hope and dream. The first problem was neither memory nor microprocessor guys wanted to run in there, initially, because a new factory for them has two dangers. A new factory, I'm going to have to struggle and maybe they don't have their act together. I can't depend on their products. So I guaranteed them the same die price that they're getting out of the current factory. That didn't do it for them, they still didn't want to go in there. So finally there was an edict: you are going to run in there. Just about at that time the market turned, not up but way up. Suddenly the whole world was out of capacity. Well, about a week later I had both men, Tom being one, Jim George being the other, come to my office and say, "I want all of MOS-11." So it went from “I don't want any of it, start with the other guy.”

The other thing I remember, a couple of other things about that factory I remember, one was that I was worried about really having enough business to start it up. We invited one of the sales guys to come in, and his job was to pre-sell one megabit fast static RAMs to a high degree, so we could count on that to

leverage the factory with early volume. And even though it was a hardship because it was a different process; that required more polysilion layers, something like that.

Walker: Yes, you had to have two or three polysilicon layers on that.

Goldman: That poor guy came to our meeting I think for nine straight months and reporting on who's designed in, what customers. And suddenly the market just turned, as I was telling you, where to a large degree we had to go back to all those customers and say we were just kidding.

Walker: Sorry.

Goldman: But to me one of the more interesting things was, "Hey Bill, I'm up here fighting to do this factory, at least tell me whether we're going to do a 6 inch factory or an 8 inch factory." I always felt he had much more and better knowledge to make that decision than I did. I wanted him to make that decision. And Bill, why don't you tell your side? Bill held a vote with his staff just—

Walker: Well, we'd been asked to go over and look at doing a JV with Toshiba and to get Toshiba to help us with building the factory. We had heard all these stories about Albuquerque and the situation with Intel and the 6 inch startup and the shutdown and the startup again. Everybody was paranoid about building an 8 inch factory since one had never been built before. And so we were over with Toshiba having a meeting with Okamura-San and his team. I kind of threw it out and said “You know, we've been giving some thought to maybe doing an eight inch factory.” And they pondered and he just scratched his head and he looked at me and said, "You're not competent enough to do that." I said “Okay.” And as we returned, I was still annoyed at Okamura-San’s comment. Murray calls me and said, "What are you going to do?" I got the team together. I had a few guys that had worked for me for awhile, about 5-10 years. I asked them to each write on a piece of paper the number 6 or 8, fold it and leave. When they left, I opened the pieces of paper. Everyone had the number 6 on it. I thought to myself, “we can’t do this. It will be a mistake.” So I called Murray and told him we were going to build an 8 inch factory. I didn’t have a clue at the time how we could pull this off, but I had lots of confidence in my team. There really wasn’t a solid equipment set, only IBM had been looking at 8 inch tools in a R&D/Pilot line in Burlington.

We had to put together a plan on how we were going to secure the equipment for the new factory, and we did that. We started with what became known as “Aeray Teams”. Teams of MOS-11 (new factory) employees would be deployed at equipment manufactures, Motorola factories, and any place we needed them around the world. Their challenge was to become more experienced and help in development of equipment and processes for the new MOS-11. If successful, we would ensure a quicker, more productive factory startup. In all, we had about 450 people deployed for up to 18 months at over 30 locations. I can remember our teams worked all shifts at some of the equipment suppliers. At Applied Materials, they were given badges similar to Applied employees. There were several occasions where our techs/engineers were running experiments for people from competing companies. Our goal was to take a 5 inch process Baseline and modify as necessary to build an 8 inch wafer. The team successfully built the first 8 inch wafer by using equipment being built around the world. We flew the wafers to each location for processing: Massachusetts, California, Tokyo and stops in between, and that is how we built the first 8 inch wafers.

As the factory neared completion and equipment was ready to be installed, we began to relocate teams back to Austin. All equipment was built to run either 5 inch or 8 inch and all equipment had been base lined for both processes. The 5 inch was a fall back if we should fail, but we didn't. We got first silicon on the date that we had set as a target date July 5th. Although the first silicon didn't yield, the second lot did. The MOS-11 experience was one of the most exciting I did in my 39 year career. It was an opportunity to build a first of its kind factory and to work with some of the finest people in the industry. I also felt Murray and the corporation had a lot of trust in me to do the right thing, and to insure the investment was a success. My biggest fear was letting Murray down which I just couldn't do that. In the end it turned out to be a real success story and one of Motorola's best factories.

House: So Van, I'd like to capture this about visiting HP and going to the airport. Let him tell this story.

Shahan: Yes, as I mentioned earlier we were working intimately, through partnership. We had a relationship, a fantastic relationship with HP workstation organization in Fort Collins, Colorado, which is 100 miles up the road from the airport, something like that. Multiple times I recall being with either Tom or Jack, and the one I remember the most is when I was with Jack, but Tom was driving the other car. And we leave the customer and we either had 55 minutes or 65 minutes to get to the airport. I won't say what speeds were being hit or anything about driving on the shoulders or the medians or anything. We're 80% of the way there, and Tom's in front of us and takes an exit, pulls into a Macdonald's and gets a milkshake.

Gunter: I needed one.

House: Did you make the flight?

Shahan: We made the flight.

Browne: We made the flight. You make more flights some days.

Gunter: I don't know of anything we ever really missed, except Bill's wheels up practically. We had a jet down here, the corporate policy, and when you were flying with Bill, you had it. And he'd always say, "wheels up" at this time. And he meant it, so you better be at the damn airport, on that plane.

House: Or you got missed, huh?

Gunter: You got more than missed. You didn't miss much.

What would you like to ask us? We've had fun, and maybe too much fun.

House: Can you tell us about how you priced these products or what your pricing strategy was on these products? Who did the pricing, who controlled the pricing?

Walker: Tom, and he beat the crap out of everybody else let me tell you.

Gunter: Including the CEO of Motorola. I came down here for one review and he asked me if <inaudible>. He wanted $286 for it. "$286. You can't charge that much." "Yes we can." See that's like saying because he had run the micro-T, the smallest transistor, he had always run the <inaudible>. Therefore I said, "Where did that come from?" Intel's part number was the 286; no literally. But the pricing, real pricing wars were always done to—I never have been a, cost or production person or building materials guy to determine price. I consider that microeconomics because you got to make certain assumptions about what the fixed costs were. I have a different model that is macroeconomics. Like one of the factories Bill talked about, MOS-13, I know to this day it cost 50 million dollars, a month, I think it was, yes, to keep open that factory.

Shahan: A week.

Gunter: No, a week, a week. It's 50 million a year, so it would cost a million dollars a month to run that factory.

Goldman: A week.

Gunter: A week.

House: No matter what you're doing with it.

Gunter: No matter what you're doing with it. So that's when I said “Well what is it going to take for us to”—

House: Pay for the factory.

Gunter: Pay for the factory? Forget about going through all this math. I said, “Well, we need to generate, we should be targeting for two million dollars a week, but we need to generate at least to a million and a half,” whatever it was. And it wasn't based on a bunch of margin calculations. That way of doing it, Finance never understood. Murray finally got to understand it real quick.

But that's how we basically did it. And the way we did pricing on most of the 68000 was to make sure that we sold every one of them. Whether it's $30 for an Apple scheme where if they'd assured us that we were going to sell a million units over the course of a year or whatever. That was 14 million dollars, we knew what that was going to be. I knew how many dollars were being generated out of that.

Goldman: We always had to look around to see what your product cost was, and the CAPs would be on the micro side. But from the bigger picture we had to make sure the factory was full. If the factory's not full then your initial calculation wasn't worth beans. Point number one. And really important is if you had

a wafer, you had to sell every die on that wafer that was good. You had to sell the mix. So maybe, I don't know, 20 or 30% of the parts would be at your high end, and you had to make sure that whatever you did with customers, however you priced it or whatever deal you did with them, that you were going to be able to sell the low-end as well as the high-end. I think those are all the factors.

Shahan: And my perception is by the latter half of the 1980s, Intel was able to negotiate a mix, "Hey, I'll give you a sweet deal on pricing but you got to buy the whole mix," with each customer, one at a time. None of our customers could really buy the whole mix. So a gentleman who isn't with us—

Browne: Mike Lusk.

Shahan: Mike Lusk was the magician who managed to work out, along with Jack, deals. They were partners in crime, making deals with multiple customers. So over the spread of all the customers we were selling the mix. And that's, as you know, coming from the industry that is so powerful.

Browne: We staged it a lot. We knew where Apple was, which is where you had to hit the production spot. A lot of times we'd do an off-spec a little bit slower than the slowest part. We had to make sure we could scrape the bottom of the barrel and monetize it. At the same time we started with the workstation guys that wanted the highest speed stuff.

House: Charge the most.

Browne: We basically managed the phases in the maturity of production.

Gunter: That worked in all cases, except one: when HP bought Apollo. It was on both sides of the table. They were coming down on me, they were so hard. "You're charging us $286 for this product and you're only charging them $35 for this product." And the mix of each of those companies at the time was totally different in terms of one was focusing on building high volume, lower cost workstations, but you'd use say 25 megahertz over on the other side, of course emphasizing the high end, and together you sold all of it. But we, like the magician was Mike Lusk, you had to balance all this stuff and sell the entirety of it. That was, I would say, one of our more interesting negotiations. HP: they were going to get the same kind of deal before. They were used to buying things with a different mix.

House: So how about the support chips, the peripheral chips? Can you tell us about the development of them and maybe about selling them? Did Apple or did the workstation people buy these chips? Were they successful? What ones went well and which ones didn't go so well?

Shahan: Discrete memory management units—there was a product called 68451, a separate MMU chip for the original 68000. I don't think we ever made our investment back on that.

House: Did you ever deliver it?

Shahan: Oh yes, we did.

Browne: Oh yes.

House: People just didn't buy it.

Shahan: Correct.

Browne: It was late.

House: It was late. That's my recollection.

Shahan: It was late. A senior circuit designer got a really spiffy patent that made it manufacturable every other day or every other week.

Browne: 15 minutes a week.

Shahan: Yes. And then on the 020 generation, as Tom mentioned earlier, we were working very closely with the workstation guys to define that second generation 32–bit data bus, discrete MMU to go with the 020 and the 881. By that point in time we had probably three to five Apple plus workstation customers counseling us on what it needed to look like. My recollection looking back is it ended up being the union of all their discrete requirements, including that Apollo at the time was infatuated with ring architecture. We implemented that with instruction set extensions that accessed it. It was exactly what you get when you take the union of four or five guys' opinions: big, late, and I think we sold fewer of those than the 451.

Goldman: Coyote ugly.

Shahan: Yes.

Gunter: Yes, worse than that. The one thing I saw, I'd say the biggest advantage of Intel was you had customers pretty much wanting, it seemed to us, the same product. You guys could define the architecture, carry it through and maybe just run it through Microsoft's lab. At the time you weren't very big in UNIX at all. We were trying to serve three different workstation products—HP, Apollo and Sun—and a lot more than that; but IBM was in there and we were doing a whole bunch that—

Shahan: NCR, Stratus, Concurrent.

Gunter: Sun had their own version of what they wanted their memory manager to do. We made the mistake of trying to do that, on these three products, and there was just no way - you needed that stuff.

House: How about communication chips?

Gunter: The only mistake we ever made with communication chips, we were not marketing them like we should have been. People came to us and suggested that we open up a design center in Israel.

Goldman: It was actually my boss.

House: Who suggested that?

Goldman: It was, yes, because remember I was saying I was walking around with this thousand foot wave over my head, and Gary Tucker called me in one day and he said, "Do you know that Intel's doing all this great stuff over there in Israel? What are they doing over there?" "Well, they have a design center, and maybe they actually built a factory there too." "National's over there and what's going on over there?" "Gee, I don't know." "Well get your butt over there."

House: I know.

Goldman: "Find out." So I went over there with some corporate types. I didn't really want to go but I went. Israel, first of all it's a very small country. If you're going in there you're going to meet the Prime Minister or somebody on your way in. We went to the universities; I was really impressed with the smarts of the people over there. Actually went to Intel when I was there. Because of the nationalistic side they were helping me understand how you can actually have a design center over there and be successful with living in Austin in the United States, and how they did what they did. Anyhow I came back and said "Boy, I'm really impressed with the people and the culture and all that kind of stuff. But, I got this thousand foot wave over my head; there's no way I can run something in Israel, unless I had an Israeli that would knock on the door, and who was great and could manage his own thing, where you wouldn't need some oversight." Okay. Well, lo and behold, three weeks later one did, and it was a guy that ran the National design center.

House: And his name was?

Goldman: Dean Sohak. Okay so Dean Sohak knocked on my door. I was really impressed with him personally. I had the rest of the staff interview him, and we just hired him basically on the spot. So now we're going to open an Israeli design center. Of course the next question is, "Hell, we've already got this team in Austin. We've got to be careful that we're not overlapping and taking their work away or causing disruption. What in the heck are they going to work on over there?" It ended up being something we were not doing in Austin, and that was communications.

He built a team over there that was phenomenal to me, at least for my eyes. He was another guy that, kind of like a Gary Daniels, in a way, where he committed something to you, you put it in the bank; it was going to happen. You go over and visit over there, it was no matter what other responsibilities they had

with the National Guard or training or anything else, they always kind of met their schedule. Anyhow, that's how we got started with communications.

Browne: Yes, but that was also in the midst of C business too so it was really—

Gunter: Yes, but it was really the same approach.

House: What timeframe was that?

Gunter: When did you go?

Goldman: 1992.

House: 1992? I was at Bay Networks in 1996.

Gunter: But I'm sure you guys were still dependent on a product called the 302, the 360. <inaudible> Instead of network processors that had caught the fancy of Intel. <inaudible>

House: So you worked on stuff like buying companies?

Shahan: Well according the <inaudible> acquisition in 1999.

Gunter: But we had this basic communication line, and we just called them communication processors. Basically they turned out to be smart communication devices, but not a whole network processor. And then the power of them was just the same device on the same board. It was just by changing the micro-code, the middleware, it could handle many different protocols, P1 through. It was pretty much the backbone of a lot of the Cisco products. But I thought Bay Networks—

House: Were those designs done out of Israel?

Shahan: Yes.

Gunter: Oh yes, the designs. They were brilliant in terms of they could go through and understand communications specs and translate it into specifications and into a design. We didn't have that kind of mental thinking.

House: No.

Gunter: Anywhere inside the section we were in.

House: Did you try any graphics processors, or display processors?

Gunter: Yes, we tried, but that depends on you having the right customer.

Browne: We had the first—

Shahan: The first one was <inaudible>

Browne: Well, the first one we did was the Tandy color computer.

Shahan: Which is 6809 based—early 1980s.

Browne: It was a companion chip to solve their problems to sell the system.

Shahan: Low resolution.

Browne: Very focused.

Shahan: TV resolution.

Browne: We had a hard time getting standardization after that. Everything was different.

House: All the workstation guys wanted to roll out—

Shahan: Oh yes. In the mid 1980s we toyed with the graphics processor and got a quarter of the way down the design cycle and decided it was a bad idea.

Browne: We were a quarter away from tape out—it was further than that.

Gunter: It was one of those hard decisions I ended up making. We told you about the capability and competence. But the design manager, especially the designer for it, is Gary Daniels. It turns out that his initial card <inaudible> I went in and said we're killing this turkey. It was kind of like I broke his heart, but he supported me. We just didn't have a customer, didn't have a commit for it. There were a pair of brothers named Campbell or something—you would be aware of this. It was a third-party that kind of specialized in that kind of chip, in the early days of PCs.

House: I'm not sure who that would be.

Gunter: I can't remember.

House: Because Intel was never successful with graphics. We just played processors. We designed a few but we never really got it going. Of course ATI and Nvidia since then were the standard suppliers in the PC market.

Gunter: What do you think it means for AMD to have ATI?

House: That it'll be a very interesting one. It'll be very interesting. It's a make or break strategy.

Goldman: Yes. But it's a big bite, that's a different company.

Gunter: I was just trying to get his opinion of where that kind of strategy plays in the world today, because SOC definitely plays in the world today in terms of communications processors and such. We didn't have the sense to call it SOC, system on a chip.

House: At Intel we had a thing called an in-circuit emulator at one time. Did Motorola ever have that in–circuit emulator? This was way back in the days of the 8080s and 8086s.

Browne: We had the in-circuit emulators, particularly for the workstation business. With all the differences in operating systems most of the customers were using logic emulators. The piece of our business where the development tools really got driven was by the MCUs. When you went to this—all there is IO and you can't see what's happening inside. I remember us arguing and arguing that we weren't going to do another generation of a microcontroller without debug capability; and we'd do one more and then we'd go, “Oh yes, remember, we learned this again.”

Goldman: Where it could check itself, self-check.

Browne: Yes.

Gunter: One of the things that helped us in that whole area, we were much more into single word. We had a DME bus, and that turned out to be wildly successful.

Browne: It was really good. I remember telling customers, first again what Tom would say, your simplest thing to do your system architecture, spend about $50,000 on off the shelf manmade boards; cobble the functional equivalent of it together, and then do some real system benchmarks to find out where the bottlenecks are instead of what you think they are.

Shahan: So the connection there is our development systems were done by the organization that was also generating a good business out of these DME boards.

Gunter: And they needed development systems also.

Shahan: Right.

Gunter: It was not something that had to be borne just by a particular version of the microprocessors.

Shahan: I don't know where it fits but my most favorite development system story of all time: The original 6800 had a development system called the EXORcisor.

House: Yes, I remember it.

Shahan: The little chassis, power supply, card slot, and feedback kept coming back from Motorola Semiconductor Japan that this is nice but it needs switches on the front. And it had an RS232 port. You hooked a dumb terminal up to it. We kept ignoring them and we kept ignoring them. And finally, I can't even remember, somebody from Japan came over and explained, “I'm losing because I don't have a development system with switches on the front.” And we asked, “Okay, we've heard this over and over; explain this.” Well at that time in Japan, because of minicomputers booting a system with switches on the front panel was men's work, but typing was women's work; therefore having a development system that could only be used by typing meant you couldn't compete in Japan.

<Break in recording>

House: Maybe we could wrap up by having each member summarize what you took away from this experience; maybe some personal insight into it. Van?

Shahan: My recollection of the first ten years of my career, which happened to coincide with the 68000 era, are: incredible excitement, felt privileged to go to work every day. I probably would have worked for a lot less money just to be involved in it.

The excitement was pervasive in our environment, and even more importantly, I think, customers were excited. Customers wanted to work with us. Having experienced the industry after that period, as it got more and more focused on cost and ratchet, ratchet, ratchet negotiations, to be able to look back on a period where innovation was breaking out across the semiconductor business and creating new businesses that had never existed before at customers, I felt it was a great privilege to be involved.

House: Thanks. Jack?

Browne: It was an incredible time. When you look at the people we worked with and the businesses they created and the attention that we had, the impact that we had, is just incredible. You just sit here and thinking about this discussion we're having today and you really appreciate how challenging it was, number one, to have that environment where we were successful; number two, to have the team as strong as we had. And the thing we didn't realize at the time, when we talked about why we were successful, it wasn't just the great technology and the customers. It was a lot of luck too. But it really was a great team, just kind of a once in a lifetime kind of opportunity, collection of people.

Walker: I feel incredibly privileged to have had the opportunity to be involved from 1965 to 2004. When I look back on the days I thought were bad days, they were incredibly good days as I think back to them now. There weren't any bad days. There were just less good days. And it was yes, probably the most fun time I ever had in my entire life, and I kind of wish I could do it all over again. It was great.

House: Tom, anything you want to leave us with?

Gunter: Yes sir. First, when you originally asked that question, I thought what did I get out of the experience of being here today? One, it was to sit down with somebody I immensely respect, representing our most formidable opponent—the other guys. I don't want to call you competitors; we were both in the market. And unfortunately for you, you gave me your card, and these days I now return all the phone calls I get. You will get phone calls from me just explaining what happened. And I was privileged to start to learn. I would like your version of the stories we told, inside at Intel. But that was the experience of today.

I won't say it any more than I've said it. It was a privilege to have been part of the team, a complete team. I don't think you saw any disrespect with anything we said today.

Hopefully you found that, with just a little bit of luck, those guys could've been more <inaudible> Hopefully you have an appreciation about that it wasn't that we lacked spirit or capability to win. Who would ever know that Bill Gates would go buy an operating system for $50,000, and it would take over everything? There are some things I think you guys lucked into, and I think there's some things that I didn't fully appreciate, and we'll talk to Jack about Operation Crush and those things. I still haven't figured out if that was factual or a good way to tell the story. But I have an immense respect for you guys. That's what I've learned out of the today is that you had a different way to attack the challenges. And the other thing, with everything you said today you always said it in such a way that you had a respect for us. I can't tell you how good that makes me feel, that the people that we respected, recognizing this, and had a respect for what we could have done. I just wish we had had been a little wiser and we could have tossed in some of the experience you guys had in your early success with microprocessors. It would have been—

House: It could've turned out either way, couldn't it?

Gunter: Well, my daughter was telling me, "Dad, if you say, 'would've, could've, should've' one more time. Stop pouting so much, stop dreaming." I salute you sir. I imagine you can tell the same kind of stories. But thank you, David, and Jack, for letting us share our experience and letting us share it in pretty much as publicly as it can be.

There are experiences that came out of the job—the ability to get into Apple and to the ones that we could win without changing, even if we had to be called brain dead and idiots and whatever by Steve Jobs. I think Steve even set you back the first couple of times.

Walker: He was my favorite. You always left a meeting with a very clean understanding of Steve's expectations.

Gunter: But my favorite story that I will take to my true retirement is Bob Galvin—but in the same way that you guys respect Noyce and Moore, all of us that were, particularly that were corporate officers have this fundamental respect for Bob Galvin. He pulled me aside one day and he said, "Tom," he said, "I want to tell you something." He said, "One of the," he didn't have to come up with this, he said, "One of the proudest day I ever had with Motorola…" He was traveling to China; that's when we tried to open up China. He got off the plane to talk to a bunch of youngsters. What happened, they saw him off and he was introduced as the head of Motorola, and they started chanting, "68000, 68000, 68000."

House: You created something that changed the world in very many ways. Personally I have ultimate respect for that: you created a superior product.

Gunter: Now I came this close to death in 2005, they tell me. To the doctor, my wife said, "My husband has something to do with technology" and my wife told them. They said, "What did he do?" "Well, he was the head of the 68000 microprocessors." He looked and he said, "He worked on the 68000?" So those type of experiences are something that you—that's what I got out of them.

House: Murray?

Goldman: Well yes, people used the words like "electricity" and "fun." To me, I almost felt like I was in a Super Bowl game every day. We all worked around the clock. It was like you worked every minute you were awake, and you loved every minute of it. There were just so many team members and so much to do. I always appreciated it because, first of all, when I came into the industry there was DTL logic and routed wires through magnetic cores. To actually be a part of the revolution that people talked about all day today, it's something that you've got to be really lucky to—I was in the right place at the right time.

All I know is when we started way back in the mid 1970s we had zero dollars for sales. I remember when I retired—and this was for all microprocessor and microcontroller and related business—the semiconductor sector was about eight and a half billion dollars in sales, and about half of that was microprocessor related. So I kind of feel like it was the kind of business you want. It was <inaudible> and it was a privilege to work on it myself. I always felt that my role was to try to create the environment. These are the people that made things happen. What's the next part? Who are we hiring? What's the next part? What factory are we doing? All the decisions were made at their level. And from my point of view I was just trying hard to create an environment where they could succeed, and it was a lot of fun. And thanks for having us.

House: Thanks, I'd like to thank all of you, congratulate you for what you've done, and thank you for coming out and telling your story for posterity. Thank you.

END OF INTERVIEW

