Oral History of William (Bill) F. Jordan Jr.

Interviewed by:
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Gardner Hendrie: This is an interview with Bill Jordan for the Computer History Museum and its oral history program. Bill, maybe the best place to start would be when you were young, what did you think you might want to be when you grew up? Before you graduated from high school, did you have any ideas?

Bill Jordan: I did actually, I might point out my father was an engineer. In fact he was a pioneer engineer in the early days of radio broadcasting and in the late ‘20s he got a job in the motion picture industry and was a pioneer in the early days of sound motion pictures and he retired as a Fellow in the Audio Engineering Society and a Fellow in the Society of Motion Picture and Television Engineers. So as a kid growing up naturally I was exposed to an environment of building crystal radios and audio amplifiers and FM tuners and stuff like that, I liked circuit design and so I guess without even thinking I guess I always just wanted to be a circuit designer and ended up going to college, taking electrical engineering. And in college, my senior year as a matter of fact, we had to do a class project and so I built a transistorized audio amplifier which was just about the time the first commercially available transistors were available and in fact the first...

Hendrie: Now when would this have been?

Jordan: I graduated in 1956, and the first job I took out of college was with a transistor factory, CBS Electronics. They were manufacturing transistors, and the job I had was a circuit applications engineer that it was a fun job in the sense that what I was doing was designing circuits to use these transistors and hence writing a lot of technical articles for trade magazines and application notes and even professional societies of different things you could build out of transistors and I found that kind of a fun job.

Hendrie: Can I pause for a second, I’d like to roll back and ask a few more questions about when you were growing up, now did you have brothers and any brothers and sisters?

Jordan: I have two sisters, one a little bit older than me and one quite a lot younger than me.

Hendrie: They did not feel any need to follow your father?

Jordan: They were not at all interested in this sort of thing. Well I might add a little bit more about my father’s background or my background with my father. Summers during vacations from school…

Hendrie: This is high school?

Jordan: Above high school and college, often times I worked in the motion picture industry, so I had some exposure to the kinds of work my father did. You know my first job was working in my father’s studio. He was head of the Sound Department and so I was involved in designing new recording studios and things of that nature. He was working for 20^{th} Century Fox and they saw on the payroll that there were two guys with the same name, I’m a junior, my father’s Bill Jordan also and so they told me they had to lay me off, they thought it was some kind of nepotism thing. But my father had a lot of influence with the trade union at the time so I was able to get a lot of work as a sound recordist in some of the other trades in the motion picture industry. So for several years I worked in the motion picture industry and was exposed to things that were going on there.

Hendrie: Oh my goodness that's fascinating. Now you lived in LA at this time?

Jordan: No actually this was-- Fox had studios in New York when the motion picture industry was originally started, you know, it was Thomas Edison and guys like that, started out in New Jersey and then they went west because the climate was a lot better for making movies. When my father left the broadcast industry, he had an opportunity to either go to Hollywood or the New York studios. Now the New York studios was Movietone News, they had 2 large sound stages and several mixing, recording studios, facilities. So my father elected to stay in the New York area because he had friends and relatives and stuff back here or back there. And so it was in New York, now the kind of stuff they did, they did some feature films in the studios quite a bit but it was the early days of television so they used to film a lot of stuff to be shown on television and of course they used to do the commercials. They used to do the newsreel, they used to do short subjects and they used to do films of Broadway or not films but screen tests for Broadway stars to decide whether they were good subjects for the motion picture industry. So I got involved in all of those kinds of activities.

Hendrie: That sounds like that would be a lot of fun.

Jordan: That was a lot of fun but frankly my father discouraged me from wanting to have a career in that industry. As I said he was involved in a lot of the pioneering aspects of radio and motion pictures and so I think he had enough vision to see that his industry was kinda flattening out. As it turned out it was because of television of course, and encouraged me more to get into more of an emerging industry which I did do as time went on.

Hendrie: So at college, when you were at WPI [Worcester Polytechnic Institute], what did you major in?

Jordan: Electrical engineering.

Hendrie: It was just and so it was all the standard things that electrical engineering?

Jordan: Well in those days of course electronics was-- I think the curriculum was such that they had the electrical engineering was divided into two sub divisions, power and it was either electronics or control or something like that, I forget exactly how they call it. I took the latter anyway, I wasn't interested in working in a hydro electric station or something and we had courses is that reached into each other's area, you know, Worcester Poly Tech where I went to school, it was quite an old school, I think it was founded in 1850 or something like that. So they had a lot of great traditions. They used to have running around the city of Worcester, they used to have electric trolleys and the kind of subjects the kids had in those days is they'd go out and measure the line voltages on the trolley tracks and things like that. But even in the years that I was there, it was very practical. One of the requirements to get through it is we had to build a bench grinder, this was a mechanical engineering type project, they poured cast iron and we made

Babbitt bearings and made a, you know, a pulley arrangement and I still have that in my garage for sharpening axes and things like that. It was a very pragmatic school and I kind of enjoyed that environment.

Hendrie: So then when you got out of college, what did you want to?

Jordan: Well I wanted to be a circuit designer and more particularly I wanted to be involved in the emerging business of semiconductors, which in those days was transistors and diodes and like I said I worked in a transistor factory and that was kind of interesting.

Hendrie: Well did you get other offers?

Jordan: One of the other offers I had was to work down at RCA; I elected to work in the transistor factory.

Hendrie: Of who?

Jordan: CBS Electronics, to put that in context, CBS was in the broadcast business of course and when television emerged here in the television business and they also were trying to manufacture television sets and they had a factory that manufactured television picture tubes, I think it was on Kalamazoo and they had purchased a vacuum tube company, CBS or HighTron, tube company and with that as a base they were setting up a semiconductor or transistor factory since that was the emerging technology they needed. In those days by the way semiconductors were made quite differently from what emerged not too long after that, there were no such things as clean rooms, it was more like a Nabisco cookie factory, they had a conveyor belt that went through an oven and they had-- although out in the back room they grew crystals and sliced 'em up and diced 'em up and they took these little chips and put 'em in a graphite boat on a conveyer belt and they put a little pallet of some kind of an impurity and the conveyor belt carried it into an oven and the oven melted the impurity into the crystal and they made alloy junction transistors, this is before planar technology came along. In later years of course it became a much more sophisticated business with clean rooms and much greater precision. After two years anyway of doing that kind of work...

Hendrie: Now where was this located?

Jordan: They were located in Lowell Massachusetts and I think it was in the same facility that became Wang Labs facility eventually. In those days by the way there were semiconductor manufacturers in the east, there was a bunch of them, there was Transitron and Sylvania and Westinghouse and CBS and Silicon Valley was probably not even as big and as in transistor stuff as it is emerged in later years, practically everything’s out here. But after several years of this which was kind of amateur circuit design work that I was doing, it was fun stuff and although I did during that period, did present a paper, a professional paper, at the IEEE with regards to the breakdown characteristics of transistors. I got a job in a computer development program at AVCO Research and [Advanced] Development [RAD]. Now at that stage AVCO was a major contractor for the Air Force developing nose cones for ballistic missiles and they wanted to diversify from that and they took on an Air Force contract to develop a computer. I was in the circuit department of that and we developed a family of circuit modules that the computer was supposed to be built out of. I worked alongside of some very competent engineers, a friend of mine was from out of IBM and so in that environment I learned how to do worse case circuit analysis and to really design circuits for computer use.

The problem was the guys developing the systems end of this thing didn't make much progress and after a year the Air Force wisely cancelled the project and so I at that time still wanting to do that kind of work, found out that there was a similar type company starting up, similar in the sense that there was a team of engineers that had worked at Raytheon and they worked on a Navy sponsored contract to develop a computer, which was called a RAYDAC computer I believe and that team of engineers I guess Raytheon was also a Defense contractor and probably didn't have any opportunities to develop more computers or they certainly didn't pursue the computer business as a business in itself. These guys formed a company called Computer Control Company. Computer Control Company obviously was able to pick up the maintenance contract for the radar computer which is installed in Pt. Mugu Naval Base out in California. And so they kept the base of operation in California whose purpose was primarily to maintain the computer and have some cash flow to help finance the starting of this new company. And the new company their business model is to build circuit card, digital circuit cards and to be sold as standard products in the market place. And they also built magnetic core memory's to be sold as standard products and standard is stretching the word there. I guess they were subsystems that had to be tailored to each person's use so I guess tailored products might be a better word and then the other half of the business was developing under contract special purpose dedicated digital systems employing these various standard products that they had done. And I went into the systems end of the business at that stage, although most of my activity was actually doing circuit designs, designing circuits to help interface the standard products with the real world. So I worked for many years developing a whole series of different special purpose computers. Now in those days the computers that we built, probably a better word is digital systems, although we had core memories which was mostly for data storage, the only programming capabilities that we had in these equipments were electromechanical switches and patch boards and keyboards. They were dedicated systems.

Hendrie: Now when did you go to move from AVCO to Computer Control?

Jordan: Oh in 1959, Computer Control Company, I'm not sure when they were founded but they were a pretty young company at that stage. They were located in the Babson College campus, they were in a building in the Babson College campus. The technology they used is really quite interesting, the circuit family that they had built the whole company on was a circuit which was … the end gates were like end gates with pulse amplifiers and each circuit element had a one microsecond delay in it, so that if you put two functions in the end gate or whatever the different function was, the output would be a pulse that would appear one microsecond later and to build a flip flop and this type of circuitry I've never seen since then of course. But to build a flip flop, the flip flop would be built by feeding back the output of the amplifier, back to the input and so that a turned on flip flop would show a stream of pulses coming out, one every microsecond and to reset the flip flop you would interrupt this feedback and then the output would be the absence of ones and zeros. So to design a system out of these things in addition to having another Boolean algebrator to connect up various logic functions you also had to have timing diagrams.

But some of the people, particularly the Executive Vice President of the company, a guy named Bob Brooks was very clever at this sort of thing and he could put together-- there was another element in the circuit family and they used magnetostrictive delay lines, which in essence is like a serial memory, you put a stream of pulses and ones and zeros in this thing and feed it back on itself and it's like a drum or something that it would just keep going around and round and by clever uses of the logic functions and these magnetostrictive delay lines they could tap off signals just at the right time and put together configurations that would solve certain algorithms. It was real interesting to work with because it was sort of like working on puzzles all the time and but as time went on and the evolution of technology came by, these approaches didn't make much sense anymore. I suspect these approaches were outgrowth of the vacuum tube computer of earlier days that's probably the kind of circuitry they must have had in the vacuum tube computers.

Hendrie: Now did they have a brand name for these modules?

Jordan: Yes the circuit family was called T-Pacs.

Hendrie: Do you remember how-- they were one microsecond delay?

Jordan: I think the clocking rate was one microsecond and everything was precisely clocked with that. I might add the memory products they had were called TCM- and then a number, the last TCM one in the series I think was a TCM-35 or something like that. TCM stood for Transistorized Core Memory and because they were-- the original magnetic core memories were invented in 1949. I assume they must have used vacuum tubes in those days because transistors were pretty early in those days. I think probably the original core memory was in the Whirlwind Computer wasn't it, I'm not sure?

Hendrie: I think that is correct. Can I pause you on the core memory bit, I just was curious now who hired you at Computer Control, who did you originally work with?

Jordan: Well first of all the four principle engineers that formed the company were, the president of the company was Ben Kessel; I think the Executive Vice President and the guy in charge of systems type activities was named Bob Brooks. The fellow in charge of all of the engineering product development was Frank Dean and the marketing manager was a guy named Bill Wolfson right, I think he was also an engineer, I'm not sure. But it was a small private company with very technical oriented type company. There were a couple of other company officers Bob Massard was the treasurer, Ed Hampson was the manufacturing Vice President. The guy I reported to was a guy named Sig Yayland that I believe reported to Bob Brooks, Sig Yayland was responsible for the special purpose system type activities.

Hendrie: As opposed to the standard T-Pac line?

Jordan: The standard product development was originally under Frank Dean. Sometime after I was there, Frank Dean hired Paul Bothwell who came in and developed a whole new family of circuit modules and started leading the company into a much more modern approach to things because frankly the business model for Computer Control Company was unsound for two reasons. One reason was that the circuit module business was doomed because the semiconductor technology was evolving to the point where they could develop man gates and flip flops and things like that, which were exactly the functions that Computer Control was trying to sell. So that business was gonna dry up and go out of business pretty fast.

But the second part of it, the idea of building special purpose computers under contract was not a sound business either because there was such a heavy engineering content and not any production volume involved in these things and therefore it's too hard to forecast engineering breakthroughs and so trying to plan for markets and trying to plan your costs and delivery schedules and things like that became just hopelessly complicated. So because it was an unsound business model, Computer Control Company very rightly redirected themselves to try and come up with a standard system products, hence their entre into the business of making minicomputer products. So they had sort of a base of operation and a cadre of engineers that could sorta help support this business but of course they had to get some engineers that understood computers a lot better in there and they did that. They did some staffing up. They did have some people on the staff, I guess out in the West Coast facility, the team of guys that was really set up in the West Coast for the purposes of maintaining the RAYDAC computer and so I think they drew upon them to help them develop some of the early microcomputer, I mean minicomputer. I may be saying microcomputer when I mean to say minicomputer; I'm getting tongue tied on that. So then Computer Control Company grew with some reasonable success as time went on and of course moved out into a facility in Framingham, Massachusetts. They got out of the small, little building they were in Babson College campus and grouped up to have quite a much bigger staff and much bigger facilities and some revenues coming in and stuff like that. I think, I kinda lost track but I think they went public, we did have stock options as employees back in those days which I think of in terms as a Silicon Valley phenomenon but I knew I was introduced to the concept of stock options and stock ownership and stuff like that as an employee of Computer Control Company.

Hendrie: Could you sort of circle back, now when you went to Computer Control, what was the first project, do you remember what the first project you worked on?

Jordan: I certainly do, most of my experience at Computer Control Company was filled with a lot of emotions one way or the other. The first project we had was a system that was the purpose of the system was to translate digital tapes into computer tape formats and this was an Air Force contract. It was eventually installed in White Sands Missile Range. And the tapes we had were instrumentation tapes from experiments I guess they were doing with missile research down in White Sands Missile Range and we had to translate this instrumentation type data into formats that were readable by-- there were two different computers, one was a Univac format, and the other was a IBM format. And so the problem was to reformat the information basically and there was a patch board involved that which we could set up depending upon what format-- there were a lot of different formats for the instrumentation tapes I might add. And so we'd set up a patch port depending upon what the input tape was and what the output tape we were trying to generate. And so as part of our equipment we had a-- in the case at Univac their tape drive I think was called a Uniservo and the IBM, I forgot what they called their tape drives but actually IBM was a higher tech type tape drive, theirs is a magnetic tape drive.

The Univac tape drive was an interesting technology, they used metal tape, unlike tapes we've seen more recently in the years of magnetic tape, plastic tape, I'm not even sure what the substrate is on 'em. But the Univac tape was like a ribbon of steel and with a magnetic coating of some kind on it and because the technology was somewhat primitive, there were places on the tape that wouldn't work, so they used to punch holes in it. These were called bad spots and so in reading the tape, one of the design problems I had as a matter of fact on this thing was to make a bad spot detector. A photo cell shined through the little holes in the tape and told you to blank out everything your saw for a period of time until the good stuff came along and I remember those old Univac tape drives because in the back they had some kind of large gas tubes that were used in the control mechanisms of these tape drives and they would flash with the explosive colors in the back because as the tape was maneuvering back and forth finding its way through.

So we developed that system and installed it down in White Sands Missile Range and got it all working down there in their computer rooms which that was the first system we did. But one other quite large system we did a little bit later was one that was sponsored by the Provident Institute for Savings, a bank in Boston, Savings Bank and they were very advanced in their wanting modern technology. And so we built a system that was supposed to be or was a real time transaction machine and it was based around the IBM file, was it the 350, the RAMAC file that IBM had used as a center piece for their file computer in those days, which was an enormous piece of equipment with large disks, they must have been several feet in radius and a big stack up of those and with arms that moved in and out of those disks to find tracks in there and to acquire data off of these things. And so all of the bank's records were to be on these files and the bank's input devices were all the normal teller machines, the Sensormatic, I think they were, teller machines and we had to wire them all up and run 'em through our computer that was supposed to provide access to teller machines all over the banking system and the bank had several branches, at least one of which was in a Boston subway station, which created interesting technical problems for us because every time a subway train rode by it stirred up a lot of electromagnetic disturbances, which tended to upgrade accounts in the bank. So we built that system and that was an agonizing process because it probably took us a year to get the bloody thing installed because of all these very pragmatic technical problems. But we ended up installing that and one of the engineers in the projects ended up having to go to work for the bank to keep the silly thing running.

Now as far as my career went, after doing this several times and seeing the handwriting on the wall with regards to this evolution of the company getting into more standardized products, I figured the best place I fit was in the memory area because I had the circuit background which I could apply into designing new generations of memories and so anyway I transferred into the memory area.

Hendrie: Now who did you work for initially?

Jordan: Initially I worked for a fellow named Bob Reichard. Bob was in charge of the memory area and I worked in the memory area for quite a while and I was trying to think of how the organization changed and frankly I can't, I know a lot-- all the guys I either worked directly for or worked one or two under but I can't quite reconstruct that in my brain about who was where. But anyway initially I did work for Bob, who's a good friend of mine and my interest in the memory area was to bring into memory design, integrated circuits because by this time I was very interested in integrated circuits and it seemed like a good opportunity at the time.

Hendrie: Now had Computer Control done anything in integrated circuits at this juncture yet?

Jordan: Not in the memory area, I don't believe.

Hendrie: They did at some point build some.

Jordan: Integrated circuit modules.

Hendrie: Yes.

Jordan: Yeah I think they ended up with a product called Micropacs or something like that. The original company had T-Pacs those are those pulse things I talked about and then Paul Bothwell came in and they had S-Pacs and then eventually they had a much smaller thing called Micropacs and by the way Computer Control Company was like said it had grown reasonably healthy and big and elected to make an investment in having their own in house semiconductor facility which they called a technique lab, it was a pilot line for making semiconductor parts. And so I'm sure there were logic functions built in there, but that was of great benefit to kind of work I was going to do. So I worked very closely with those guys because in developing the first generation integrated circuit memory a lot of the circuitry we were able to buy industry standard circuitry because that was low cost and in good supply and stuff like that for mostly data registers and control functions. But the one area of circuit design that I thought would lend itself well to improvement with a custom type design was in the address decoding area because it was highly replicated, there was lots of areas that you could make a special circuit that fit the requirements of memories quite well.

And it was in that area that I was able to come up with a design and work with our own prototyping capability within Honeywell to develop a circuit that I filed a patent on called, I'm not sure what it was called, the nomenclature for it was the F06 and I think the description of the patent was that it was a multiemitter follower memory decode circuit. Essentially what it did in the design of memory systems, the addresses went through some logical decoding and then another layer of decoding was accomplished by the pulse transformers which ultimately drove discreet transistors which ultimately drove the X and Y addressing access lines of the memory cores. The pulse transformers were put together in a matrix like arrangement where pulling certain combinations of circuits connected one end of the transformer and certain other combinations connect the other end so that you'd find just the right transformer that you wanted to drive a line by putting the right combination of logic in. This is kinda muddled I'm sorry. But my contribution to that thing was I came up with a circuit which had in one transistor four emitters which connected to [a] different transformer on one end and on the other end of the transformer you could use conventional end gates or man gates, whatever we were using at that stage and so by having multiple emitters it takes a lot less silicon real estate to build one transistor with four emitters than it does to build four transistors in other words. So we made this circuit and then we got an outside manufacturer, I think it was Sylvania at the time or maybe Texas Instruments or probably both.

Hendrie: I remember it was Texas Instruments.

Jordan: Well the next generation we were very heavily involved with Texas Instruments. I think you're right. I think Sylvania and Texas Instruments may have built this in addition to their in house… One of the things we computer manufacturers always insisted upon was having multi sources of supply for obvious reasons that you didn't want your computer business to go down the drain if one guy had a fire in his factory or something like that. Anyway we went through that generation, I think that product was called the ICM 40 and I think it was used in the 16-bit computer families; I'm not exactly sure which model computer it was.

Hendrie: Now was this a flat pack, was this package a flat pack?

Jordan: This package was a flat pack and it was soldered onto one of the circuit boards just like any of the other circuits. Having been through that experience and as technology emerged a little bit better, I became interested in the next generation computer. By the way that particular generation was based on I believe a 30 mil core. Core technology also was facing an end of life type problem in that the concept of building magnetic cores it was necessary to string three wires to reach core to build a functioning memory array, one for the X axis of address, one for the Y axis of address which went in a different direction and one for the data lines and so the idea of stringing these wires through the little teeny hole of a core, you wanna make the cores as small as possible to make things work fast and not take up much room and stuff like that. As you made cores smaller and smaller it became harder and harder to string the wires through them and as the wires got thinner and thinner they broke more easily and nobody ever came up with a way to do this with any automation at all so it was always a matter of going to overseas labor markets and having people string together all these tiny little things. The ICM 40 generation were 30 mil cores.

Hendrie: And they had three wires through them?

Jordan: And they had three wires.

Hendrie: Hadn't cores originally when Forrester did it, didn't he have four wires?

Jordan: I think they did.

Hendrie: I think he had a sense wire and he had an inhibit wire and then the X and the Y?

Jordan: I think you're right and I'm a little bit vague on this, I may be wrong in the ICM 40 too but I thought-- I'm under the impression that the inhibit wire in a sense were combined but I may be wrong.

Hendrie: I think you're right, that's my line.

Jordan: Somewhere along the line I think that happened anyway, but three wires it was difficult.

[End of tape 1]

Hendrie: Okay, let's see. Where did we leave off?

Jordan: Well, I had just described that we had just finished the design of an integrated circuit core memory based on 30 mil cores. I think the cycle down is something like 750 microseconds or something like that. So we got that one into production and sold those as a standalone product in the outside market and integrated them within to our minicomputer product line, and embarked upon a next generation, which I believe was based on 20 mil cores, and we went one step further in the circuitry. And by that time we had found a way to integrate the transistors that directly drove the X and Y current lines in the core memory array. The current levels, by the way, were something like 400 milliamps. That's why in the first generation, that was pretty demanding of an integrated circuit, to try and cope with that kind of current and the power that it required to switch that in a relatively fast time. But the next generation we did totally integrate eliminating the need for the pulse transformers, and we totally integrated it with a circuit which had output power transistors that were capable of switching 400 milliamp drive currents. And so we put together that family of product and I think the memory was called the ICM 500, and essentially went through another cycle, another generation of memory products and sold those on the open market, and I believe we integrated them into the computer line somewhere and I'm not sure where.

Hendrie: As I recall the ICM 500 was the basis for the memory in the [DDP-] 516 computer, which was the first integrated circuit computer that was done, but I'm not certain about that. It may have been later, a later model. Was it a two-and-a-half D memory, or was it still a conventional three-D, three-wire?

Jordan: I think it was and I don't know what that means, now that you mention it. It rings a bell in my brain but, what is a two-and-a-half D memory?

Hendrie: I don't know, but it's somehow folded-

Jordan: You're supposed to be the memory expert.

Hendrie: So there's less circuitry required around it, and it somehow goes faster.

Jordan: I know we scrubbed the design pretty hard on that to the extent where we even laid out the printed circuit boards carefully to consider the electrical characteristics of the printed circuit wiring to make sure that we could affect as sharp a rise time and full time in our switching characteristics as possible. And it was a very challenging design, and in fact as I recall, the marketing people were pushing us to make a spec of 500 microsecond cycle time I guess it was. And I think, frankly, the system was somewhat marginal at the spec that we supposed to have. I think it worked at a looser spec, so the computer may have run at a looser spec to make things work good. We were under a lot of pressure on that one to get things working right. I guess it went into production. Everything worked out okay.

Hendrie: Now with this integrated circuits, these were still P-channel metal gate silicon.

Jordan: No, the drive circuitry was for the integrated circuit memories was all bipolar.

Hendrie: Okay, yes, of course.

Jordan: And I might add, the circuit design for that particular system, we worked in conjunction with a design team at Texas Instruments. That was a very challenging design for them also to get a circuit that could handle that kind of current and that kind of power. So they had to do a lot of sophisticated studies, thermal mapping the chips and things of that nature to make sure there were no local hotspots in there. Very interesting engineering type design problems. And also compounding the design is we had to attach the chip to the printed circuit board with a good solid contact. I think that we had a solder flow under the chip somewhere on this. We actually soldered the chips to copper surfaces on the printed circuit board to help draw away some of the power that was in the chips so that they wouldn't run too hot. Anyway, we completed that circuit design and it was then that the next generation that I became interested in was integrating the memory cell itself to eliminate the core memories, because it was clear that the smallest core size that I was aware of got to be 18 mils and I was clear they weren't going to go much smaller than that. Everything else was progressing technologically so well in the computer business, but it was clear that we needed to come up with some kind of batch fabricated approach to building memories, and that in itself created quite an interesting challenge for the whole industry, because there were many different people from all different angles arguing for one approach or another approach as to how the heck do you build computer memories in the future.

Hendrie: Can we take a pause here, and then I'd like to roll back. Maybe you could tell us a little bit about your involvement in 3C's custom integrated circuits that they — I don't remember the time when they did that, but it must have been around 1964 or so. You had alluded to them earlier as the Micropac product line, but you were involved somehow in that. Could you tell us about how you were involved?

Jordan: I'm a little bit vague on that. As I said I had come into the Computer Control Company as a circuit designer working in the systems area, and so I was involved in a lot of circuit design projects, some of which were under contract, stuff like that. In fact I even worked on a design of a circuit that was to be the basis of a circuit used in the Mariner space probe, Venus Space Probe, Project Mariner. But somewhere along the line I was given an assignment to define a new family of circuit modules based on integrated circuits. In other words, plug in cards that had n-gates and end gates and registers and the kind of things that we had, the Computer Control Company, had previously done with discrete component type designs. And I remember working for some period of time, not a real long period of time, but some period of time putting together what I thought was a product family that could be used for such an application. But my recollection, it's the kind of a project which it's like painting a picture. You could ask ten different guys and each guy had their own whims of what was the proper way to do this sort of thing, and then it didn't…

Hendrie: Did this include not just what the functions are but sort of what would be the voltage levels and all- ?

Jordan: Well, how many pins are on a card and how many, you know, it was a logistical kind of thing.

Hendrie: It was a family. What would the family look like?

Jordan: Trying to make sense out of what practical things were available, and my recollection of how that — I don't think I ended up a very significant contributor in that area, because my recollection of how that went was that I defined this whole family and then the vice president of engineering came around and said “Now, this is the way it’s really going to be.” And he had his own opinion of how these things should be. So I can’t really talk with much authority on being the person that defined the basic building blocks of any of the computers that came later. My contribution was mostly in the memory area.

Hendrie: Okay, well let’s go back there.

Jordan: Getting back to memory. It was around this time which was the early to mid 60’s and I can’t pin down the date precisely that I started becoming passionately interested in the concept of building semiconductor main memory. Of course I wasn’t alone in this. There was a whole industry of people that were interested in this thing. First of all, the semiconductor guys wanted it for a very compelling reason that the whole nature of semiconductor manufacturing suggests that you really want large volumes of the same thing. Because it’s always an agony to get something into production and if you’re only going to sell a thousand of them by the time you built your one thousand-and-one you’ve spent all your money. You want to build millions and millions of things, and one of the few areas that you can define millions and millions of products is to build memory arrays for computers. The magnetic memory industry at that stage, they also had a compelling interest in trying to perpetuate their activities, and they recognized the idea of building these little <inaudible> ferrite devices and stringing wires through them was not going to continue to improve.

So the general approach in the magnetic memory area was to try and build thin film memories. Some companies were oriented towards trying to have a flat substrate and build a flat thin film memory. A thin film memory was accomplished by depositing thin films, thin magnetic films on top of some kind of a controlled substrate. And there was a whole other camp that figured the whole key to building magnetic thin film memories was to build plated wire memories, to plate a thin film on a copper wire and embed them in boards and overlay wires in order to provide different connections to them. So institutions like MIT Lincoln Laboratories, and companies like Ferroxcube, and even companies like Honeywell became very interested in magnetic thin film memories. Honeywell was interested in it because they had had a program I guess under military contract of some kind, where they built thin film memories, or I guess it was for avionics type applications. Thin film memories, first of all, on those kind of applications you’re going to spend a lot more money per bit to build these memories, but the thin film memories like I said, the advantages and ruggedness and perhaps radiation insensitivity and things like that.

Hendrie: Oh, you mean in terms of if there was…

Jordan: Military applications.

Hendrie: And nuclear radiation…

Jordan: Well, Honeywell figured they had developed some confidence in this area and gee, why not commercialize it and apply it into the computer businesses that Honeywell had. Somewhere along the line I may not have mentioned here Honeywell acquired Computer Control Company. And so there was a faction within the Honeywell management that wanted to build plated wire memories. In fact, that faction prevailed to the extent where they set up a facility within the computer operations Framingham for the purpose of producing plated wire memories. And complicating my life was the fact that they transferred my department to work for the guy that was in charge of that facility and his background was building printed circuit boards and his whole focus on life was dragging wires through chemical baths to put platings on them and things like that.

Hendrie: Who was this?

Jordan: Bill Lehrer [ph?] was the guy's name. So I reported to Bill Lehrer which was kind of awkward because I'd go to engineering staff meetings and then they'd go around the room and each guy would talk about this chemical composition, this that and the other thing, and they'd get to me and what I had to talk about wasn't very interesting to those guys and what they had to talk about wasn't very interesting to me. It was sort of a funny environment that I was in. I'm digressing a bit here anyway. But to talk about all the divergent approaches, because Honeywell at that stage had a lot of different computer operations all over the world. They had a computer operation in France. They had one in Italy. They had computer operations, Framingham which was us, the minicomputer people. They had the mid-size business data processing machines were centered in Waltham, or the engineering was in Waltham anyway. And they had an operation down in Phoenix, Arizona for the real large machines, and so each of the engineering departments within each of these organizations had their own pat approach as to how to do this thing. Also for example the fellows in Waltham, they wanted to build a custom chip to be manufactured only for the use of Honeywell based on a 2k, 2,000 bit on a chip approach.

And then just to round out the story, there was a whole other sort of approach to building main memories in computers, and that was companies that wanted to use pretty straightforward memory arrays, oftentimes just flip flops with four or six transistors per cell; but focus on the problem of attaching, of assembling multitudes of these chips. And in fact that was best personified by IBM Corporation who was the biggest at that time, the biggest use of memories in the world. Their whole approach was to build an array. They built chips with little solder bumps on them and then lay them all upside down on a substrate and melt the solder so that all the chips got glued on to a substrate. So they'd have these sophisticated assembly technologies, and not only IBM but there were a group of guys that quit IBM. Formed a company called Cogar that tried to- their business plan was to use these IBM technologies and try to sell memories in the open marketplace. And there were guys out in the California area that were connected with the semiconductor manufacturers which were taking semiconductor chips and using techniques to- with some batch fabricated approach attach the chips to control substrates. I think Computer Microtechnology was one of the companies. So there were a whole bunch of guys that were kind of using that approach.

Hendrie: Were these using MOS technology, or bipolar, or some of both?

Jordan: Some of both. In fact IBM I think some of the real fast smaller machines used bipolar, but it seemed to be as far as semiconductor memories go, it seemed to be most of it centered around MOS technology. The approach which I favored was to build an MOS array of the very simplest form you could make which at that time was three transistors. I understand now they do it with one transistor. I haven't the slightest idea how that works but the very simplest cell that could be conceived was with three transistors, at that stage. And to put somewhat of a burden on the driving and sensing of that circuitry onto the peripheral circuitry of the memory array, a lot of the semiconductor manufacturers whose life had been building end gates and stuff like that that were used to very discreet signals in and out. Thought that was too difficult to do. That's why some of them were oriented towards trying to build flip flop type memory storage devices because of signal to noise ratio considerations. But those of us that had built magnetic memories in the past trying to build MOS dynamic memories with three cell approaches was not demanding at all, because we were used to having 400 milldrive currents and very small output signals, and we were used to living in a world where the signal to noise ratios were very difficult. So the demands on the type dynamic memories that we were conceiving were not really all that rigorous. So the whole approach was to make the simplest cell you can because that's the thing that's repeated over and over again, and then take your lumps a little bit on the drive and sense circuitry. At that time by the way, dynamic memory, there were a bunch of different people working. Each one had their patent position in working on dynamic memory. I think AT&T had a patent position, General Instruments. Just about every semiconductor company and several computer companies had conjured up different ways to make memory cells, and three transistor memory cells. It's kind of hard to pin down, you know. I don't think it's ever been adjudicated.

Hendrie: As to who- who thought up the idea first. It was just a-

Jordan: As to who was *the* inventor of dynamic memories. I would suspect it's probably Bell Labs but I may be wrong. At least I don't know. But by this time I had evolved into management. I was in charge of a department of memory design people, and within our organization one of our engineers designed a cell, a three transistor cell which had essentially three wires connected with it. The designer's name was Bill Regitz, and we had a team of engineers, the most prominent other guy in the group was a guy name Hank Bodio who was designing the system that incorporated this chip. And we were able to — because we had within our organization the semiconductor pilot facility — we were able to build a relatively small array as samples of this device to prove the feasibility of it. Build 16-bit arrays. That was the original form of the thing. It was always my vision that hopefully we could come up with a design that would become an industry standard because well, for one thing, it was kind of hard to justify this as a custom circuit. It was hard to get the semiconductor manufacturers to be interested in building this, to committing all of their resources which was their most precious asset that they had the engineering talent and even the wafer starts, to something that's going to be used by one customer. So their whole interest of course was to try and have a bunch of different customers. And our whole interest was to have several different suppliers so that we could negotiate the most favorable terms giving some kind of competition. So I was hoping to promote our design approach to become the industry standard, so I devoted a lot of my time to giving talks and papers and stuff like that on this subject, and became quite emotionally involved with it. I was really turned on. I was quite zealous about the whole thing at that stage, even to the extent of being argumentative at times. But anyway, we embarked upon it and we eventually built a 1000-bit array and we started working in conjunction-

Hendrie: This is in house? You were able to build a 1000-bit array in house?

Jordan: I'm a little bit vague on whether it was in house. We certainly built a 1000-bit array in conjunction with a semiconductor supplier. We negotiated with several suppliers and the two we selected were Fairchild and Intel. Intel had just started up in '69. Let me back up and describe Intel. Intel of course was a group of guys that left Fairchild Semiconductor. The founders were Bob Noyce and Gordon Moore. Their business plan, they wanted to of course further their cause of semiconductor technology, and the most promising product at that time was to try and build MOS main memory. So they started the company, and they had a bipolar line of products also. The MOS products was based on the silicon gate process which I think was developed in Bell Labs. Certainly Fairchild had it. And their original product which was to some extent a vehicle to get their process working was the 1101 which was a 256-bit static memory. It had some market application and they sold them as buffer memories for some applications. So they needed to really get into the main memory business, they needed a customer to work with and an MOS main memory design approach. So, we were able to work out terms with them so that we collaborated on the development of what was the 1102, the patent of which was filed by Bill Regitz. We also at the same time were working with Fairchild Corporation. So we went through a development phase. It was all defined. You know, first they built 16-bit arrays. I'm sure we must have built 16-bit arrays within Honeywell's pilot facility, and I assume we build a 1000-bit arrays but I'm a little vague on that, quite frankly. But we did build the 1000-bit arrays successfully at Intel if no place else. And in fact, in building the 1000-bit arrays I remember distinctively and perhaps you do too, we put together a memory system with the 1102 memories and we hooked it into a 16-bit computer, probably the 516, and were able to run memory diagnostics on it so I think we proved to ourselves at that stage that it could be done. I don't remember exactly what year but it was approximately 1970 that that was done.

Well, reached an interesting point at this stage because when it came down to trying to set up the contract for the next phase of the program and to start defining production orders and things like that Intel presented us with an interesting dilemma in that they also had a design approach which they called the 1103. We had the 1102. They had 1103, and they also had an 1104 I might add. And I'm trying to remember what the 1104 was. I think the 1104 was their fall-back plan. I think it was a very conservative design approach. Maybe even a four transistor approach. I think it probably was a four transistor approach. And they had that in the works because there's a long lead time in developing the masks and running the pilot production and going through all the stages to get the test programs working. So they had to have things in the pipeline to save themselves if the other stuff died. But there was a significant branch point where we had to make a decision as to how to proceed. I mean we knew it was going to work, but the details of it we had to work out. And Intel had a design which I'm pretty sure was patented by Ted Hoff which was the 1103, and they had started independently developing that. The 1103 and the 1102 had an awful lot of things similar, and there was a lot to be learned by the 1102 that was based on the 1103. But the 1103 design was a little bit more conservative from the semiconductor manufacturer's point of view. It put a little less demand on the peripheral circuitry and it had four wires instead of three associated with each cell. It still had the three transistors, and the storage phenomenon was really based on the spurcharge [ph?] and the parasitic capacity of one of the transistors. But Intel pointed out to us that gee, we're at least initially getting better yields on the 1103. Philosophically, perhaps it was a not-invented-here syndrome, but I loved the 1102 better, and certainly Bill Regitz did because that was his baby. And it made more sense in my whole rationalization to how this business should proceed because it had the simplest cell in terms of area usage, and put a little bit more demand on the periphery.

Hendrie: So it was a slightly smaller cell for the same lithography.

Jordan: I think it was a slightly- it had to be a slightly smaller cell because it had fewer wires interconnecting it.

Hendrie: Fewer wires going through it, yep.

Jordan: But Intel argued that they were getting a little bit better yield on the 1103 and so the choice to Honeywell was if they would be happy to proceed on the 1102 with us but they were going to do the 1103 anyway. Now, behind the scenes, this has never been spoken to me certainly or anybody and I was a corporate insider at Intel in later years. I was part of the executive staff there. Behind the scenes, in retrospect Intel couldn't very well base the whole essence of their business on an invention from Honeywell. They couldn't sell the Honeywell part to other Honeywell competitors. And so from a business point of view they had this other compelling argument that they wanted to have their own invention be the essence of the company, the 1103, the industry standard if you will. But they made us a deal that we couldn't resist. I mean you could see the handwriting on the wall that we really needed to base our future programs on the 1103 because that's the one that we're going to have multiple sources.

I should talk a little bit about multiple sources. As part of their initial strategy at Intel, recognizing that to be a supplier of critical components and computers, they had to have multiple sources. And so in the very early stages of Intel they selected a company in Canada, Micro Electronics Ltd., MIL, which is a subsidiary of the telephone company in Canada. And they made a deal with them that they would be their multiple source, and they would not only supply, you know, the cookbooks on how to make the process and how to make the products even, but they would send a team of engineers to MIL and the engineering team would stay there and get the process up and running until it reached a certain yield level, and then Intel would get paid off. Actually, Intel got paid $1,000,000 on the front end of that thing as a startup bonus, and then having sent the team off there and run through the whole thing, and having completed successfully the program, Intel got paid another $1,500,000 so they got $2,500,000. It was quite a controversial thing within the ranks of Intel because of course the engineer is saying "Hey, you're giving away the family jewels," but Bob Noyce of Intel-

Hendrie: He understood the need to have a second source.

Jordan: Two and a half million dollars today seems like a pittance; but one, they needed a second source and a credible second source, and two and a half million dollars was a significant portion of the net worth of Intel. I think Intel was founded with $10,000,000 or something in those days. And so as true in the Intel tradition they completed the whole thing and picked up their $2,500,000 and they took the whole engineering team to Hawaii for a big vacation sort of thing to celebrate. Probably to help soothe a lot of hurt feelings because I think some of the engineers were kind of unhappy with the arrangement. But I digressed a bit.

The point was now having developed the 1103, Intel was able to spin that off to MIL and therefore have a second source for the 1103. Well, once they did that and once they had not only Honeywell but several other computer companies, eventually they got something like 19 out of the 20 computer companies committed to the 1103 as the main memory element in their computers. Intel was very good at promotion in addition to being pretty good at engineering. And so the other semiconductor manufacturers at that stage figured you know, we're going to get lost in the dust here, so they started attempting to reverse engineer the 1103, which was a very difficult project because the 1103- of course you had a circuit design and masks and everything was highly tuned to the process they had. Intel had it all tuned up right. I remember once they were interviewing an engineer from one of the competitors of Intel and had been through this problem of trying to reverse engineer the 1103. And he pointed it out. He said "It was like Intel shot the arrow at a target. It landed somewhere in the target, and then we had to go shoot the arrow and make it go in the same hole in the target. That's a harder thing to do." Anyway, a whole bunch of second sources emerged, you know, that had nothing to do with anybody's patents and had nothing to do with any contracts with Honeywell.

Hendrie: Any intellectual property transfer. Yes.

Jordan: Well, reverse engineering is legal I guess if you do it right, but it's not very easy to do on such a product as that. So it turned out MIL was kind of a paper- all of these second sources, and including the authorized one, were kind of paper tigers because once the Intel team had left, MIL had a tough time upgrading things and keeping things going.

Hendrie: I thought that that was viewed from the computer side, that that was one of the strategies of the semiconductor. Get a second source but make sure they are weak.

Jordan: I'm embarrassed to say that, but I think it is. It was something that we always chose our words carefully when we said that but it certainly was good to have a second source that you could brag about that people would believe but that really couldn't deliver. In fact I think that MIL dried up somewhere along the line. I think we had to develop another second source which I think was National [Semiconductor] in the 1103, if I recall. I kind of forgot. I think we authorized at least one other second source in the 1103. There may have been several others, but there were certainly a lot of guys trying to copy us. And so there was a period of time where Intel really enjoyed a very dominant market position on main memory, and that period of time was through at least the first half of the '70's to some extent. They enjoyed very good business fortunes in the second half of the '70's too but they were slipping in memory as this time went on. I'm getting ahead of the story a little bit here. Anyway, so we had a development program. We had at least a working prototype, and I was very emotionally involved in this sort of thing and running all around promoting it everywhere I could. What happened within the context of my employment at Honeywell anyway was as I mentioned I was reporting into this plated wire facility which really galled me. Around the same time- oh, one of the perhaps through my experience in the past of having given technical papers at the Solid State Circuits Conference and having a little bit later-

Hendrie: That's the one that was traditionally held in Philadelphia or outside Philly?

Jordan: Traditionally held in Philadelphia at the University of Pennsylvania. I had given papers there and in later years in my attempts to promote my approach to semiconductor main memory I was on panel discussions. But more importantly, I used to go there as sort of a religious – it's like going to Mecca, you know, go there and meet all the guys in the semiconductor industry and computer industry, and sit up in the bars at night and argue about different things.

Just as an aside, a thing about computer business that I remember once and I would estimate it was around 1969 or something, being with a bunch of engineers including Bob Noyce and it was before I worked at Intel. And we were arguing about semiconductor technology or something like that, and of course I was very zealous about the place to really apply semiconductor technology is in the main memory arena and that's where you have these large volumes of usage and very orderly displays are easy to debug the parts. There was a lot of good arguments as to why this would be a good place to make my- well, to my surprise Bob was kind of arguing with me, him taking the view that where he really saw semiconductor technology was going. And this was way back like I said ’68, ’69 something. Where he really saw it was going was putting computers on a chip which I thought was stupid. I bring this up because poor Bob died, and in recent years I’ve heard Gordon Moore and Andy Grove make comments about, you know, we had this microprocessor thing. We didn’t have a clue as to what it was all about and we stumbled into it and stuff like that. Well, I think that probably was true with Gordon and Andy because they were very focused on the process technology and the state of the art and stuff like that. And Gordon is a brilliant strategist, technological strategist. But Bob was the one guy in the company that he really did have an ambition to put computers on chips and make a business and set the world on fire doing that. And as I said, I was arguing vehemently against that thinking that was a stupid thing to do because I knew having read the business plans within our minicomputer business, that the market size was like 10,000 computers a year for the whole industry or something like that, or maybe 20,000. I knew 20,000 chips wasn’t going to pay the engineering expenses and the whole thing didn’t make sense to me. But I made the same mistake that people a generation earlier had done and the whole idea of computers. I remember the stories being that nobody thought you could make a business out of making computers. Everybody thought you build one for census and one for-

Hendrie: Yeah, you didn’t need more than-

Jordan: Who needs more than three computers? How can you make a business out of that? Well, in retrospect, Bob was right and I was wrong, but I was right and Bob was practical about in starting up a semiconductor company at that stage. The best application of this technology was in the memory arena and Intel certainly started focusing on the memory arena. Anyway, to get on with my career, I-

Hendrie: Can we do a pause?

Jordan: Sure.

Hendrie: To change tape?

Jordan: Good heavens.

[End of tape 2]

Hendrie: All right. Let's see. Where were we?

Jordan: Okay. Well, I was talking about-- it was-- actually, it was 1971.

Hendrie: Okay.

Jordan: And I had mentioned I had got in the habit of going to the Solid State Circuits Conference and I had a spiritual need to do that each year and I'm not sure what was going on at the business, at

Computer Operations Framingham, at the time but that particular year, Bill Regitz and I had planned to go to the Solid State Circuits Conference and we found out our request was rejected. We didn't have any papers or participation at that stage, we just wanted to go in attendance, and our request was rejected, which made me rather unhappy. So Bill and I told our boss that we would take a couple days vacation and pay for our own airplane tickets...

Hendrie: This is the request at Honeywell?

Jordan: At Honeywell.

Hendrie: Yeah. Was rejected. Okay.

Jordan: And Honeywell didn't want us to go. They were trying to save on their budgets and so we told them we'd take a day's vacation and buy our own airplane tickets and go and we did. But we were kind of stewing in our juices and Bill and I were flying down to Philadelphia and Bill informed that Intel had approached him and was trying to hire him. I was Bill's boss at the time and he says, "But, you know," they wanted to hire him as a circuit designer and, at the time, well, he said, "You know, I'd like to go. It's a good company but what I'd really like to do is build memory systems," he says, "But I don't know how to talk them into that." So I said, "Well, I know how to talk them into it. We'll send them a business plan." <laughter> Because, by this time, I was kind of fed up with the environment. In addition to the fact that I was organized in this funny place in the organization, the things I was pushing were kind of hard to sell within Honeywell. One of the reasons was the EDP division, the Honeywell group that was based in Waltham, they had their own approach and were trying to promote developing a custom family of circuits, including a 2K main memory and they had more muscle in getting attention because they had a bigger market than we did, I guess, and so I was struggling with that and I was struggling with some people trying to apply plated wire memory and it was a whole bunch of things. The environment was not particularly healthy for the kind of work I was trying to do.

Hendrie: Now, was this a 2K dynamic RAM memory that they were...?

Jordan: Yeah, they had their own-- that position and they had a chip design and they...

Hendrie: Where was that done? In...

Jordan: Well, I don't know as it was ever done. They were going-- I think what happened was they were going around to the industry and I think their approach was a little bit less collaborative with the industry. I think they were going around and saying, "We're Honeywell..."

Hendrie: "Do this for us."

Jordan: Yeah. "We're a big, big market, do this for us," and the computer manufacturers...

Hendrie: And we'll love you.

Jordan: ...looked at them and said, "Well, you know, I can't really do it. We're too busy." They kind of finessed their way out of it. I remember traveling around to all the semiconductor manufacturing, in an attempt to make Framingham and Waltham collaborate and I went around with the computer team and meeting all of the big shots, all the semiconductor companies to talk about, you know, what they're going to do in the future and stuff like that and I think it was part of a ploy to make Honeywell look that we were all part of the same team, sort of thing. But, anyway, I digress. So Bill and I conspired that, gee, maybe what we should do is try and talk Intel into getting into the memory system business. Intel, as far as we knew, had no memory systems capability. They did have this one laboratory, under Ted Hoff, which was, like, a couple of engineers and a couple of technicians and they built boards up, mostly as an applications tool to demonstrate to customers how to use the various circuits they had and stuff like that. And so, in that context, they had built a couple of dynamic memory boards but they really weren't in a position to embark upon a business doing this. And so I, with Bill Regitz, we decided we'd try and approach Intel on the idea of setting up a memory system business within the context of Intel. And so, for the first step, what we did is I sent a telegram to Bob Noyce at his house. I figured, Bob Noyce is a big, famous, busy guy, you know, you send something in the mail, the secretary's going to open it and it's going to go in the "in" basket and I'm going to get lost in the shuffle there. So I sent a telegram to his house saying, you know, Regitz and I have a proposal to make and I'll send you a business plan if you're interested. And, you know, you get a telegram at your house, it's a scary thing. It's just like somebody died or something.

Hendrie: Yeah, exactly. <laughter> Your mother is sick...

Jordan: So I figured I could get his attention this way. And so we did that.

Hendrie: And you did.

Jordan: And I immediately got a telephone call from Bob and my business plan was rather primitive but I put together, like, about five pages of handwritten business plan to the extent of, you know, scoping out market sizes and the essence of the business plan was that we would put together memory systems and, in addition to being an aid in applications for them, we could generate revenue from selling memory systems in the open market because I had experience doing that...

Hendrie: Yes, right.

Jordan: ...in the early days of Computer Control Company, although it was only a few million dollars a year. It didn't amount to much. But, more important than that, that we could pursue the business of IBM add-on memories. Now, if you think, in these-- 1971, IBM had 80% of the computer market in the United States, 70% of the computer market in the world and so, in terms of numbers of memory bits, they had an awful lot of memory bits. And that was not available to Intel as a memory combine market because IBM was building these things, like, soldering little chips on substrates and they weren't at all interested. But the climate was right because IBM was under pressure, under lawsuit, from the Justice Department for anti-trust and so IBM had to define all the interfaces to their sub-assemblies because they were locking people out of building memory boxes for IBM so this business was emerging at that time that people could build IBM add-on memories. So I think that's really what appealed to Bob Noyce, the idea of, gee, I'm trying to be this big shot in the memory business and 80% of the American market is not available to me. It's all IBM. So he liked that. He bought the deal and-- with one exception. <laughter> He said that the problem is, we're having a real tough time getting any yield out of the 1103 and so Regitz is going to have to come work in the components division and you, Bill, came out here and set up the memory systems division. Well, that was okay with me and Regitz reluctantly-- he argued a little bit but Noyce's argument was rather compelling saying, you know, if we don't get the bloody 1103 working, you won't have a memory system.

Hendrie: You won't have a memory system. <laughter> That's right.

Jordan: And now, and the second thing...

Hendrie: And maybe you can go move to that later if you really want.

Jordan: Well, yeah, I think that was sort of the big-- for Regitz. But the second part of the deal was that that I wanted to set up the memory systems business in Massachusetts and Noyce wouldn't have anything to do with that and for a historical reason. When he worked at Fairchild Corporation, although he was general manager of Fairchild, the corporate management was in Long Island. Fairchild Corporation was originally a Long Island corporation and he thought that arrangement was just terrible. For one thing, he had to fly back and forth a lot in days when it was hard to fly back and forth and I'm sure another thing, which I have felt in other companies that I've worked for in later years, that when the management is from a different culture than you are, and I use the word broadly, they don't understand what you're up against. They're not living in the world that you're in and it's awfully hard to deal with them and that kind of thing. So I think that was one of the reasons he left Fairchild. He didn't like the idea of the management being far away. So he said absolutely not and so I went through a series of arguments: I don't want to come to California and this, that and the other thing because I got a family with six kids and was really settled in Massachusetts and the whole idea of moving to California was agonizing to me and then I fell back on arguments like, you know, you have earthquakes out there and stuff like that. I was really flailing. And Bob, being a very logical, scientific guy, went on to quote the statistics of how many people died in snowstorms in Massachusetts and how many died in tornadoes and how many died in hurricanes...

Hendrie: He did? <laughter>

Jordan: ...and he had some wonderful arguments about, you know, nobody dies in earthquakes except a few, I guess, in 1906 or something. Well, as it turned out, I moved to California and I bought the house and the San Andreas fault trace ran right through my property on the house so I really bit the bullet when I came to California. <laughter>

Hendrie: You bought that lock, stock and barrel.

Jordan: The first house I had, yeah. So, anyway, eventually we convinced Bob that this was a good idea, to set up a memory system because it's not-- by the way, I really never knew but rumor was that he was talking with somebody else about setting up a memory systems business before-- I think I might have caught him just at the right time on that anyway but it worked out. We came out. Regitz went to work in components. Haven't seen him much since then, actually. <laughter> And...

Hendrie: He never came back.

Jordan: Well, he came back after I left the company briefly, I understand, but, anyway, so we came out and set up the memory...

Hendrie: And what year is this that you moved?

Jordan: ...or I came out. 1971.

Hendrie: 1971.

Jordan: And I came out and-- it was around April of 1971, I think it was. And was able to, well, the first thing was pulling the marketing guy to find what the heck we're doing. At the time I came to work at Intel, by the way, it was still a private company. It was all in one little building in Mountain View and the old Union Carbide building. They processed wafers in the back and I shared an office with a component quality control guys and it was kind of a primitive setup in the beginning but Intel grew like a weed and, within a matter of months, they had moved their headquarters down to Santa Clara, which I ended up inheriting a big-- they kept wafer processing, they had one in the back of our building but I ended up the whole front of the building was where memory systems was set up. And I was able to attract-- well, one of the areas that I needed a lot of help in was building IBM add-on memories so I was able to attract some guys from AMS that had embarked upon that business and a couple of guys from Cogar who had originally been out of IBM so they knew a little bit about that business and put together a team that could do that kind of work, engineering, and I brought some of the Honeywell guys out. Besides Regitz and Bodio, there were two other engineers, Russ Roberts and I forgot the other guy.

Hendrie: That's okay.

Jordan: And so I started to put together a team of guys and we developed systems. Bodio came out and was quite helpful in developing the system because he had a lot of background very directly applicable in that area. And we ended up getting a pretty good business going and there were two elements of it, the OEM business and the IBM add-on business. Now, the OEM business, we sold our products through the Intel sales organization, which was mostly sales reps and stuff like that. There were often cases where computer companies didn't quite have the resources to pull together a good memory design or, more importantly, there were cases where they'd start off on a memory design, got all screwed up in it and we went and bailed them out. And the biggest customer for us at that particular time in the OEM business was Univac. We got very involved with Univac and built memory boxes for years for them. The IBM add-on business was a whole different business. We had to organize that quite differently because the whole marketing problem was a very different one for us. The marketing, of course, for the OEM business and for the components business was we had salesmen and sales reps that would call on the purchasing agents of computer companies and ultimately talk with the engineering staffs within the computer companies. But, in the IBM add-on business, we had to call on banks and insurance companies and, not only that, we had to provide maintenance capabilities and, not only that, we had to provide lease financing and so it became a much more sophisticated business. So we put together a sales organization and a maintenance organization I might add, of salesmen that wore three-piece suits instead of sports jackets, it was that sort of thing. And so that was an interesting phase of our life but it all worked and we were able to put together a team of guys that really did a good job and, in fact, one of the key marketing guys we had was Dick Egan who eventually formed EMS, the...

Hendrie: EMC?

Jordan: EMC. I said it wrong. He's the ambassador at Ireland now. <laughter>

Hendrie: Is that right?

Jordan: Oh, you didn't know that? Yeah.

Hendrie: No, no, I did not know that.

Jordan: Yeah, he left EMC a long time ago, at a good time because their stock went in the tank, but he's become...

Hendrie: No, I didn't know he had worked...

Jordan: He became a very wealthy guy, of course, and went on to different things.

Hendrie: But he worked for Intel?

Jordan: He worked for me, yeah.

Hendrie: He worked for you?

Jordan: Yeah. He was my marketing guy.

Hendrie: Okay. Now, was he located out there? Yeah.

Jordan: Oh, back in Massachusetts. I hired him and brought him out here and he worked for us for several years and then he went back to Massachusetts.

Hendrie: And started EMC.

Jordan: So he had a big family and he was very Massachusetts oriented and came out here as an adventure more than anything else.

But the memory business was quite successful. I stayed there for seven years. I left in '78 and, by '78, the revenue in our division was something, I think our revenue in '77 was 47 million and we were making over 20% profit before tax and we were probably growing at 15% a year. The problem was, though, at that period of time, Intel was starting really make some inroads into this microprocessor business and they were growing not in percents per year but in multiples per year. Actually, the early days, one of the highest-- I think everybody knows it now but, in the earlier days, one of the highest profit items within Intel was the EPROMs. They were making a tremendous profit on those EPROMs and that was carrying the profits of the company. Intel was always a very profitable-- well, during that period anyway, it was always a very profitable company but the EPROMs was where they were really making their money.

But, anyway, like I said, in memory components and even memory systems, we had a very dominant position for the first half of the '70s and we had a very healthy position for the second half of the '70s and into the '80s, but several things happened. One is the focus of the company shifted to the microprocessor stuff, you know, the resources, the priorities were there. Not that they bled us in any way but that was a fact of life. And it turned out to be a proper strategy for them because, at the same time, the Asian manufacturers were starting to build memories and so the competition was starting to heat up in that business but, in addition to that, Mostek, which was a group of engineers that had left Texas Instruments, Mostek was [tape glitch] got to the market before Intel in the 4K chip and later in the 16K chip. Mostek got there a little bit earlier. Intel still made good money and had a good, growing business but, like I said, in '77, our systems revenue of 47 million, the whole corporate revenues, I think, were something like 240 million or something like that in that period of time so we're starting to slip as a percentage of the whole company and it was getting harder to get attention.

Hendrie: Yeah, of course you were going to.

Jordan: And that was the fact of life that was happening at that time. Oh, I digress a little bit, once again, I wanted to show you this thing here because, during these many years that we were building semiconductor memory systems at Intel, this paper weight, a party favor, if you will, [tape glitch] tend to be, like, a Lucite or something with a ceramic Intel package in it. Well, the story goes like this. One of the customers, which was a very large account, prominent customer for Intel, was Univac and, at Univac, we were supplying them memory systems in the form of big cabinets that they hooked multitudes of them together to make pretty [tape glitch] fast computers representing thousands of chips. And, as they put together these big computers, they were having trouble keeping them running. They were having failures in the memory area of an intermittent nature and, well, after some tracing around and diagnosing them, we discovered that we had a rather serious problem, that, within the packages, there were some loose binding wires or tails of binding wires floating around and this is particularly problematic for Univac because they had gone to the added expense of getting their chips mounted in ceramic or Sure-Dip packages thinking that they were much more reliable than the plastic packages. It turns out they weren't, in this case, because what happened was, in the manufacturing process, way overseas, in this assembly process, actually, you assemble them by putting the chips onto the substrate, which are open cavity ceramic packages, and then binding all the little wires up and, in part of that process, the ends of the wires get cut off some place or something and the wires aren't supposed to get in the cavities and they don't, during that part of the process, but they would load up these ceramic chips on Styrofoam trays to hold them and then they'd stack Styrofoam trays on top of each other and...

Hendrie: And did these have-- did not have the lids on yet?

Jordan: And the lids are still open because they wanted to go through an inspection before they sealed them up.

Hendrie: Yes.

Jordan: But Styrofoam has the property of being electrostatic in nature, it picks up little things, especially little metal things, and somehow or other the bottoms of the Styrofoam trays were picking up these little tiny whiskers that had been somehow or other got into the room. So you'd lay one tray on top of another and the top tray would drop little whiskers into the cavities of the chips. Well, it happened at a very, you know, it wasn't a wanton thing. It just happened at a very small percentage of them, maybe one percent of the chips had this problem, which-- a one percent problem is usually not bad because usually you can test it out but this loose chip rattling around in this open cavity, sometimes it would short out. You'd test the chip and throw it away and sometimes it wouldn't short out. You'd [tape glitch] test the chip and pass it and then you'd go, you know, put them on boards and you'd test the board and, every once in awhile, one would fail and you'd throw that one away and you'd finally get the board working and you'd put it in a rack then you'd put racks in the cabinets and then you'd put dozens of these-- or bunches of these cabinets together and, by the time Univac got their computers all put together, you know, every time somebody sneezed, something was failing on them. Well, this-- sounds like a very-- probably just stop doing it but the problem is you had millions and millions of dollars of inventory in Malaysia and in Intel Memory Systems Division and in Univac's various stages of their manufacturing and trying to-- and, of course, shutting it all down wasn't an option because it would have put them out of business for six months and put us out of business for six months. So we figured out what had happened and we're running-- explained to all of Univac. They were just livid and furious but very quickly realized they had to work with us, otherwise, they were going to go down the tubes. So we got a collaborative program to try and sort this thing all out and we ended up solving the problem by re-screening all of the unit level inventory by having an acoustical device and vibrating the units and, with this acoustical device, you could hear the little pieces rattling around inside.

Hendrie: You could literally hear them? <laughter>

Jordan: Yes. Well, I think...

Hendrie: They put microphones, yeah.

Jordan: We had some kind of an electronic way of putting this together, I guess. And then, at the board level, we re-screened all of the boards and we put together a system which had a pneumatic vibrator that just vibrated the heck out of the boards when you tested them, rattling all the wires around so that, eventually, it'd short out. And we re-screened all of our boards and all of their boards and got everything put back together again. It was an agonizing process but we saved the day, eventually, after a lot of high blood pressure and then, at the end, we held a big party for the Intel engineers, anyway. We had dinner and wine and a good time and, as a party favor, handed out these party favors mocking the loose wires in the cavity problem. Of course, the size of the wires here are about 100 times bigger than real wires but... <laughter>

Hendrie: That's-- oh, wow, that's quite a story.

Jordan: There were several incidences like that in my experience. There was one incidence where-- actually, this wasn't Intel, this was Mostek, when Mostek was trying to work with Honeywell at Honeywell where they had put together their packages and the ceramic material they had was translucent, light could get through it. Well, the concept of semiconductor dynamic memory is that you have a very small charge on a very small capacitor in a very small chip and radiation sources could discharge that capacitor. So, light, for example, I mean, they could use these things as light sensing devices. Any light gets in the package, all of a sudden you lose your stored information. So I remember Mostek showing up at Honeywell once with a chip that they were so proud about and they wanted to sell us and stuff like that and somebody shined a light on it to look at the numbers on it and, all of a sudden-- we had a system where you could display a map of all of the storage within the chip and he shined the light on and, all of a sudden, you'd see all the ones drop out, you know? <laughter> And the fellow, L.J. Sevin, I think was the head of Mostek, and he was there at the time delivering this wonderful chip that was going to set the world on fire. We shined a light on it and all the data dropped down out of it. The poor guy, I mean, he immediately knew what the problem was and it was kind of a minor problem for them because all they had to do was change the pack-- or paint...

Hendrie: Change the...

Jordan: ...them or something, I don't know.

Hendrie: Paint them or, yeah, at least...

Jordan: And there was another similar problem. We had ceramic packages and we were getting the package materials from some source in Japan-- oh, and I guess you put the lids of the package on by some kind of a glass seal and the glass had radioactivity in it. <laughter> I think a lot of glass and ceramic problems have possible of having trace radioactivity in them but the trace radioactivity in the packages would start to interrupt stored data.

Hendrie: Oh, my goodness.

Jordan: There were cases where they had problems like and they finally figured it out and traced it back and corrected it but this was one that was a very dramatic one.

Hendrie: That's a perfect example of the thing they teach in quality programs now. <laughter> That you cannot test quality into something because that's, you know, it didn't work. You had to understand it and fix it.

Jordan: Yeah, it was very easy to correct the problem back at the source. The real issue was how do you save all the inventory up...

Hendrie: Exactly. Oh, that's a great story.

Jordan: Well, let's see. So...

Hendrie: So, yeah, you were in the memory systems business and so sort of what happened? It was becoming a smaller and smaller portion.

Jordan: Well, it was becoming a smaller and smaller part of Intel. It was a wonderful experience during the period of time I was there and it was still a very healthy business, by most standards, but Intel was a skyrocket. I mean, it was going to the moon at that stage and, for me, what happened was actually they-- as part of the normal evolution of a company, they decided to make some organization changes and I ended up reporting to a guy that I didn't particularly want to report to. Up until that time, I had always reported to the president of the company and...

Hendrie: Who was Noyce or Moore or...?

Jordan: Well, originally, it was-- well, Noyce and Moore are very interesting guys. They're real researchy kind of guys and, in the very early days of Intel, their management style was like you would see in a research laboratory. In fact, I remember, when I first went to work there, you know, I was in Noyce's office and I asked him, "What's your organization here?" He says, "Here's the organization." He went to the blackboard. "Here's the organization." And he drew a circle, "That's you," and then he drew all these radial lines out, "That's all the other guys. That's the organization." And, just at that time, I had read the book, "Up The Organization". I don't know-- did you ever read that book?

Hendrie: No. I don't think so.

Jordan: It's by Townsend or something like that and it was a book, somehow or other, promoting the idea of

[end of tape 3]

Hendrie: One of the things I was curious about was the process when you went around to try to get somebody to build what became the 1102. Didn't you go to quite a few manufacturers, if my memory serves me correctly...

Jordan: I did, yes.

Hendrie: ...trying to get them interested? And maybe you could tell me a little bit about some of the people you went to and what the various reactions were. Probably a wide range, I suspect.

Jordan: Well, first of all, being part of Honeywell, and I suspect, to the semiconductor manufacturers, it was pretty hard for them to discern, you know, what the different parts of Honeywell, how they related to each other. I guess it was pretty hard for us in Honeywell to discern that, too, so a lot of it, you know, from their point of view, the guy back at the factory would always think in terms of, "Boy, I wish I could get the Honeywell account because, you know, they use a lot of memories," if you add up all the different places in Honeywell. The local salesman, he was most interested in the ones that were in his region and so there was a lot-- there was probably a lot of confusion kind of stirred up as to how much purchasing power we really-- or how much market we really represented to these guys. But I think they attempt-- because we had a pretty good knowledge of semiconductor technology, I think they probably felt that we had more chance of our program succeeding than some of the other people came in, their rather naïve approaches to it. And so, in answer to your question, first of all, we were able to get pretty good attention because we could talk the game right and, not only that, we had guys on our staff that knew semiconductor manufacturing because we had a pilot line...

Hendrie: Yeah.

END OF INTERVIEW

