An Interview with

JACK S. KILBY

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Conducted by Arthur L. Norberg

on

21 June 1984

Dallas, TX

Charles Babbage Institute
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Abstract

The interview covers Kilby's entire career, including his education, work experiences at Centralab and Texas Instruments (TI), and his independent work after leaving TI in 1970. Kilby graduated from the University of Illinois in 1948. He then worked at Centralab under Alfred Khouri and Bob Wolff, initially on resistor-capacitor couplings for television sets. In 1952 Kilby attended the Bell conference on transistors, which led him to work on transistor technology at Centralab until he joined TI in 1958. At TI he worked under Willis Adcock on development of germanium and silicon transistors. Kilby discusses the organizational structure of TI in the late 1950s and details its development and manufacturing of integrated circuits. He discusses his involvement in the development of the first hand-held calculator at TI. He also mentions semiconductor developments at Fairchild Corporation and his own career after leaving TI.

JACK S. KILBY INTERVIEW

DATE: June 21, 1984 INTERVIEWER: Arthur L. Norberg

LOCATION: Dallas, TX

NORBERG: Today is June 21, 1984. We're in the offices of Mr. Jack S. Kilby in Dallas, Texas, for an interview about his years with Central Lab, Incorporated and the Texas Instruments Company. I'd like to begin by obtaining a little bit of background information about yourself. I know that you were born in Jefferson City, Missouri, in November of 1923, but I noticed that you went to the University of Illinois, where your parents had gone. I'm curious to know whether you remained in Jefferson City throughout your younger years, and therefore what education was like there, and how you came to end up in Illinois.

KILBY: Well, when I was, oh, I think four my parents moved from Jefferson City to Salina, Kansas. My dad was with a utility company and took a new job in Kansas at that time. So I don't really consider myself a Missourian. I was born there, but left before it made much of an impression.

NORBERG: Then you went to school in Salina, Kansas?

KILBY: When I was about--when I was in the sixth grade his company moved its offices to Great Bend, which is a town about ninety miles from Salina and I went to high school there.

NORBERG: What do you remember about that high school in terms of the kind of courses that you took at the time?

KILBY: I think there were something like 750 students in the school when I was there, something over a hundred, maybe a 150 in my graduating class. They had a fairly basic set of courses, I guess. Language was... The school was divided into college preparatory and I guess the term was commercial curriculum and if you took the college preparatory you ended up with two years of the only language they offered, which was Latin. Just a little short in math, which caused me some trouble.

NORBERG: How about sciences?

KILBY: Oh, we had biology, physics, and chemistry, a year each.

NORBERG: I understand that early you became interested in becoming an engineer.

KILBY: Yes.

NORBERG: Was this fostered by your parents?

KILBY: I certainly wasn't pushed in any direction to do that, but Dad was an engineer. Basically, he ran a power company that was scattered across the western third of the state. During the summers and at some other times I used to travel around over the property and see some of that and what they did and that interested me. It was an indirect decision I guess.

NORBERG: Do you recall how early that was that you were traveling around to the various parts of the company?

KILBY: Oh I'm sure that it must have happened some and almost constantly after I was 12 or somewhere in that--14 somewhere, well, before 14.

NORBERG: When you approached something like 16, did you ever have any summer jobs, say with the company?

KILBY: Not with his company. One summer I worked with a neighboring power company doing basically manual labor in a power plant. If I had really thought that was typical I guess would have done more to discourage me than anything else. Cleaning out these big oil tanks in the middle of the summer. Well, all of the things seemed to involve

heat. The tanks that they used had tar or one thing in the bottom that had to be mucked out. From time to time they would shut down some of the steam generators, you'd crawl into the boilers and clean out the tubes, which were up in the top, a hundred degrees outside and this was inside a power plant with boilers on both sides of the ones you were working. I have no idea how hot it was.

NORBERG: Did you particularly take any of the science courses in high school with the intention of studying a particular kind of engineering?

KILBY: No, it was more simple than that. I took all that they had, which were the three that I mentioned. There were no others offered. I don't really remember, but I think at the time that if you were taking a college preparatory course you had to take all three of those whether you wanted engineering or not. There were not a lot of options.

NORBERG: Do any of the teachers in high school stand out as being particularly influential?

KILBY: Oh I think by far the best teacher I had was one who was involved in American History. She was quite good. An interesting figure in a lot of respects. One of the few people in town that had been out of the country. She had traveled through Europe, and one thing and another. Put a good deal of stress on why things had happened, not the dates, but what actually happened.

In the science area none of the teachers were in the outstanding category and I think the same thing was true of math.

NORBERG: When it came time to begin thinking about university work did you seek any advice from any of these people? Did you get any advice from your father, say?

KILBY: I don't know how I made the decision, but somewhere along the way I decided that I wanted to go to MIT

and didn't really think about another school throughout the high school period. I don't know how early that decision was made.

NORBERG: Did you apply subsequently to MIT?

KILBY: I did.

NORBERG: And to which other schools?

KILBY: Only to MIT. Yes, well I think maybe school applications were not quite as well organized as they are today, but no, I applied to MIT. They required college board tests for admissions and I had some trouble in math. They had a remedial course, which was offered over the summer, and I went to take that and took the boards again. As I recall, their minimum acceptable level for admission was 500 and I ended up with 497 so I did not go to MIT.

NORBERG: Depressing. So then did you just simply show up at the University of Illinois or was there some sort of process for applying there?

KILBY: Well, since I had stuck with MIT through the summer it was about the end of August, I guess, before I knew definitely that I was not going to go there. And we had something like a week, and Illinois seemed like a reasonable choice. Dad still knew some of the faculty there. It was a much better school than anything that Kansas had to offer at that time and it seemed like a reasonable second choice. So no, I did not apply there, we simply went over and walked through the process and I was enrolled.

NORBERG: And enrolled directly in electrical engineering from the beginning?

KILBY: Yes.

NORBERG: Can you tell me something about the program at Illinois during those years? I'd be interested in who the faculty were, what sort of textbooks, and so on.

KILBY: Well, I had two years at Illinois before World War II and then two years after I was discharged from the Army. The first two years really were not much involved with the electrical engineering department. EE courses began at the junior level, so I saw very little of the EE department before I came back from the service. When I came back and began to take EE courses in '46, the department was somewhat in a state of transition. The older and established faculty --I know now I suppose the ones with tenure stature -- all had very strong power background and there were some outstanding teachers in that group. The electronics courses were relatively few and tended to be taught by guys who had just got out of the service and perhaps had served as a radar officer during the war or something of that sort. I think they knew their subject very well, but they didn't have the same teaching skills by quite a long shot. So the courses that I took were a mixture of power and electronics, in part because there weren't enough electronics courses so that you could have taken all electronics anyway.

NORBERG: Had you had any experience with electronics during your wartime service?

KILBY: Yes, and before that. I had become interested in amateur radio and was an amateur radio operator for the last couple years in high school. Then during the service, I went into the Signal Corps, went through their radio operator's training school and then went into the OSS, which was the predecessor of the CIA. I went to India, and in India the group had agents, basically private armies scattered around through Burma and they had to maintain communications with them. So I was involved as a communications technician through much of that career.

NORBERG: Stationed where?

KILBY: Mostly in India, right on the Burmese border. I spent a little bit of time in Burma in a place called Myitkina and then when the Burmese campaign ended up, we went to China and I spent the last six months of the war in China

doing the same kind of thing.

NORBERG: Who were some of the faculty who were involved in electronics after the war?

KILBY: Buck Knight, Gil Fett, Stan Helms, Archer and Keener were kind of the power group that I had mentioned. That was sort of in between power and electronics. The electronics types were Bill Albright, Mel Carouthers, Paul Hudson. I'm sure there were some others but that's a sample.

NORBERG: Did you become close to any of these men in any way, either as a research assistant, a laboratory assistant?

KILBY: No, not really.

NORBERG: Did you have any undergraduate jobs at all, especially after the war, in the department?

KILBY: No.

NORBERG: Did you have any outside employment at that time?

KILBY: No. No, this was the period of the GI bill, which didn't really cover things but came close enough.

NORBERG: One other question in this period occurs to me and that is if there was an interest in high school in amateur radio, did that interest continue, say in the first two years at least and then did it continue after the war?

KILBY: The interest continued but it wasn't very easy to do much about it. The equipment wasn't very portable, living in a fraternity house didn't provide much of a place to set it up and so I really didn't do much with it after that.

NORBERG: Did you participate in any extra-curricular activities, besides the fraternity?

KILBY: Yes, there was an amateur radio group that I was a member of, somewhat active. I was photographer for the Illio?, which was a year book, and did things of that sort.

NORBERG: When you were beginning to think about employment in 1947, did you have any particular objectives in mind that you remember?

KILBY: I knew that I wanted an electronic company and in those days most of them did not interview on campus and so I sat down and wrote, I guess, thirty letters to companies that I was familiar with.

NORBERG: Do you remember any of those companies?

KILBY: Collins, Centralab, Hallicrafters, which was in Chicago, Amphenol, maybe RCA, I'm not sure.

NORBERG: That's an interesting list of companies. How did you know about them and the sorts of work they were doing?

KILBY: Well, this amateur radio and Army experience had given me some--I had at least seen the name plates on equipment. I knew the kinds of things that they made.

NORBERG: Had there been any tours during junior and senior years of companies that might be reasonably close to Champaign-Urbana?

KILBY: I don't remember any tours at all during that period. I'm sure they had them before and I know they have

now, but I really don't remember any and I don't think we made any.

NORBERG: Out of the letters that you wrote, how many--maybe that's not the right question, what interviews were you called to participate in?

KILBY: I guess I didn't have a very good batting average. I think there may have been three interviews out of that. One with Collins, one with Centralab, and I had taken a couple of interviews on campus with GE and with some part of the Bell system. I really don't know which one.

NORBERG: But you said they came to the campus in that case?

KILBY: Yes.

NORBERG: Can you contrast the types of jobs that these companies might have offered you, and therefore why did you choose Centralab?

KILBY: GE, at that time, had a training program which was universal. What you did was start out on that without any particular definition of what kind of thing you might be doing or where you'd end up. I think there was some mechanism for incorporating your feelings in that, but it wasn't obvious at the time. I think the Bell system deal was with the Illinois Bell operating company. I suppose that that would have been in their transmission and engineering works.

NORBERG: Seems reasonable.

KILBY: And neither of those had too much interest for me. Collins was a very impressive company at that time and I did go to Cedar Rapids and talk to them. They were interested, but eventually decided not to make an offer, so that

one didn't do too much. The Centralab was involved in making silk screen circuits and wanted me to work in that area and that was by far the most interesting of the group.

NORBERG: Before getting into that I'd like to ask you about Khouri. First of all, I'm not sure what his first name is. A. S. Khouri?

KILBY: Alfred.

NORBERG: I don't know much about him, can you tell me anything about him?

KILBY: Well, during World War II, as they began to think about the invasion of Japan, they knew that they would need a lot of anti-aircraft ammunition and the proximity fuse had been considered. They decided that they would like to move that into production for that period. And the electronics industry at the time was considered to be completely loaded and so people at the National Bureau of Standards, Jacob Rabinow in particular and others, apparently called in some companies and asked them to think about how they might solve this problem: how can we build proximity fuses without using conventional electronic components. And the group at Centralab was called in there and had some ideas on how to approach this --perhaps the only ones they got for all I know. So that a program was started. Al Khouri was working at the University of Florida at that time, I think maybe on Bureau of Standards programs and money, and became involved with the effort and was hired by Centralab somewhere along the way, probably in 1945, and became really the program manager of that effort within Centralab.

NORBERG: Now getting back to Centralab itself. What was it like when you arrived? I'm interested in size, type of projects, number of people and so on.

KILBY: Well Centralab was part of a larger group called Globe-Union. At the time I began to work there, their principle business was making storage batteries to be sold under private labels, particularly for Sears, but also for

some of the oil companies. Because of the Sears connection the guy who ran the company, C. O. Wanvig, had been in Chicago and found that -- somewhere in the twenties -- Sears wanted to buy radios. He didn't know anything about making radios, but he came back with an order for 10,000 radios. And they set up to make these, including most of the parts for them.

NORBERG: This is in '47?

KILBY: No, this would have been in the late twenties. I don't know just when. By the time I started their interest in radios was over, but they were still making a variety of electronic components. A lot of rotary switches, such as those that you use to select channels on your t.v. set, volume controls for variable resistors, ceramic capacitors. They had made fixed resistors, carbon resistors and just gone out of that business. They were beginning to use this new silk screen technology to make multiple resistor and capacitor components and also for some things such as hearing aids, where the components were formed by silk screening and then vacuum tubes were attached.

NORBERG: You were talking about the silk screening process and the hearing aids.

KILBY: And I began to work as an engineer in that group, reporting to Khouri. You were asking about the size of the company. I don't know how big it was in 1948 when I went to work there. In 1958 when I left, the total company, storage batteries, components and all, was about 65 million dollars per year in billings.

NORBERG: Now is this just Centralab or is this Globe-Union?

KILBY: No, that's Globe-Union. Centralab was somewhere between 15 and 20 million of that, perhaps closer to 15. Today certainly, the Centralab part would be considered a very small company.

NORBERG: Do you have any guess as to how many people worked for Centralab?

KILBY: No. Well, I'll try, but Centralab was really pretty well integrated with Globe-Union. That is, we shared the same physical space. At total, I think, Globe-Union probably had 2500 people, maybe two thirds of whom were in Milwaukee and the others were scattered around in battery assembly plants around the country.

NORBERG: The next obvious question, of course, is how many of these 2500 were professional engineers, scientist types of one kind or another?

KILBY: Well, that's a number that I can just about give you, because the battery people really didn't have much in the way of professionals, perhaps 3 or 4 engineers were on that side of the business. Centralab probably had 25, couple those.

NORBERG: What sorts of projects were these 25 working on?

KILBY: They were split into groups, 2 or 3 of them worked on switches, 2 or 3 of them on volume controls. Actually, I suppose that number would have been closer to 40 or 50, because there was a sizable group working on ceramic capacitors, ceramic substrates, 15 or 20. And there were three or four of us working on the silk screen technology and another three or four working on resistor compositions for the silk screen technology.

NORBERG: Now here's a case where you had just come out of undergraduate school, in spite of the war-time experience. How did you fit into this group, in terms of being able to contribute to the sorts of things that were being looked at in the silk screening process?

KILBY: Well, in retrospect it wasn't a very painful process. I think that Khouri and his boss, Bob Wolff, were both pretty good supervisors and understood how to break tasks down into things that you could do and I didn't have any particular difficulty in making that adjustment.

NORBERG: Can you walk me through one of these projects then in the silk screening area? I'm not familiar with the techniques used in the late 1940s.

KILBY: O.K., well, the biggest chunk of that business was in making resistor- capacitor combinations for television sets. Of course, that was the period when television was really beginning to take off...

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KILBY: Typically, we would get a t.v. chassis from a manufacturer and we'd go through it and try to identify groups of components that could be integrated and then designed a component that would replace this chester, make some of them, put them in, see if the set worked, and see whether it worked as well as it did before at any rate. Then we would develop the costs and talk to the set manufacturer. The only real incentive for anybody to buy these things was if they were cheaper. The t.v. people measured their costs in term of dollars per thousand components and if you were off--well, if the part that you had designed cost 50 cents a thousand more than the parts it replaced, you knew that it was dead, that there was no possible there. If it saved 50 cents or a dollar a thousand, you had a very good chance.

NORBERG: What does saving 50 cents on a thousand mean in this case? Is it 50 cents out of a 5 dollar set of components or 50 cents out of 50 dollars?

KILBY: Oh no. No, well typically these components might sell for 10 to 15 cents and so this 50 cent-a-thousand saving would represent a half unit saving of the cost.

NORBERG: Who were some of the coworkers in Centralab with you with whom you would have worked on these projects besides Khouri and maybe Wolff?

KILBY: Well, there were a number of these. One of the other engineers working on silk screen circuitry was Bill Fischer and his responsibility was primarily to work with the production operation. I worked very closely with some of the ceramic engineers in developing the substrates. That group was headed by Roland R. Roup. The people in that group that I worked most closely with were Roland, McClelland, Tom Lunak, Carl Rapp, Frank Reichell.

NORBERG: Were these people all engineers?

KILBY: Yes. That group was.

NORBERG: Had they come out of places like Wisconsin?

KILBY: Well, there are not very many places to get ceramic engineers. Several of them were from Illinois, a couple from Alfred, which is part of the State University of New York.

[INTERRUPTION]

NORBERG: You mentioned they'd come from places like Alfred.

KILBY: Yes and the University of Illinois supplied the largest single number of them. And most of the other engineers tended to be from Wisconsin, Marquette. Bob Wolff was from the University of Chicago. I don't know whether they had an engineering program in the '30s. I think maybe he had been a physics major and made the transition.

NORBERG: Did you get a chance to observe the relationship between Khouri and Wolff very closely?

KILBY: Yes. Basically we were all in one large office and we could pretty well see what was going on.

NORBERG: Now as I remember Wolff was the director of Centralab?

KILBY: Wolff -- the title may have changed but -- was the chief engineer of Centralab.

NORBERG: I see. Now that's a little different than suggesting that he was the director of Centralab.

KILBY: Yes. Well, there really wasn't a director of Centralab. As I've said, it was pretty well integrated with Globe-Union itself. Wolff reported to J. Fletcher Harper, who was the vice president in charge of engineering for Globe-Union. Bill Parsons, who headed the Centralab marketing effort, may have had the title of president of Centralab, but that was more a convenience than a descriptor of his function.

NORBERG: Do you remember whether or not the NBS connection continued after the war?

KILBY: Yes, it did. During much of the period when I was there, Centralab had a continuing contract with the Bureau of Standards. It was a task-type contract, that is, a blanket contract that covered a variety of efforts and they would be asked to work on specific projects. And I spent some time on those.

NORBERG: Do you remember any of those projects?

KILBY: Yes, one was an attempt to build a particular type of--well really to integrate the antenna with the other circuit components. We looked at some techniques for doing that. There was also an interest in further integrating the transmitter and I spent a lot of time trying to improve the performance of spiral inductors, which would be required for those transmitters.

NORBERG: Can you detail some of the specific steps in the project?

KILBY: Of that one?

NORBERG: Yes. First of all identify the problem for me and then some of the steps of the solution.

KILBY: Well, in the case of inductors, what we wanted to be able to do was to screen a spiral of silver material on a ceramic substrate and to make a coil with it. One of the problems of this was that these coils were very lossy. And I think they're lossy for two reasons. One was that silver paint wasn't a particularly good conductor, because it had quite a lot of glass foil? mixed in with it. And the second problem is I think that basically the spiral configuration is a very poor one, because it exposes so much of the conductor to the field. So what we tried to do was to make some improvements on this by changing the substrates on which we were screening it, looking for lower loss ceramics to put it on. We tried to improve the silver conductivity by changing the silver compositions by plating them with additional silver or with gold or things of that sort. Tried to change some of the coil dimensions to see how that impacted on it, things of that sort.

NORBERG: So that this was to reduce the size of the coils in general, I would assume.

KILBY: Well, I think the original fuses had been made using conventional turns of wire, which had to be assembled to the structure. The hope was that if you could just screen those on the substrate then you wouldn't have to attach those separately and that they would probably be more accurate and not change.

NORBERG: During this period you also obtained a master's degree. Was this at the University of Wisconsin - Milwaukee?

KILBY: Well it's kind of a mail order master's degree. At that time the University of Wisconsin in Madison was

offering courses in Milwaukee on an extension basis. In the case of graduate courses they did not have, I guess, a dispensation from the legislature to offer graduate courses in Milwaukee. And they preserved the fiction that we were residents in Madison by having us go to Madison to register and to graduate. But they sent the instructors over twice a week and taught the courses in Milwaukee. So my degree is really from Madison. I'm not sure that even Wisconsin understands that, but the Milwaukee Alumni Association keeps sending me material and I'm sure they'd be glad to have a contribution regardless.

NORBERG: Did you notice any difference in the courses between those you had taken in the last couple of years in Illinois? Had they improved any in terms of content, quality?

KILBY: No, I don't think so. These were clearly advanced level courses and the instructors we had were good. T.J. Higgins was the best of these. I had a couple of courses from him, a couple of math courses.

NORBERG: Can you be more specific about the courses themselves, which ones?

KILBY: Not really. Higgins's specialty was servomechanisms and one of the courses was titled that.

NORBERG: Did this have any relationship to your job?

KILBY: Not very much.

NORBERG: Did the company pay for it?

KILBY: I kind of think so, but I'm not sure.

NORBERG: In 1952 the famous Bell Labs conference occurred and you and, I think it was Wolff attended the

conference. What brought this about? [Long pause]

NORBERG: All right. I had just asked you what occasioned the attendance at the Bell conference in 1952.

KILBY: Well, the public announcement of the transistor was made in 1948, I guess, and in 1952, Bell suggested that they thought that their interests would best be served by licensing this very broadly and getting a number of other companies involved. I guess a few people had already begun to work on transistors, certainly GE and RCA had, but this represented an opportunity for companies which had not been in or near that business to become involved. And the price was right. Bell asked 25,000 dollars for a license, which was a nominal sum even in that time. And Centralab decided that they would like to do this and that they were interested.

NORBERG: Do you recall who made such a decision?

KILBY: Well, there would have been a number of people involved. Bill Parsons, who headed the Centralab marketing effort, Bob Wolff, Fletch Harper, and the ultimate go-or-don't-go decision would have been made by C. O. Wanvig, who was the president of Globe-Union and the chairman of Globe-Union at that time.

NORBERG: Were you involved in any discussions about whether this was a good move or a bad move?

KILBY: No. No, I think the first that I knew of it was when I was told that the meeting was going to be held on thus and so date and could I go for two weeks or something or would I go for two weeks.

NORBERG: And it was just you and Wolff who went?

KILBY: Yes.

NORBERG: Not Khouri?

KILBY: No. No, I'm not quite sure why. In principle each licensee was entitled to send four people and I think almost everybody else did. Centralab did not.

NORBERG: Do you recall how many companies were represented at this conference?

KILBY: 24, 26. Almost all of them were U.S., but I think there were four from outside the country. Philips was certainly one.

NORBERG: I'm not so concerned about that, because we can look that up. What I was more concerned about is how you would find yourself among this group. And if there were roughly a hundred people from these 20, say 25 companies, then this, in the course of a couple of weeks, would have given you adequate possibility to get around and talk to a number of these people.

KILBY: Yes.

NORBERG: Was there any trading of additional information from the company representatives themselves, or was it all one way from Bell to the potential licensees?

KILBY: This was basically one way. The people from the companies who had been working in the area and knew something about it were very careful not to transmit anything, I think, to Bell, and certainly not to the rest of the attendees. So it was a kind of a careful meeting.

NORBERG: Can you describe the meeting?

KILBY: Well, physically we stayed at the Statler Hotel in midtown New York and were loaded on buses every morning and taken to Murray Hill. We'd get there at what seemed like an early hour. Bell would start presenting papers. They certainly did this every morning for the first two thirds of the meeting and I think much of the afternoon. Although some parts of the afternoon time were spent on tours through the Murray Hill lab. The last couple of days we moved over to Allentown and went through the beginnings of their manufacturing activities there. But it was a very intensive kind of thing. The papers that were published were in 3 volumes and trying to absorb that in a two week period on a subject I'm completely unfamiliar with was a tremendous project.

NORBERG: Now these volumes didn't appear until 1958 so that would be...

KILBY: Well, that's a commercial version.

NORBERG: The volume is edited by F.J. Bieandee from the Bell Telephone Laboratory staff, published by van Nostrand, 3 volumes entitled *Transistor Technology*.

KILBY: Strictly speaking, this is the one that was sent out at about the time of the meeting and then it was published, in the form in which you see it there, later. This would be the title page of the original set.

NORBERG: Restricted. Restricted by whom, Bell?

KILBY: By Bell.

NORBERG: Let me find the date on this. Yes, 1952.

KILBY: 1952, but you'll notice this has the Globe-Union name printed on it.

NORBERG: Solely for that company's own use.

KILBY: Yes.

NORBERG: I see. So that was very quickly published, if that's the case?

KILBY: Yes.

NORBERG: September '52, about six months, I guess, after the conference.

KILBY: Right.

NORBERG: As you were listening to these presentations by the Bell people, how did you see this as transferable to Centralab?

KILBY: Well, transistors at that time were still on a very elementary form but it seemed very likely that they would impact Centralab's business and that they would be a type of component which Centralab could make. And it was also felt that probably transistors could be combined or integrated with the silk screen circuitry that we were making to provide complete circuit functions -- certainly hearing aids which was a significant part of Centralab's business.

NORBERG: When you returned to the plant or the laboratory, I know that you were part of a team that built a reduction furnace, a crystal puller, a zone refiner and all the rest for a production of geranium transistors. Was that part of the presentations given by the Bell people? Did they talk about such manufacturing processes and were those just wholesalely transferred back to Centralab?

KILBY: Well, with some exceptions. What Bell was talking about at that time, some of the meeting was spent on

point-contact transistors, which were not of much good to anybody. Some of it was spent on grown-junction transistors, and we had an opportunity to see the kinds of equipment that were used to produce these. They didn't transmit any drawings or any technical packets of that sort, other than the material that's included in these books, which were really written more as scientific papers I think than how to do it. So when we got back I began to design and have built one of each of these pertinent types of equipment, that is reduction furnace, zone refiner, crystal puller, things of that sort. By the time that was complete it was pretty clear that grown-junction transistors were probably not the best for our purpose and so we used that equipment with some other steps to make alloy-junction transistor.

NORBERG: Now I'm a little puzzled as to the time process here. When you say by the time you were going to do any manufacturing yourselves that it was not obvious that the grown-junctions would be very useful for your purposes. How much time elapsed between returning from the Bell conference and beginning to do any alloy work?

KILBY: Well, I don't have a good... I have a feeling that nothing much happened for a month or two after we came back and that then this project was established perhaps in the fall of '52. I think that it took us at least a year, perhaps a year and a half, to get this equipment set up. And we did make some grown-junction transistors, but there were really only, at that time, 2, later 3 of us working on it, so it didn't go very fast.

NORBERG: Had Bell been manufacturing a substantial amount of transistors at the time that you were at the conference?

KILBY: No, not really.

NORBERG: Did they ever?

KILBY: They'd begun to... Part of Bell's problem was that while they knew that they needed these things in principle,

they really didn't need a whole lot of them. The telephone, physical plant at that time was all electrical/mechanical, a few amplifiers here and there, but it was a long time before they could build transistor amplifiers that worked as well as their vacuum tubes. So they really didn't have much in the way of applications for this sort of thing. They were proceeding pretty much on faith I think through all that period.

NORBERG: Let's go back to September of 1952. Can you think a little bit more about the actual steps that you people decided to follow once the project had been authorized in Centralab? Why, for example, did you try to build a reduction furnace or what was the purpose of a crystal puller and how did it relate particularly to earlier types of equipment available for other purposes?

KILBY: Well, most of the equipment that we saw at Bell was quite specialized. They had gone through a couple of generations of this sort of thing. In the case of the reduction furnace, this was really a kind of a simple proposition. We just ordered an existing furnace that was mounted on a stand that was inclined so that the hydrogen wouldn't all run out. But the other stuff was quite different. Zone refining was a new process which had been invented by a guy named Bill Pfann, at Bell, to purify particularly by germanium. This was simply a long, straight quartz tube with a series of induction heater work coils, about a dozen of them, scattered along the length of it. And the germanium was put into a boat and very slowly pulled through this. As the bar went through each of these work coils or hot zones, it melted. The very fortunate thing was that the impurities in germanium at that time were such that they tended to segregate on freezing and so the alternate heating and cooling, I mean melting and freezing, tended to move all of the impurities to one end or the other end of the bar and then you could just cut those off and have a very pure section left. Physically the equipment was rather simple and not difficult to build, but there were no commercial counterparts and if you wanted one you had to build it.

NORBERG: Was this a fairly standard technique then in the industry, say in '55?

KILBY: Well, I don't know exactly when it was invented, probably around '50 or '51. Bell was beginning to use it on

their things, but I don't know that anybody else in the country was using it at the time. Of this '52 seminar I'm sure that everybody got ready to use it immediately after that, because it worked so well and was so relatively simple that there was no reason not to.

NORBERG: Now let me understand this. Actually Bell was using this technique and therefore you transferred it back. What sort of improvements did you make on the system?

KILBY: Probably none that I know of. In that case we simply built up one as much as I had remembered the way it had looked and it worked well enough so that there was no reason to spend much more time on it.

NORBERG: Michael Wolff in his article in IEEE Spectrum back in the bicentennial year, 1976, has a quotation from Robert Wolff that a lot of Kilby's own ideas went into those transistors and he was really responsible for our first really small transistorized hearing aid. Now it seems to me a long way from attending the Bell conference and coming back and producing some germanium transistors to actually producing a very small hearing aid.

KILBY: Sure. And there were two steps...

TAPE 2/SIDE 1

KILBY: There were a couple steps in the process. The first thing that we had to do was to learn how to make any kind of transistor, because this was completely foreign to Centralab, certainly to me and to Wolff. Once we had done that then the question became how we might use them. What physical form they would be in. How they would be incorporated with the other circuit elements or resistors and capacitors that were needed. And so, much of our work in terms of building transistors was not very original. On the other hand, I think the second part of it departed almost completely from the established practices in that area.

NORBERG: Which second part now?

KILBY: The physical form of the transistors, the way that they were actually put together and used with the other components, things of that sort.

NORBERG: Now in this case had you begun to silk screen these right along with the other components in the hearing aid?

KILBY: No, we couldn't silk screen the transistors. Nobody knew how to do that then and nobody knows how to do that now really. But we could make them in a form so that they could be easily attached to the silk screen circuitry and we could incorporate the ceramic substrate that we had for the other components to serve as the package for the transistor. So the germanium part of the thing itself was not very novel. Everything that was done after the germanium fabrication was.

NORBERG: Now this is what you referred to in your own article as the novel part of it, the packaging of the transistor at that time. Were there any peculiar problems in developing the packaging technique?

KILBY: Yes. Germanium transistors at that time were very sensitive to heat and moisture, light I guess for that matter and very fragile and their physical properties tended to change when they underwent any of those operations. Trying to incorporate them as a part of a larger package was very difficult.

NORBERG: How did you overcome the problems?

KILBY: We made a small carrier for the transistor which could be attached to the ceramic substrates and then in several different versions we developed techniques to actually seal that to the ceramic and encapsulate with a solder-seal.

NORBERG: Were other companies working on similar problems that you know of?

KILBY: Not at that time. I don't think they were.

NORBERG: As I remember the transistors in the period of about 1960, they were coming out fairly well packaged in what looked like little diode devices.

KILBY: Yes. Well, and that was the main stream of transistor development. At that time the people that were making transistors in volume, the TIs and the RCAs and Motorolas were packaging the transistors as an individual unit with three leads coming out of them. Basically, they didn't much care how the end user incorporated that into his circuit.

NORBERG: Which would be just like the earlier tube business, which was essentially the same thing.

KILBY: Yes.

NORBERG: How long did the Bell license continue?

KILBY: I think it ran indefinitely, subject to payment of royalties and a few paperwork things. The financial terms were renegotiated, I think in 1956 Bell had to accept a consent degree. They didn't change things much either.

NORBERG: I want to ask two different questions here, let's take the second one first. What was the volume of production within Centralab in terms of the number of transistors that would have been produced for incorporation into hearing aids?

KILBY: It was very small. A few thousand a week I suspect was probably the peak that we reached.

NORBERG: Was it one transistor per hearing aid?

KILBY: No, it took 4 for a hearing aid typically.

NORBERG: Were the hearing aids marketed through Sears still, or through someone else?

KILBY: No, the hearing aids were not marketed through Sears. They were marketed through a number of hearing aid manufacturers. That industry is heavily fragmented. As a matter of fact Minneapolis used to be the big town in the country as far as hearing aid makers were concerned.

NORBERG: That I didn't know.

KILBY: Yes.

NORBERG: Is that the basis for it's current medical instruments activity perhaps?

KILBY: It might be, I don't know. But there were companies called Telex which is still in existence, but has, I think, completely lost interest in hearing aids. Maico, Johnson, and 3 or 4 others, making hearing aids used to be pretty close to a garage shop kind of operation.

NORBERG: Were there other products besides hearing aids using the transistors?

KILBY: We did some work on parts for military circuits, particularly with RCA for the helmet radio, things of that sort.

NORBERG: But it [Centralab] never became a large second source I take it?

KILBY: No.

NORBERG: In the case of the Bell licensing, were there continual updates provided by Bell in terms of the transistor technology?

KILBY: No. We really had a two-shot transfusion, I guess. The first symposium was held in 1952 and then there was a second one, a much shorter one, held I think in '56 in which they announced the diffused transistor, the mesa transistor. Except for those there was not any kind of continuing interchange, at least for Centralab.

NORBERG: Can you be more specific about the '56 conference? I was going to ask about that anyway.

KILBY: At that time, Bell had done quite a lot work on diffusion processes and knew how to make germanium mesa transistors. So they convened what may have been a 3 or 4 day meeting in much the same format as the original and I guess with basically the same participants and went through this material.

NORBERG: Do any of the people who attended either of those meetings stand out in your mind? As being friendly with you.

KILBY: Oh these were not very friendly occasions I guess. Certainly met people there that I've seen a great deal of since, but it's hard to say that, except for the acquaintance, anything much resulted from those meetings themselves.

NORBERG: O.K. what I was looking for was an influence from 1952 on the later interviews that you went through in 1958, subsequently selecting the position at TI.

KILBY: Well TI was represented at that '52 meeting, but I don't think when I interviewed down here that I talked to any of those people.

NORBERG: I see. Now during the years from 1952 through about '56 or '57, lets just keep it to '56 for the moment, did you obtain any knowledge of work at other companies who were also in the transistor business?

KILBY: Well, there were a great many technical meetings during that period, some of which I attended. A lot of publications, things of that sort. There were no visits to other companies or personal interchanges with other companies during this period.

NORBERG: How did you keep up with the literature?

KILBY: We read as much as we could.

NORBERG: Were these journals obtained by Centralab or did you have to go somewhere else to use them?

KILBY: Oh no, you know when you wanted them you could get a Centralab subscription.

NORBERG: Where was the principal material appearing?

KILBY: In the earliest days much of it in journals like the *Physical Review*, more scholarly things. As time went on, it began to be picked up by the trade press, magazines like *Electronics* or *Electronic Design News*, things of that sort.

NORBERG: I would think there would be, first of all, two different types of information in those.

KILBY: It was in part, but I think there was something of a transition from the more scholarly journals to the more

applied. The Electro-Chem society became interested and along through that period began to provide some publication.

NORBERG: Which societies were you a member of at that time?

KILBY: Of the IEEE, but it would have been the IRE in that period. I use to go to the Electro-Chem meetings, but I was not a member.

NORBERG: Were there local sections as well of those groups?

KILBY: Maybe, but if there were, I didn't go to the meetings.

NORBERG: All right, by 1957 Centralab had established a small production facility and was producing the amplifiers for hearing aids and other applications, but apparently the operation was only marginally profitable. Was there any attempt at the time to expand activities, for example to do work for the military?

KILBY: Well Centralab did not have a very good marketing organization to work with the military. Basically, all of the Centralab parts had been sold through manufacturers' representatives, who work on a pure commission basis and while from time to time they would turn up some of these military things, nobody at Centralab knew how to work with the military R & D process. Most of the reps didn't have enough patience to work through the military procurement cycles, which were very long and not very rewarding. So there were some sporadic efforts from time to time, but nothing significant.

NORBERG: It's been suggested that part of the problem was that the military was interested in silicon devices.

KILBY: That's a part of it. Certainly toward the end of this period we're talking about, I think by 1960 or so, the

military pretty much knew silicon was what they wanted.

NORBERG: 1960 sounds a little late to me.

KILBY: Well, they knew that they wanted silicon, but the original devices, which began to become available in '54 or '55, were extremely expensive and I think it took a while for them to be convinced that they were going to be able to afford them.

NORBERG: The other half of that reasoning was not only did the military want silicon devices but that the necessary expenditures to be able to develop a process or facility were too high for Centralab.

KILBY: Yes.

NORBERG: Now why were they too high? Or considered too high?

KILBY: Oh, by today's standards we really weren't talking about a whole lot of money, but Globe-Union was an interesting company in that period. Wanvig, who was still very much in command, was uncertain as to whether he wanted much of anything to do with electronics at that period. He began a nervous breakdown which caused him to commit suicide a year or two later and they really weren't ready to make any substantial commitments to anything, I don't think, at that time whether it was electronics or storage batteries or anything else.

NORBERG: Were you keeping up with the silicon work?

KILBY: Yes, to some extent. You know as well as you could from the outside. In that period much of the good work with either silicon or germanium was kind of in the trade secret category so you had to guess and read between the lines.

NORBERG: What I know about the transistor developments is becoming vaguer and vaguer as I get older. Can you recall for me what the advantages of the diffused transistor were in this period 1956?

KILBY: Well, the key problem in making a transistor then, and now I guess, was to be able to form a base region between the emitter and the collector, which was very narrow, very thin, and very well defined. The alloy process, which seemed like a tremendous leap forward at the time, was not too good at that. Basically what that did was to take a germanium wafer and put a dot of indium on either side of it and then to heat this up and to let the indium alloy width dissolve the germanium three quarters of the way through the wafer or even more if you knew how to do that. That process has a lot of chance in it. The diffusion process is basically you were doing all the work from one side of the wafer, offered the possibility of a much thinner, much more controllable base region. It was very attractive in that sense.

NORBERG: Now it wasn't very long after that when transistors were improved further, most of the work being done by Bell labs as I remember in getting beyond the mesa-transistor into various bipolar junctions and so on.

KILBY: Into what?

NORBERG: Bipolar junctions.

KILBY: Well all of the these were bipolar devices. The next real improvement after the diffused transistor, which was used to make mesa transistors, was the planar device and that work was done at Fairchild.

NORBERG: We'll come to that in just a couple of moments. Now around this time were there any other companies in the general region with people doing work similar to the kind of work you were doing?

KILBY: Not really. RCA at about that time had begun a program which they called the micro-module program. That used many of the techniques that Centralab had been working on, but put them in a somewhat different form factor. Instead of trying to get as much stuff as possible on a single ceramic wafer, they wanted to break these up into wafers with a single component on each, but to make them all to uniform size and shape. So there was a strong element of commonality there, although there was a basic philosophical difference.

NORBERG: It was about this time, then, you began thinking about leaving Centralab?

KILBY: Yes.

NORBERG: And for what purpose? Why did you begin thinking that?

KILBY: I, by that time, was very much interested in semiconductors and what you could do with them. I wanted to stay with that field and I became convinced that Centralab was not a very good place to do that. So I began to look around.

NORBERG: You claim that you wrote to several leading electronics companies. Do you remember which ones?

KILBY: The three that I remember were TI, Motorola, and IBM. I suspect there were some more.

NORBERG: And what was the response?

KILBY: I had interviews with IBM, with Motorola, and TI; job offers from TI and Motorola, not one from IBM.

NORBERG: What sort of work were the other companies doing that they discussed with you during the interviews?

KILBY: Well, IBM didn't discuss their work very much but by the time I was there I'm sure they had begun to work actively on what was later called the SLT technology. And again, like the RCA thing, this drew rather heavily on silk screen technology as some way to integrate the transistors with substrates and things of that sort. Motorola was not doing any work of that type and neither was TI, but both of them were interested in doing some.

NORBERG: How did you come to choose TI?

KILBY: The Motorola offer was to work on things of this sort, these more integrated applications, half-time and to help in their conventional transistor area the other half of the time. I really don't know what's wrong with that, but at any rate the TI offer was not limited that way and so I took it somewhat by default.

NORBERG: What tasks did TI wish you to perform when you came aboard?

KILBY: Well, at that time, this generic title for the kind of work we're talking about was called micro-miniaturization and it was understood that I would work in that field. If TI had any ideas as to what form that should take and how I should go about it, they didn't say so. I was pretty much left to proceed on my own.

NORBERG: Who did you work with directly when you went there?

KILBY: I was hired by Willis Adcock and worked in the section that he had, which was called Research-In-Engineering at that time.

NORBERG: What sort of projects were these people doing in this group?

KILBY: Well, most of the people in his area were involved in advanced semiconductor development work across the board. There was a section interested in diodes, one in silicon transistors, germanium transistors, tantalum

capacitors, maybe another one or two.

NORBERG: Did you have a project of your own then or were you assigned to one of the groups working on one of those?

KILBY: Neither one. I began working for Willis on special assignment. Since I was by myself, it wasn't called a group.

NORBERG: Now what does special assignment mean?

KILBY: Well, it just meant that I reported to Willis and not to one of his branch heads. That is, I was not incorporated in one of the other projects.

NORBERG: So did he give you a project of your own? Did you design one? How much time elapsed between going to the company and the two week vacation that you talk about when you were doing your own work?

KILBY: I started with TI in May of '58 and began to think about configurations that would use the TI strengths and defined an approach using tubular components, in part because they were already making resistors in that format, could make capacitors in that format. So I made some tubular-type type transistors and worked on some techniques to put them together for a few months. That was really the first project.

NORBERG: Was that TI's strength that you referred to? The tubular nature of the components?

KILBY: Well, certainly if TI had been generating a long list of things that they were strong in that wouldn't have appeared, but that seemed to be a sort of a common element as I consider it.

NORBERG: What would TI have identified as their strengths at that time?

KILBY: Well, I suspect they would have said that they were the world's largest producer of transistors in that period, certainly of silicon transistors, and I think also of germanium devices. They also had interest in a number of other types of electronic components. At that time, they were making carbon film resistors, tantalum capacitors. They had bought and abandoned an operation making panel meters. They made some transformers and I think at that time they really intended to become a kind of a general supplier of electronic components.

NORBERG: Mostly for military purposes?

KILBY: No. No, there was a significant military interest, but TI's first... TI had real claims to fame in 1954, which was when they really became noticeable. One was that they had built the first working silicon transistors and the second was that they had announced the first pocket radio, which was made with germanium devices. In that case, they had done the design work, but they really didn't want to go into the consumer business and so they found a small company called Regency, which made and sold the Regency radio. So by '58, their biggest single contract certainly was in making germanium transistors for IBM. So I don't know how the business split between military and commercial, but it was certainly not all military.

NORBERG: What were the differences in production methods in TI verses Centralab?

KILBY: Well TI was a much broader based company. In '58 they were building transistors and diodes by perhaps a half dozen processes. They were still making a lot of grown-junction devices, particularly in silicon. They made a lot of alloy devices, the IBM ones were of that type. They had some diffused devices, although not too many. I suspect at that time they were probably involved in more processes and more products in the semiconductor field than anybody.

NORBERG: Had they developed any peculiar techniques, different than what you had been using at Centralab, for producing?

KILBY: Well, of course we used only a very limited set of techniques at Centralab.

TAPE 2/SIDE 2

KILBY: At Centralab we used only those techniques which were required for making alloy junction germanium devices. They were using techniques for grown-junction devices, in both germanium and silicon. They made a lot of alloy transistors with processes much like those we used at Centralab. And they were working pretty hard in the diffused device area and that was different.

NORBERG: This was your first experience with the military, then, in terms of producing components. Did it make any difference in your activity at all?

KILBY: Well, yes, because when the integrated circuit concept came along, the TI marketing people knew exactly what to do with it, where to take it, which services were most interested, and who within those services to talk to, and things of that sort. So, yes, it made a big difference.

NORBERG: There are so many threads now that are going to be difficult for me to weave together. I'll try to separate these out, one at a time and I hope I don't forget any. Let's go back to the joining of you with TI in May of 1958. Can you describe Willis Adcock to me? What his strengths were in terms of both running research groups as well as his technical strengths?

KILBY: Well, Willis has a PhD in chemistry, basically, and had been working with an oil company in Tulsa when he was recruited to TI in the early '50s. He became a key member of the group that worked on grown-junction

transistors. He invented a couple of processes that significantly improved them. Somewhat before I joined TI he had been split out of the Central Research Group, which was under Gordon Teal, and assigned to the semiconductor product department, which was under Morris Sheppard, and began to establish a R&D group within the semiconductor product activity. And at the time that I started there were probably forty professionals in the group, something of that sort, with reasonably good facilities to do the things that needed to be done.

NORBERG: What about other people in this group besides Adcock?

KILBY: Well, the branch managers were Bob Prichard, who is now with GE; Jay Thornhill, who was with JPL and died; Elmer Wolf retired from TI a little bit ago; Archie Brudo, who was in charge of the tantalum capacitor effort for a long time. Jim Fischer, who is now the chief financial officer of TI.

NORBERG: What sorts of things did these people do? You mentioned only one project, the tantalum capacitor.

KILBY: I'm sorry. Well, going down the list, Jim Fischer was in charge of a project working on making silicon material, converting silicon-tetrachloride into pure silicon. Jay Thornihill was in chard of the diode development activities, beginning some of the microwave work. Brudo was in charge of tantalum capacitors. So that each of these guys had small groups of 3 to 6 professionals working for them in those assigned areas.

NORBERG: Did you work with any of them in the 2 or 3 years after you went there?

KILBY: Not directly. Frequently I would use their people or their facilities or that sort of thing on a borrowing, kind of an ad hoc basis.

NORBERG: You mentioned facilities as being adequate. Can you compare the facilities at TI with facilities you had available at Centralab?

KILBY: Well, the Centralab facility was really very small. All of our germanium transistor fabrication was done in a room about the size of this one and that secretarial office.

NORBERG: Which is 20 feet long by 12 feet wide roughly.

KILBY: And we had one crystal puller and one zone refiner, one reduction furnace, a saw, and a furnace to do the alloying in, and that was it. The TI thing at that time was probably 10 or 20 times that. Their comparable operations were in a space that had maybe 10 to 20 times that much space and probably about 10 times as much equipment. So it was quite a difference in scale. And those were only the R&D facilities at TI while the stuff that I described at Centralab was all of it, that is not just R&D, but what amount of production we did also went through there.

NORBERG: Did you follow designs from the concept stage where you people in R&D were working on them to manufacturing, or was it handed over to another group?

KILBY: Where?

NORBERG: At TI.

KILBY: At TI. The typical pattern is that they would be handed over to another group. Now in the case of the integrated circuit, it didn't really work that way, since there was not a group in being that would logically take that.

NORBERG: I'll come back to that, I don't want to betray that story until we've started that one at the beginning. In a situation as large as the TI groups were in 1958, and I realize it's not like today, as large as they were at that time was there any discussion among the groups about allocation of resources for R&D; money that would be needed, staff, added staff that might be needed, and did you participate in such discussions?

KILBY: I certainly participated in ones that pertained to my projects, but I did not participate on a more general basis.

NORBERG: That would be Adcock and above, I take it?

KILBY: Right.

NORBERG: Adcock you said came from Tulsa?

KILBY: Well he had been with one of the oil company laboratories there for a couple of years. I don't know when he graduated from Brown.

NORBERG: That's all right. What I was after, he was Gordon Teal's assistant, was he not, at this time?

KILBY: No, at this time his relationship with Teal had been severed. He had worked for Teal when he was in the central research lab, but when they set up this research in engineering within Shepard's domain under the components division, he no longer reported to Teal.

NORBERG: I'm trying to establish some sort of link between Adcock and Teal before either one of them came to TI.

KILBY: I don't know whether there was one. They both went to school at Brown. Whether they had known each other there, I don't know. There may well have been one, because I'm sure that Gordon hired Willis...

NORBERG: And very soon after Teal came to TI.

KILBY: Yes, he was one of his first hires. So there probably is a relationship there, but I don't know what it is.

NORBERG: What about the relations with Bell at this time. Did you know of any at all between TI and Bell.

KILBY: I was not much involved with them but I think they were much closer. TI was doing things that were of a great deal more interest to Bell than Centralab was and I think that they spent more time talking to each other.

NORBERG: But you didn't have any contact with them?

KILBY: No.

NORBERG: How about other organizations in the industry, other companies? Any contacts with them? I'm speaking now of the late '50s.

KILBY: Yes. Well, when we began to announce the integrated circuit, we had contact with most of the companies in the industry in one way or another. T.J. Watson of IBM came down and was given a dog-and-pony-show to show him what integrated circuits were. We had a continuous procession of visitors through the early '60s.

NORBERG: I'll come back to the procession of visitors. One last question before moving on to the integrated circuit and that is after having spent a couple of years at TI -- '58, '59, '60 -- could you give an indication of what the benefits of being with a company like TI were at that time as opposed to what it was like to have been with Centralab?

KILBY: Well everything was considerably easier to do at TI. They were more familiar with the kind of things that had to be done, the kinds of expenses that would be incurred and they were completely convinced at that time that they wanted to be a major factor in the semi-conductor business and were willing to go in any direction that would be required to get them there. That feeling had implications all the way up and down the line, I think, in terms of getting

resources or people, selling ideas, or anything else.

NORBERG: What was the process of selling ideas? Maybe we can start with the integrated circuit, when you had to sell it.

KILBY: Well, within TI that process was fairly straightforward. I described it to Willis and he became enthused. I'm sure that he informed Shepard, not that Shepard reacted much, but Pat Haggerty, who was president of the company at that time, was very enthused. He responded very directly, even though Shepard may have had reservations from time to time, because Haggerty was such a strong supporter, it was able to move ahead.

NORBERG: For completeness here, I know you've described this in the '76 article, but for completeness in this transcript, can you tell me again why it is you decided to work on what became the first integrated circuit device?

KILBY: Well, the first project that I had been involved with at TI had given me a chance to learn something of the cost structures within a company like TI and these were very different than they had been at Centralab.

NORBERG: In what way?

KILBY: Much higher overheads, things of that sort. Somewhat higher wages for the people involved, so that given task at TI would have to been sold at a much higher price than the same gadget made in a Centralab environment. And there were very good reasons for this. You just need to accept it and get on with it. And in the process of doing that, I do remember thinking that because of this cost structure that the only kinds of products that a company like TI could make were semiconductors. Therefore, it would be very desirable to make an all semiconductors circuit to make everything from a single material. Once I had begun to think in those terms, it was possible to see ways to make all of the circuit elements that would be required for transistors or diodes or resistors, capacitors, things of that sort, and how these could all be made within a single wafer.

NORBERG: How did you go about developing this idea?

KILBY: Built a couple of rather trivial examples to show that the idea did work and that you could build more than one kind of component in the thing. One of these was a phase shift oscillator, which was chosen to show that you could make analog type circuits. One was a flip-flop, to show that you could make digital circuits. Once that was complete, then we really began to think about what kind of product you wanted that somebody might want to buy or that you might want to build.

NORBERG: But going back to the original design, how did you develop the original design? What became that first integrated circuit during the summer of '58?

KILBY: Well basically, what I did first was sit down and sketch this out in a good deal of detail with colored pencils showing the various layers and progressions, sequences in which these things would be put together. Then, in order to show that you could put all these things together, I took some existing germanium wafers and made what were really almost the equivalent of breadboards of circuits to show that they could be made so that all of the components worked well on a single wafer. So those were kind of the two steps through that period.

NORBERG: Was the actual fabrication of the first circuit done in standard ways, using the same refining techniques that were used in manufacturing semiconductors in general?

KILBY: Yes. The basic semiconductor process steps were completely conventional. Actually, rather than go through all of these from scratch, at that time they were beginning to make some diffused germanium wafers, germanium transistors, and I got some small wafers on which those transistors had already been formed and then simply etched them and attached leads to them to show that the idea worked.

NORBERG: Now why had they been formed on the wafer?

KILBY: Because they intended to cut them up and make transistors from them.

NORBERG: I see. So this was just something that was laying around that you tried a new technique on?

KILBY: Yes. This has caused some problems, I think, because those first circuits looked and were just incredibly crude.

NORBERG: Why should that produce problems? That's always been the case in engineering design.

KILBY: Because some of the other people who have chosen to advance their claims in this area began to show pieces which had been made with good photographic masks and looked a little cleaner and looked more like a circuit does now.

NORBERG: I see. I would think that wouldn't have made much difference to a patent examiner, because it would be the claims that would be made for it.

KILBY: It didn't matter to the patent people at all.

NORBERG: Now you have got this device in June, July I guess of 1950?

KILBY: No, in July I had the idea and had this first set of sketches. I think it was September before we really had a unit that worked.

NORBERG: I see. All right, now I'm beginning to understand some of the things that are in the 1976 article. So that

you had sketches and designs at the end of that summer vacation period?

KILBY: That's right.

NORBERG: Those are the things that were presented to Adcock and then presumably up the line to Shepherd at least. Now, what was their reaction?

KILBY: Well, I think we touched on it. Willis was initially enthused, a little skeptical, wanted to see some evidence that it worked, but generally favorable. I think Haggerty much more was completely enthused and not much inclined to question or quibble with it. I think he endorsed it very completely.

NORBERG: What sort of needs did you have that you would have to get in terms of resources from them in order to pursue the design further at that time?

KILBY: Well, I really didn't need much in the way of resources to build these original breadboards. On the other end, if it was to go beyond that there was a tremendous amount of work required and significant expenditures. Some of which came from the defense department. More people.

NORBERG: How was the analysis defined in terms of what people would be needed and what monies in addition to salaries would be required?

KILBY: Yes, worked out a plan showing the number of people required, the amount of equipment required, the expense dollars, things of that sort. A timetable as to when you might have the first devices and things of that sort.
NORBERG: Now, how did you go about designing this? Not the device, but designing this plan for producing a manufactured product?

KILBY: That was really done, I guess, in two stages. The original work was to pretty much to devise an R&D plan, which we expected would be funded by the Defense Department, showing the additional R&D work that would be required. Those plans were submitted in, maybe March of 1959 or something of that sort. The first real plans for production probably began in 1960, well in late '59.

NORBERG: What sort of things did you identify as needing more research?

KILBY: The initial work that we wanted to do was to kind of determine the limits of the technique, to see how far we'd be able to go with it; what kinds of circuits we'd be able to build; what sort of specifications we'd be able to guarantee; what the circuit should be to perform real functions that somebody needed and wanted to buy. It also included a good deal of work on techniques to build one, because we knew that some advances would be required in that area. TI was just about to begin to use photolithographic processes. We knew that that would play a very heavy part.

NORBERG: Was that a new technique at the time?

KILBY: Relatively so, within a year or two.

NORBERG: Was all or at least most of this analysis that you've just described done before the application for the patent in February of 1959?

KILBY: No. That plan was prepared almost concurrently with the patent application. Of course, the work described on the plan, much of that wasn't done until long after the application was filed.

NORBERG: When was the military brought into discussion of the integrated circuit?

KILBY: We began to talk to them in the fall of 1958 and had meetings with the Army and the Air Force I think in October, maybe in November.

NORBERG: What was their reaction?

KILBY: Well, the people we talked to in the Air Force were quite enthused. The Army had just committed themselves to a major program on the Micro-Module and their reaction was mixed. I think they really would have just as soon that it hadn't come up, but since it had, they wanted to show that eventually it would be compatible with the Micro-Module and all that. Therefore it all fitted together. So we got some support from both groups, but the most useful, by far the most useful and meaningful support, was from the Air Force.

NORBERG: Did the Air Force participate in the analysis in any way? The analysis of the economics of the situation, principally?

KILBY: Well, much of that was done with their funding. So yes, they did.

NORBERG: Did they help to specify any of the requirements that would subsequently have to be met in order to get major contracts from the Air Force, say?

KILBY: Oh not, perhaps, in 1959, but certainly by '60 and '61 they were doing that. No, the Air Force at that time, the group that we dealt with was run by a guy named Dick Alberts. He was probably the best of the managers that I've been involved with and he felt strongly that it was necessary to do more than just invent these things. We worked with him on techniques to choose test vehicles to not only build the components but to demonstrate that they would perform some function useful to the service. And in the process, we got a good deal of guidance as to what constituted a practical device. In '61, we actually delivered a computer to the Air Force, which had 576 circuits in them I guess. By computer standards it was kind of trivial, but it provided a good deal of guidance through that

period.

NORBERG: Can you be more specific about some of the guidance and some of the discussion with the Air Force people in terms of how to develop such a product?

KILBY: Their contributions were not so much in terms of how to do it, but they did, as I said, want to be sure that these things that were done were useful. So they were in complete agreement that a small computer would be desired and I'm sure we talked some about the functions that this computer would perform. I don't think they gave us any directions in terms of how to get there. That was really pretty much up to us and it was a very good way to work. It didn't provide much in the way of binding constraints. It gave us a good deal of freedom and I think they got what they wanted.

NORBERG: If the Air Force, and in some respects the Army, provided some of the finances for doing the research and development, what was the ratio between what they provided and what the company provided form internal resources, if any?

KILBY: Well, it varied. It was probably not much more than half during any part of that period, but it could have been as much as half.

NORBERG: Now that suggests the companies commitment to the project, because other companies dealing with the military have often made sure they recovered all of the research and development costs.

KILBY: No. It was really kind of a synergistic arrangement. I think because the Air Force was willing to commit this kind of funding, TI was...

TAPE 3/SIDE 1

NORBERG: Because the Air Force was willing to commit, TI was willing to commit as well?

KILBY: Yes, and I think they both got some support from the fact that the other was involved.

NORBERG: Would this be a fairly typical way TI would have responded in those days?

KILBY: Yes.

NORBERG: Put in a substantial amount -- it didn't have to be half.

KILBY: Yes. Right. Correct.

NORBERG: Moving from the concept in the research and development, what sort of evolution of the project from a concept to a prototype and then to manufacturing occur red? Because when you talked in your article in '76 about the invention of the integrated circuit, it doesn't go beyond the concept stage.

KILBY: Well the sequence, I guess, was that TI had announced their first commercial integrated circuit at the IEEE show in 1960 and this was a flip-flop that was in the first flat-pack, priced at 450 bucks. We really didn't expect to sell very many, but thought that it would provide a good vehicle for people to buy one and evaluate it and see what happened. The first serious commercial product, announced in the middle of '61, was a family of 8 circuits, digital circuits, and that coincided with the delivery of this first computer to the Air Force, and one thing and another. And we had a series of meetings around the country, one in Washington, one on the West Coast, and in Dayton, in which Haggerty described these and gave his first talk on the glorious future of integrated circuits, I guess, and that was really the commercial launching of the product.

NORBERG: Is it possible to describe the R&D phase of this development? I'm wondering where there are any company proprietary information problems associated with this?

KILBY: Not at this point. I guess in looking back on it, the thing that's amazing to me is how short that period was, because I'm not sure that you would move that fast today -- but I don't know.

NORBERG: Why not?

KILBY: I don't know. But at any rate it did move very quickly at that time. If you consider that the first act on it at all was in the middle of '58 and there were viable commercial products on the market in the early part of '61, it moved pretty fast. The R&D organization grew rather rapidly during that period. I suppose there were 4 or 5 people by the end of '58, maybe 20 by the end of '59, probably 50 or 60 by mid '61 that we're talking about. All of these were professionals.

NORBERG: Did you recruit these people?

KILBY: I was involved. I think I said earlier, basically this project was not transferred from an R&D operation to a manufacturing operation, but rather built up within R&D and then transferred to a product department status. The people and the facilities and the whole shebang was transferred to a product department status as a group.

NORBERG: All right, but that doesn't explain how the people were recruited.

KILBY: Well, I recruited some of them; some of them came from within TI; some of them were recruited from outside.

NORBERG: Were there any phases to the recruitment? I guess what I'm looking for is in the beginning did you look

for semiconductor people and then you needed -- oh I don't know -- some sort of substrate people, and then you needed production people and so on.

KILBY: Oh, I guess the transitions weren't that abrupt. One of the first guys that was hired was a photo-resist expert who came from outside. So we certainly did add specialty skills for things like that. Many of the people who were ultimately involved in manufacturing were transferred at the very junior levels from the existing manufacturing operation. A lot of them were new hires out of college.

NORBERG: What sort of problems did you run into in trying to develop a manufacturing process?

KILBY: Well, there are always problems in semiconductor manufacturing. At least in the beginning and that's close enough to it. There was a great deal of black art, much less solid scientific knowledge than we have now. So processes that would work one time would not work the next; processes that worked for one wafer would not work for two wafers; processes that would work for two wafers would not be worth a damn for 20 wafers. And so the build up process was very painful, very agonizing, very expensive, didn't always work very well.

NORBERG: Was there any attempt to do what used to be at least a favored technique in engineering -- the scale up, what works for one should work for two and therefore should work for 20 and as you go up the line you meet various problems and solve them one at a time. Now, were there any particular difficult problems that stand out in that process?

KILBY: It would be very hard to single out one. There were just an incredible variety I guess. You see, TI did not really know very much about how to make diffused transistors at that time. They were really just beginning on that process, particularly in silicon. Nobody knew very much about photo-resist processes at all. Most of the things we wanted to do we presented departures from the past. In principle, we were able to do some of this kind of quick, because there was a relationship with the previous semi-conductor devices. We didn't have to start form scratch, but

you sure had to adapt and change and do things somewhat differently in order to make good integrated circuits.

NORBERG: Can you give me some examples of those departures? Especially those developed at TI now, not what we might find in the literature in general.

KILBY: [Long pause.] Well, let's see. I'm trying to think of one that might be illustrative...

Some of the differences came about because of the difference in size. When you were making a thousand transistors on a chip and you were going to scribe one of them and pick out the good ones and throw away the bad ones, it really didn't matter much whether the process was uniform over the whole circuit or not. Obviously you'd be better off if it was, but it wasn't a disaster if you weren't. For most of the integrated circuit designs, this was very much more of a problem and so we had to do things in the diffusion furnaces to assure that the conditions were more uniform than those they had had for transistors, for example. The same thing was true of the photo-resist processes and the metalization, and things of that sort. And so we were using conventional processes, but we were putting more demands on them, at least different demands. And they didn't know... It usually took some work to get them to meet the...

NORBERG: And was there then a substantial amount of modification of the equipment used to produce the devices?

KILBY: Some, yes.

NORBERG: Some, not substantial?

KILBY: Well, you're talking about these very early days, basically we used the equipment that was there and then started modifying it a little here and there to cope with these problems that came up. Somewhere later, and I don't

know just when, all of the new equipment designed began to be tailored for integrated circuit manufacturers and that part of the problem kind of disappeared.

NORBERG: Were you involved in that phase of the development, that is the new equipment later on?

KILBY: Yes, well through the '60s. I've not been involved since.

NORBERG: Yes. No, I was actually only thinking of '62, 3, and 4, not beyond that.

KILBY: No, we didn't separate. I mean there were not rigid boundaries between engineering and manufacturing for that kind of research.

NORBERG: What was the interaction with Fairchild, if any, after their announcement in the summer of '59?

KILBY: In the summer of '59?

NORBERG: Yes, it was about six months after your patent application and public announcement that the planar process was announced, was it not?

KILBY: Yes. Initially the transistor people at TI began to look at the planar process and concluded that it was of some interest and began to do some work on it. Their first integrated circuit was announced in March of '61 and of course when those became available, we got some of those and looked at them with great interest. There was not any communication channel between the companies at that time.

NORBERG: Did you begin using the planar process for manufacture of your own circuits?

KILBY: Yes, some time in 1960.

NORBERG: How was that done? Was it done through some sort of cross-licensing arrangement?

KILBY: Not initially. No, you know, it has been a characteristic of semi- conductors, and I think electronics in general, that patents have not been of very much impact. If you are building a hundred million dollar oil refinery, you don't want somebody coming by with a piece of paper and telling you you can't use it. But if you're soldering circuits together in your garage and he tells you that you can't solder this wire over here, you just move it over there and then you wait until it does that. I don't recall, but I'm sure that TI and Fairchild began to discuss licenses somewhere in '60-'61 period, but I don't think that anything was finalized for several years after that. TI and others had begun to use the planar process well before that.

NORBERG: In comparison with earlier production processes for semiconductors, how new was the Fairchild planar process when it was announced? Was it an essentially new concept or had the earlier contributions in places like Bell demonstrate a natural progression to the planar process?

KILBY: Well, you have to make a kind of a distinction there I think, in that the planar process did two things. One is it made the surface flat, which is the planar part of it. But the thing that was of most significance initially was that it also did a better job of protecting the junction, I guess, from moisture and contamination than any other process, and that part was a revelation. Bell had done some work on structures which had completely flat surfaces. In fact, they had formed them in exactly the same way that Fairchild did except that in their last step they stripped all of the oxide off and thereby gave up that degree of protection.

NORBERG: And as I recall without knowing they had stripped off the oxide?

KILBY: No, they did it on purpose.

NORBERG: Oh they did?

KILBY: Although I don't know what their purpose was. The traditional approach had been to get the surfaces as clean as possible and then to put something on that would protect it. The thought that the oxide, which was on there when the device was formed, was better protection than anything else that you could do to it, was a new idea and a very revolutionary one and very important.

NORBERG: But tended to confuse the issue of the integrated circuit invention, I presume?

KILBY: Well, yes, quite a lot. One of the problems is that Fairchild had already credited it to Jean Hoerni with the invention of the planar process. I don't think anybody questions the significance of that achievement. When Fairchild began to think about integrated circuits, they rather very naturally wanted to use the planar process and did in their first circuit. There's no question that this significantly improved the performance of the circuits that were made at that time. And no arguments up to that point. The differences would occur after that, I guess, in that I think that Noyce feels, and the Fairchild people feel, that this change was so revolutionary that it really constituted starting over. It was basically a new idea. I guess I don't see it in quite that light. I think it was a worthwhile improvement, but there were other techniques like epitaxy that have been phased in over the period without restarting the clock and I guess I really don't see why this one would.

NORBERG: So it was just the serendipitous convergence of these two events that made it more feasible to produce better integrated circuits then?

KILBY: I think that's right, although it has become even more complicated. The stories that I have seen most recently suggest that Noyce feels that he had the idea for making integrated circuits at about the same time that I did and that while he didn't do anything about it for a while his activities were concurrent. He's begun to used the title of

co-inventor. It doesn't fit with what I understand to be co-invention, but that's become accepted. So it has become even more complicated I think.

NORBERG: And it's going to be difficult to sort out the two situations without some documentary material to demonstrate the differences and I should think that the best documentary material would be some sort of designs or laboratory notebooks or whatever, which have some dating and some direct statements that one could interpret as meaningful definitions and concept.

KILBY: Yes. Well, copies of my laboratory notebook for that period have been available. I have not talked to anybody that has seen Noyce's.

NORBERG: I don't know of any of Noyce's.

KILBY: All of these things keep referring to the fact that he made some notebook entries at some undisclosed time and undisclosed date. The patent office didn't attach any credibility, any weight to those. But I don't know what they are.

NORBERG: I wasn't trying to pin you down on that one particularly, but what I was more anxious to explore was any interactions between the two companies, and you suggested that they were not interacting before 1960. Secondly, how quickly you people picked up the planar process, and you indicated that you were interested in it right away. Now, after the first integrated circuits were manufactured -- the 450 dollar ones that TI put out at -- what was it? the IRE meeting? -- and then put them into some sort of repeatable mass production, what did you do then? Did you stay with these tasks or not? I know for a while you had several titles and we should clear up what those titles were in that decade from '58 to '68 and you were also involved somehow in hand calculator work. Can you sort this out for me?

KILBY: Well the next big thing that happened after this '61 release, after we had delivered this computer to the Air Force and had what we thought was a viable commercial line product, was that again the Air Force helped us and Minuteman was about to undergo redesign at that time. Minuteman had established a reputation for extremely high reliability in their first generation computer. As a backup program, they decided that they would like to build a Minuteman II computer of integrated circuits. This put a tremendous load on us because this was a real computer. It had 2200 circuits of I think 24 different types, not just logic elements but core drivers and sense amplifiers and all the rest of it. So we began what was really a crash program to build those Minuteman circuits. The commercial offerings were continued through that period but much of the engineering work was on the Minuteman program. That worked out fairly well. The first computer with those circuits in it was flight tested by the end of '64. But that pretty well soaked up a good deal of that period.

The titles changed but through much of that period I was responsible for the engineering work on integrated circuits. For a couple of short periods, I was the manager of the product department, which included not only engineering but manufacturing and marketing and that sort of thing. After that the Minuteman crash was over, I went back to the research and engineering group and established an integrated circuit research activity within that.

NORBERG: To do what sorts of things?

KILBY: To continue to move forward in integrated circuit development, to build bigger ones, faster.

NORBERG: Now, I have a note that says that you were an assistant vice president of Texas Instruments from 1958 to 1970.

KILBY: No. These damn forms give you one line and ask you to say your title. I was an assistant vice president for the last two years of that period I guess. I was not prior to that time.

NORBERG: In the succession of positions that you had, how did the hand calculator fit into this? I'm a little puzzled when you say you went back to doing research and development on integrated circuits, did these end up in specific types of products like the hand calculator?

KILBY: Yes. No, the calculator was very much a part of that. By chance I was going to New York on a flight and Haggerty was on the flight and we were talking. There were three things that he thought would make very good products.

NORBERG: Can you tell me the year?

KILBY: I suppose this was '64, perhaps. One of these was a hand-held calculator. The other was a lipstick size dictating machine. The third one I don't remember. It wasn't within the possible realm. For that matter, neither was the lipstick size dictating machine, but I did think we could build a pocket size calculator. So, as a part of the process guiding our advanced integrated circuit development, we did design and build a hand held calculator, but that was a part of the integrated circuit development responsibility.

NORBERG: Were there any differences in the problems associated with designing and developing a hand-held calculator as opposed to some of the other devices that you had done earlier?

KILBY: Yes, the calculator had several problems that were unique. In '64, people had begun to build the first electronic calculators and they were about the size of this thing. Obviously a CRT display could not be used. Nor for that matter could you use Nixie tubes, or anything of that sort. So we had to have some way to display the results. We had to do something about a keyboard, because the existing keyboards were much too large. We had to find ways to build considerably more complex integrated circuits if we were all going to get the thing in a package. So we worked on all three of those areas and had solutions to all of those problems.

NORBERG: Within a couple of years?

KILBY: Yes. I think it was '67 when we finished it.

NORBERG: Other groups were working on such a problem at the same time weren't they? Hewlett-Packard was interested in a hand-held calculator. Wang was making noises about it anyway. I don't remember what they did with it.

TAPE 3/SIDE 2

NORBERG: Did you know the work of other companies at all?

KILBY: No. I knew about the Hewlett-Packard work later, of course, when it came on the market. I guess I still don't know what Wang did.

NORBERG: I've just essentially three more questions for you if you can take the time.

KILBY: Sure.

NORBERG: One of them is that in this period from 1958 to say 1968, TI changed considerably as a company. Its margin of gross income went way up; its profits increased; its share of the market was substantial for all of those years I believe. What sort of changes in the company did you witness during this decade?

KILBY: Well, in addition to the obvious ones of growth in size and people, I'm not sure that the company itself changed too dramatically during that period. At the time I started, the chairman of the board and I guess the president were Eric Jonsson and Eugene McDermot, and Haggerty was, I think, probably listed as the executive vice

president. Somewhere in the early '60s he moved to president and later to chairman. None of those changes had any dramatic impact, I think, on people or on the structure of the company, things of that sort. Most of the complications in that period were the ones that just went with bigger size. In the last ten years, there have been some other things that were not as fortunate or as favorable but...

NORBERG: But that would be seen from the outside, I think, more than from the inside.

KILBY: Yes.

NORBERG: Which leads me to ask you about your decision to leave TI in '70-71.

KILBY: I had been moved into spots where it seemed that I would have less and less to do with these things that I was interested in. I thought that I wanted to see if I could function on a free-lance basis in one way or another, and decided that that was a good time to try it. It wasn't any immediate dissatisfaction or anything of that sort of thing.

NORBERG: Can you comment then on some of the work that you have done since leaving TI? Things that aren't classified of course.

KILBY: Initially I worked on a number of potential electronic consumer products, telephone accessories, then I became interested in solar energy and I spent a great deal of time on a particular scheme there. TI became interested in that and acquired the rights to it and for 4 or 5 years I've spent much of my time as an almost full-time consultant to the company on the solar project. Last year they decided to abandon that. This is not a very good time for solar projects. At the present, I have no connection with the company.

NORBERG: Do you have multiple patents? I haven't checked to see how many you have.

KILBY: I guess there are about 60. I don't know exactly.

NORBERG: Are these mostly in the semiconductor area and mostly signed over to TI?

KILBY: They're mostly in the semiconductor area. There are about a dozen I guess from the last few years to which I have the rights, that are not assigned to TI.

NORBERG: I can't go away without taking the opportunity to ask you what I've missed. We did some research as you can see about the activities with regard both to you and to TI. TI more generally. And we also have looked into the Fairchild situation so as to know some of the connecting links. But there are always surprises. There were a couple that came up during the course of your answers, but not as many as I would have expected, which leads to me think that I must have missed something.

KILBY: Well I don't know. On the other hand, I think this subject has been of some interest and I did try to set down in this '76 article what I thought I remembered of that period. As far as I know there are no particular changes in that. If there are problems with that article, I'm still not aware of them.

NORBERG: No, we didn't see any problems with it. One of the areas that is not explored in it was interactions with the Patent Office and answering claims and counter claims and so on. That was not elaborated very much.

KILBY: No.

NORBERG: What I would like to do eventually is to see whether or not we can get from TI the documents associated with the case.

KILBY: Well, there's a better way to do it than that and that's to go to the Patent Office.

NORBERG: Directly.

KILBY: And it's very interesting. There's a reporter for the Washington Post named Tom Reid. A few years ago, they took away his typewriter and gave him a word processor, and he became curious about these things and I guess started to write a book on maybe how word processors came about and how they work and what they do. He became pretty much interested in the integrated circuit origins and things of that sort. He's a lawyer by training and his wife is also a lawyer and he is probably the only guy in the world who has read through the complete Patent Office file on this. And he has a book that is due to appear, I think maybe this winter. I'm not exactly sure what he's going to do in it, except that I think that he's departed from his original purpose. He said that the editors wanted to call the thing *Kilby vs. Noyce*, which sounds like he got very far from original goal. [T. R. Reid, *Clip: The Microelectronics Revolution and the Men Who Invented It* (Simon and Schuster, 1985.]

NORBERG: Doesn't sound like an appropriate title either.

KILBY: I don't think that would sell worth a damn.

NORBERG: Well, I wasn't thinking of it in terms of sales, but in terms of telling you what's in the book.

KILBY: But you may find that of interest.

NORBERG: Did he interview you in a substantial way?

KILBY: Yes. He was here for I think a day or a day and a half for the first time and then he came back and picked up some odds and ends in a shorter period.

NORBERG: Can you characterize the difference between this interview and the one that he spent a day and a half doing?

KILBY: Oh sure. In that interview I think he was much more interested in the personalities involved and things of that sort.

NORBERG: I tried to elicit some of that from you and we didn't really...

KILBY: I think you did. Frankly, I'm not sure there's a big difference in the thing. Both of you have done enough homework so that you knew what you wanted. I do have, I think... He sold one chapter of this thing to a magazine called *Texas Monthly* and that appeared some time last year... Two years ago. [July 1982.]

NORBERG: Thank-you. Well, I want to thank you very much, this has been very helpful.

END OF INTERVIEW