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Bill Oldham

William "Bill" Oldham: Materials Science and Microelectronics at the UC Berkeley College of Engineering

Interviews conducted by
Paul Burnett
in 2021–22

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Winetasters. Back row (L–R) Don Pederson, Tom Everhart,
John Whinnery, Dave Sakrison, Mac Hopkin
Front row Steve Schwarz, Art Bergen, Oldham, circa 1974.

Intel founder Gordon Moore, Oldham, Intel co-founder Andy Grove, EECS colleague David Hodges, UC Berkeley Chancellor Michael Ira Heyman, 1981.

Abstract

William "Bill" Oldham is a Robert S. Pepper Distinguished Professor Emeritus in the Department of Electrical Engineering and Computer Science at UC Berkeley. With a background in the materials science of semiconductors and research on aspects of transistors, Oldham joined the faculty at UC Berkeley in 1964, where he evolved into an expert on process technology, or the means by which materials are refined, optimized, and integrated into functioning microelectronic devices. He helped found and was first director of the Electronics Research Laboratory, or "Microlab," and led industry-government-university research programs at Berkeley with SEMATECH and DARPA. He has worked in industry on academic leave and has served on numerous company boards. He is the author of over two hundred publications, including textbooks, and a number of patents in the fields of materials sciences and microelectronics. Oldham served in the Academic Senate of UC Berkeley, both on committees and as Chair.

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Interview 1: July 20, 2021

01-00:00:22
Burnett: This is Paul Burnett interviewing Dr. Bill Oldham for the University History Series, and this is our first session, and it's July 20, 2021, and we are here in the Oakland Hills. So welcome, Dr. Oldham, it's great to see you, and you're freshly here from Hawaii, so it's been—you've been traveling a little bit in the last few hours. I'm wondering if you can start off by talking a little bit about your family background.

01-00:00:56
Oldham: Yes. Thank you, by the way. I was an eastern kid in—well, some people call it Midwest—Detroit, where I was born and raised. I'm from the generation before World War II where it was a completely different style of families and so on. And my mother, for instance, was the housekeeper or home keeper, and my father worked. Happily, I was the third child, because the first child gets way too much attention, and I was just left to my devices. The parents were bored by the third kid, and the first kid was not allowed to ride a bicycle, stupid things like that, the third kid, just "get out, come back by six o'clock for dinner," that kind of thing. So this was really the idyllic childhood, which unfortunately, no kid gets to live today.

01-00:02:04
Burnett: Yeah. Well, can you tell me a little bit? So in Detroit, urban Detroit, suburban Detroit, where exactly?

01-00:02:13
Oldham: This was urban Detroit, probably actually in a neighborhood, which was not that old, but they were—people were by then wanting to live in their individual houses. I think when our house was built, it was even coal-fired but then gas came along and replaced all the coal, but a little neighborhood. Detroit was by then pretty well-populated with a mixture of whites and blacks. I think our neighborhood a few blocks away, the block the black area started. So the high school I went to—I started high school in Detroit—it was about, probably about 30 or 40 percent black. In those days when I was in high school, let's see, early fifties, there was really no problem. I mean the race riots in Detroit came after I had moved out of Detroit, so I never sensed a problem then luckily, so it was actually a good place.

01-00:03:18
Burnett: If it's 30, 40 percent African American, it's less segregated than a lot of schools today.

01-00:03:26
Oldham: Yeah. But what happened during that period was—and that was the tragedy of Detroit, which persists to this day that when a black moved into a neighborhood, the whites moved out, and they called it blockbusting and all this. It was terrible racism. I didn't detect it as a kid as racism, I didn't know, but when you look back. So Detroit was abandoned by the whites, by the mid-

sixties, it was totally abandoned, everybody moved to the suburbs except the blacks, and whole neighborhoods were just boarded up and then empty. It was the darndest thing. The neighborhood I lived in, I visited—I had some work in Detroit in the eighties and I visited there—it was still a decent neighborhood, it was still okay. Our neighborhood never got abandoned. Somehow, it got some mixed racism, but it wasn't abandoned like some of the neighborhoods. Yeah.

01-00:04:29
Burnett: Maybe it was because it was already mixed, then it was spared the kind of deliberate real estate policy of redlining and all of that but—

01-00:04:38
Oldham: I really don't know. I was apolitical, I wasn't aware of it, I was a naïve kid.

01-00:04:46
Burnett: When were you born, what year?

01-00:04:47
Oldham: I was '38, I was born in '38.

01-00:04:49
Burnett: Born in 1938? Okay.

01-00:04:50
Oldham: So I lived in Detroit through two years of high school when my parents moved to Chicago. But I was going to say that the schooling in those days, there's a tradition of American schools were good schools, so I had a good grade school, really good. That was pretty much lily-white, the grade school, that part, but five or six, ten blocks away, the high school, that was not, and it was a great grade school.

01-00:05:30
My mother was—unfortunately because of divorce in her family, she was kicked out in the streets at sixteen, so she never even finished high school; whereas my father was very, I would say, lucky. He was Canadian, but he was sent to the University of Pennsylvania, the business school, which became the Wharton School, so he was pretty lucky. But my mother was actually the one who pushed education, not my father, my father didn't do much, my mother insisted. Well, she understood the value and so she was the one.

01-00:06:10
Burnett: Who pushed education for the kids?

01-00:06:12
Oldham: Yeah, for the kids, yeah, for the kids.

01-00:06:14
Burnett: And so he's Canadian, I almost detect a little—I guess, I suppose if you're that close to the border, there's a little bit of an accent transfer?

01-00:06:24
Oldham: I would hope, [laughter] but unfortunately, I have that standard Midwestern accent, which 80 percent of Americans have today.

01-00:06:33
Burnett: Right.

01-00:06:35
Oldham: It became the TV English.

01-00:06:39
Burnett: It became received pronunciation?

01-00:06:41
Oldham: Yeah, the—

01-00:06:41
Burnett: Like in the UK, they have a standard pronunciation?

01-00:06:43
Oldham: What I call TV English, yeah, TV English is what dominates now.

01-00:06:47
Burnett: Like the regional became the nonregional.

01-00:06:53
Oldham: Yeah.

01-00:06:53
Burnett: Well, tell me a little bit about—

01-00:06:55
Oldham: And—

01-00:06:57
Burnett: Do you remember anything about World War II? What—?

01-00:07:01
Oldham: Yes. Yeah, World War II was interesting. We had like rationing. "Ray-tioning." Is it "rey-tioning?" "Rah-tioning."

01-00:07:10
Burnett: "Rah-tioning," yeah.

01-00:07:12
Oldham: "Rah-tioning." Anyway, we don't use that word much, maybe it'll come back.

01-00:07:17
Burnett: Right. [laughter]

01-00:07:20
Oldham: So sugar, butter, all those things. I remember my father was into photography and was taking movies then. And I have some old family movies, and there he

is with a hatchet cutting up rubber hose to send in—there was the rubber shortage, all of those kinds of things happening.

01-00:07:39
Burnett: Right, the—

01-00:07:39
Oldham: But—

01-00:07:39
Burnett: —recycling of war materials, yeah?

01-00:07:41
Oldham: Yeah, because there was the shortage of everything. Yeah, so that's what I remember. Other than that, of course it was—again, I wasn't following the news yet.

01-00:07:58
Burnett: Yeah, you would've been eight when the war ended?

01-00:08:01
Oldham: Yeah, I wasn't following the news. Korean War was a different matter. Of course then, I was of an age where you followed the Pusan Perimeter of the Korean War in the newspaper. So, yeah, other than just those things, like we had a so-called Victory garden, we had Victory gardens, we had one in our own backyard, we're growing our own vegetables and that kind of stuff.

01-00:08:23
Burnett: Wow, that's great.

01-00:08:25
Oldham: I spent my summers in Canada. My mother was more than happy to get rid of us for the summer, and I had two sisters, and so we all went to Canada and my grandmother for some reason, loved to take us up there. My grandfather died when I was—yeah, and he died in '45, so I was pretty young. We just spent our summers up in Canada on the lake—it was pretty marvelous up on Lake Huron, so we were very lucky.

01-00:08:57
Burnett: So were they in Windsor, your Canadian side?

01-00:09:01
Oldham: No, they were in Sarnia, which is just up across from Port Huron at the very, bottom of Lake Huron, just where Lake Huron becomes into the St. Clair River.

01-00:09:11
Burnett: Sarnia is steel? What was it?

01-00:09:13
Oldham: No.

01-00:09:13
Burnett: No, what was it?

01-00:09:14
Oldham: Petroleum.

01-00:09:15
Burnett: Petroleum?

01-00:09:16
Oldham: Yeah, it was an oil-refining place. I remember in that period, in the earliest period we used to go up there, I was so impressed because in the forties, the cars were not so common. Some funny, little British cars, which were really cute, it was like those. But a lot of men going to work on bicycles, and that wasn't happening in Detroit, men did not ride bicycles to work at all.

01-00:09:45
Burnett: No, not with [Henry] Ford's plan. That five-dollar-a-day [wage], he wanted people to buy the cars.

01-00:09:54
Oldham: It was a car community, but there within Canada, they still had bicycles, it was very nice.

01-00:10:01
Burnett: It wasn't all that developed outside of the major imperial cities. Like Montreal was a very cosmopolitan city.

01-00:10:12
Oldham: Yes.

01-00:10:11
Burnett: But I remember the story of—my family grew up on—across the border in Manitoba, and for the longest time, you would hit the border going from North Dakota, and it would go from pavement to gravel. It was kind of an underdeveloped, industrial country, you know?

01-00:10:33
Oldham: Yeah, very definitely. Well in those days in Detroit, of course, the small towns were distinct from each other. There was countryside in between, which of course now, most places those are all—it's urban, right? Detroit is some huge urban area like all American cities and the Bay Area especially. But in Canada, you would go a mile outside Sarnia, and it was country. And so we actually lived in a place called Brights Grove, which I regarded as a long distance. It was too long to walk, it was, so you couldn't walk it, right, and I didn't have a bike in Canada, so I didn't bicycle. It was easy bicycle ride, probably five miles or something, and now it's all part of Sarnia. So Brights Grove is part of Sarnia, yeah, so it's like you say, it developed and the gravel roads became paved in the meantime.

01-00:11:34
Burnett: World War II is such a watershed period, and you lived through that, and there's a before and an after. The United States was industrial, and you were in one of the industrial centers in the United States, but development exploded after that. The war effort just made the United States—put it on the trajectory that it's in today and so you were witnessing that as you were growing up. I don't know if it was all that evident except for seeing the differences between Canada and the United States or Canada and the Detroit area.

01-00:12:18
Oldham: Yeah, that was distinct, but of course, the urbanization of America, it's—there's no—it just happened. It's so slow you don't notice it, but until you compare your youth with today. I mean you realize it was—Eisenhower started the interstate system, so that was probably four, five years after the war.

01-00:12:44
Burnett: Oh yeah, even more maybe I think.

01-00:12:45
Oldham: We started to build major, major highways. I guess probably inspired by the autobahns in Germany because—

01-00:12:55
Burnett: Yeah, no doubt.

01-00:12:56
Oldham: And that changed things. That just connected everything so much that—and then it wasn't a long ride to somewhere and then—oh.

01-00:13:08
Burnett: There was a fantasy even before, in the twenties, of this motor society and this vision of a major highway, and the cities would be four miles, two miles on either side of the highway and seventy miles long. And in a way, that's come to pass, right? Everything built around the freeway, and Oakland is an example of that I suppose. Can you talk a little bit about your father? What did your father do?

01-00:13:44
Oldham: My father was a salesman. Again, in those years, you went to work for a company, and you expected to stay with them. Actually, he went to work. Remember he graduated from college just at the start of the Depression, and he got a job with Lees Carpets, Lees Carpets, and he stayed with them his entire life and retired in his sixties, probably around age sixty, so he had a job through the Depression. They didn't pay much of course, and during the Depression, they weren't selling many carpets and then the war, they weren't selling many carpets in the war. I think they were making tank covers or something like that, I don't know what they were doing, but after the war, then was it was good, and the company succeeded and so he kept the job. And my mother never took a job. She did volunteer stuff, she's a big Girl Scout and all

that, but that was how it was then, the woman stayed home and the husband went to work, yeah.

01-00:14:53
Burnett: So he got kind of the company watch at the end of that career that—and he moved up in the organization?

01-00:14:59
Oldham: Yes, he moved up, and that's why we moved to Chicago in the middle of—much to my dismay, we moved to Chicago, I was a junior in high school, and I pretty much had figured out how to run that high school. I was on the newspaper, and I was the photographer. I became the photographer on the newspaper, so I just had the run of the high school. In those days, you have to have hall passes to be in the halls, so if I had all that stuff, I could go anywhere. I mean I had the high school under my thumb and then he moved.

01-00:15:38
Burnett: Oh, no.

01-00:15:40
Oldham: So in the middle of my junior year, I had to start over.

01-00:15:45
Burnett: Well, being a photographer of a school newspaper is often a real stepping-stone in the development of a young student, right? Can you talk a little bit about—? Because as a photographer, you have to be everywhere in all the social, you're photographing the football team, you're photographing—tell me a little bit about that, that kind of work as a formative experience for you?

01-00:16:13
Oldham: I should have learned to be a little more of an entrepreneur. I never became much of an entrepreneur; it wasn't in my family history at all. None of my parents or grandparents—they weren't businessmen. But I used to take movies for the football team and then privately, I'd—the guys wanted movies of them and stuff like that, so yeah, I did that kind of stuff. But as you say, in the school newspaper, you're able to see—you get exposed to things. Like we went a visiting trip to University of Michigan to see the newspaper there, which was a daily newspaper, and we had some kind of a monthly newspaper I guess at high school or something, I don't remember. I was so impressed, I mean I was very impressed. The University of Michigan, I thought that was the mecca of knowledge and all that stuff. And so that I saw some, let's say, academics. I got introduced to that, but it didn't—well, it didn't interest me at that point in my life. I was—

01-00:17:37
Burnett: That's a very prestigious school to this day and at the time, I think it was as well, a regionally excellent school, University of Michigan?

01-00:17:47
Oldham: Yeah. It was a good school. Like I say, it was the only college I was familiar with because we went there and we visit and we were in the newspaper office and the kids are coming and going and doing their stuff. And you're a high school student, and it's awesome, but I went back there. It's very funny when I was—just to jump forward. I'm at Berkeley, ten, fifteen years later, teaching at Berkeley and I get—come out there for—to do a talk at the University of Michigan. I was going to do some talk there or something like that. And I went to find a coffee shop, and there was not an espresso coffee shop in Ann Arbor. I asked around, and there's all these American coffee shops selling this awful drip—not even drip—percolated-type coffee for ten cents a cup but no real coffee. And I said, "This place is not the center of intelligence;" I wrote it off. [laughter]

01-00:18:50
Burnett: What year was that roughly?

01-00:18:51
Oldham: I don't know—

01-00:18:52
Burnett: Like seventy?

01-00:18:52
Oldham: —it was probably early seventies.

01-00:18:54
Burnett: Early—they had not been touched by civilization because—

01-00:18:58
Oldham: Yeah, yeah, it's funny, I had to come there. Whereas Berkeley, there was North Beach and when I was first at Berkeley, there was actually one coffee shop in Berkeley on Euclid Avenue right close to us, and it was Café Espresso, this Italian guy, and the guy who started the competing shop across the street called it Café Depresso, but anyway. [laughter] But there was one, but to get coffee, you went to San Francisco into North Beach and that was—there was all this—I mean it was really great.

01-00:19:35
Burnett: Yeah, the influence of Italian Americans on the culture of the Bay Area is—I mean from wine to coffee to fine food and banking—

01-00:19:44
Oldham: But I thought a university without a decent coffee shop is no university, [laughter] anyway.

01-00:19:51
Burnett: I think that's a fair statement. Well, that became the pattern around the country, for the college town to have these kinds of amenities?

01-00:20:02
Oldham: Yeah, I think, yeah. I don't know why, but, yeah, they were first there and then of course Starbucks came along and that's just—[makes sound], that just exploded everywhere.

01-00:20:12
Burnett: Right, absolutely. Before you moved, before this high school transition, a young guy in the forties and fifties, what do you do for fun? Yeah, what were the passions?

01-00:20:34
Oldham: Well, my father did have hobbies and so that was a little bit of modeling, although he never brought me into his hobbies, I copied them. He was a terrific photographer, way better than I have ever been able to. And my mother was a little bit of an artist. In those days, she would take black-and-white photographs and then color them, that kind of thing, they would do that, they retouched negatives. He actually had a large-format camera, so the negatives were a part of photography. Now, of course, that's all gone, but when—even in 35-millimeter photography, the negatives was something you didn't even deal with. It went into the machine, and out came the positives. So they were doing all that stuff.

01-00:21:22
But at any rate, I got the knack of hobbies, so woodworking and all that. The best course in the high school was machine shop as far as I was concerned and so I learned metal machining, they were great. In high school or in grade school I was the master in the—we had what they called manual training, which was really a woodshop and we learned to do etching of copper and to do woodworking, and we did fancy things. Somewhere I have a picture of myself, I've got to dig it out, presenting this tray we made to Henry Ford II, because the teacher was a bit of, I don't know, a publicist and entrepreneurs, and Henry Ford donated a lot of money to Detroit schools in manual training, in that kind of stuff. And so this guy knew that, my teacher—Mr. Madden—I think was his name—and so he concocted this scheme. His two top students would make this beautiful wooden tray with inserts for glasses and copper engraving and present that to Henry Ford as a thank-you gift for and so there we are. So I have this photograph of myself handing this tray to Henry Ford somewhere.

01-00:22:52
Burnett: Wow.

01-00:22:53
Oldham: It's very cute.

01-00:22:54
Burnett: That is really interesting. And it also makes me think of the—this kind of what the historians call welfare capitalism of the big—the original industrial families taking responsibility.

01-00:23:10
Oldham: The Fords were that way, yeah. I even think Henry [Ford, Sr.] was very much that way, although he has his other dark history, but I think he really realized that he wanted these workers, right, he wanted those workers, yeah.

01-00:23:29
Burnett: Yes, they had an understanding of some kind of pipeline, that if you don't take care of people to a certain degree and prepare them, you're not going to have any workforce, or customers.

01-00:23:39
Oldham: Yeah, although he was so fiercely anti-union, and that was some of the worst parts of his history were anti-union. He was the guy who said, "We got to pay them a buck an hour so that they can buy the cars we're making." He's famous for that. Yeah, anyway, so I did those hobbies. We got into rocketry and—

01-00:23:59
Burnett: You did?

01-00:23:59
Oldham: —things and—

01-00:24:00
Burnett: I was going to ask about that.

01-00:24:02
Oldham: —building rockets and then one day one exploded, and we said, "Wow, that's—" And so we got into making bombs, much more interesting than rockets, and we were doing a lot of that stuff. And luckily about then, we—I moved to Chicago. [laughter]

01-00:24:24
Burnett: You were heading down a dark path?

01-00:24:25
Oldham: I was going on the wrong path. [laughter] We weren't professional bombers or anything, but the things we did today when—we would be seriously in jail or you can't make pipe bombs and explode them in the city. It's just not a thing you can do today.

01-00:24:43
Burnett: But there was a romance around that. I mean even when I was growing up much later in the seventies, friends of mine were into the—the nicknames for these guys would be "pyros," pyromaniacs. One made a rudimentary gun that worked, and my father's best friend blew his thumb off building a rocket. And it was part of like "boy culture" of these things that are attractive to the destructive side of young kids, right?

01-00:25:25
Oldham: Yeah.

01-00:25:27
Burnett: So you were squarely in that, some of those informal traditions of boyhood. Did you have a chemistry set?

01-00:25:40
Oldham: Oh yeah, yeah, yeah. I'll give you one incident. So chemistry was you had glassblowing. You could actually make an alcohol lamp and then by blowing air on the alcohol lamp, it's going to get hot enough to melt glass. Well, this was tricky because then to do glassblowing, you have to blow on the flame to make it hot enough and then you have to blow on the glass, and that was an enormous trick, but we're all trying to do that. And there was an incident where I was doing something in the basement, and I lived in the basement in our house. Eastern houses had basements, so I lived down there, I had set up a shop in there. And so I'm talking about like the first year of high school or last year of grade school kind of thing and with my chemistry set or whatever. And I was able to make some glassblowing thing and so I—so my mother is up in the kitchen reading as she always is. So I come running upstairs with this alcohol lamp and all this and tripped at the top of the stairs, and the alcohol lamp spills on the carpet, and above the carpet are all the coats, they hung in the back of the door to the basement. And so there's these flames coming up on all the coats and so that kind of thing. So my mother gets up from her reading for a minute, and we just take the carpet and throw it outside, and she goes back to reading. This was just like—it's no big deal. [laughter]

01-00:27:14
Burnett: Proof that you were the third child.

01-00:27:16
Oldham: Yeah, it was absolutely proof, yeah. [laughter]

01-00:27:19
Burnett: The other two had worn her down and now you were just—

01-00:27:22
Oldham: She was yeah, she was. And I was a boy too. The other two were girls, and they were into different things, but boys will be boys, yeah, I don't know.

01-00:27:33
Burnett: So there are two other domains that I wanted to ask about with respect to that. One is cars. You had machine shop, and you did metalwork and sometimes there's an—I imagine in Detroit there would've been the automotive shop, no?

01-00:27:52
Oldham: We didn't have that at our high school and so I wasn't into that. I really tried to get my parents to allow me to build a motorcycle. You could build these little—they're really like—

01-00:28:05
Burnett: Scooters.

01-00:28:06
Oldham: —motor scooters more. And they were insistent that I could not do that. They realized that was death and so I wasn't able to do that and very disappointed of course. So I never got into the car culture at all. I was not in the car culture in Detroit.

01-00:28:25
Burnett: Oh, what about electronics, is that later?

01-00:28:30
Oldham: No, I mean we did what little electronics there was. We built our own stuff. I guess that was more when I was in Illinois in high school but we—you build stereos, you build stuff like that. I guess I was into it enough that I remembered there was this store called Allied Electronics in Chicago where you ordered all these parts from, and your dream was to go to that store. I mean can you imagine all that stuff as a kid doing electronics? And then we moved to Chicago, and that was the one good thing, I knew Allied Electronics was there, and I could actually get there on a bicycle from La Grange where we lived. So I must have been a little bit into electronics in Detroit.

01-00:29:16
Burnett: Can you talk a little bit about—and this is hard to do because it's somewhat abstract, but tell me a little bit about the process of building and tinkering and what—not just the skills you learned, but the values you learned. What kind of values do you take away from working on building things from scratch, from—even from kits, what do you take away from that looking back?

01-00:29:55
Oldham: Hmm, I never thought much about that. I really don't have a good answer to that question. I guess what I remember most is when I would meet somebody who had a high skill, and I was always very impressed and hung by that person and tried to get to know that person. Over my career, you come across a dozen people that have exceptional skills in an area—in an area you care about, and so the whole idea is to become friends with them and steal their skills right? [laughter] No, I mean really. Even then I appreciated that kind of thing.

01-00:30:44
I remember it was a little bit later, but when I was working at IBM, there was a guy who could—I used to build electronic things and a printed circuit board that kind of stuff. And then I met a guy at IBM, and we used to do prototypes at IBM of stuff that was going to be an IBM product or something they used. And he did it in a way I never saw anybody do before, and the way—it was neat and just beautiful, it was artwork. I immediately copied that, and I remember later when I built a stereo or something like that and then—you used to build a radio and then you have to take it in to get the—to get it aligned. They called it getting it aligned, that is tuning all the intermediate frequencies in the old superhet radio technology. It doesn't exist today, now it's all digital, but anyway. And so I took this kit in that I had built, and the

guy looked at it and who was going to do the tuning, and he says, "I never saw anything like this." He never saw one that wasn't just this hodgepodge of wire. So I had met that guy, in shop, you would meet people that just knew how to do things and so you copied them. I guess for me, that was the important part of that. My father was this great photographer, and in the darkroom, he had enormous skills, and once in a while, he would let me work with him in the darkroom and so the idea there was just to absorb those things. I don't know, that's about the only profound thing I can remember.

01-00:32:18
Burnett: Well, it is profound. In the history of science and technology, there's this phrase, tacit knowledge, which is as opposed to teaching when you explain something to them in words or directions right, do this, do that. But the research showed that so much of the transfer of knowledge is through this, as you said, absorption. You watch someone do it, you're side by side, shoulder to shoulder working on something, and you notice how people do things. And there's a famous story about the—after World War I, the French confiscated one of those ammonia fertilizer plants or bomb plants, depending on how you look at it, from the Germans and they—

01-00:33:09
Oldham: Nitrogen fixers.

01-00:33:10
Burnett: —yeah, and they took it back to France, and the Germans had all the instructions for how to do this kind of thing, and they [the French] couldn't build it, they couldn't put it back together because so much is in the kind of tactile experience. So you grew up doing things, making things, pulling things apart—

01-00:33:33
Oldham: Yeah, yeah, oh, I mean, my grandfather used to bring me watches and say, "Oh, fix this watch," and of course as a little kid, just I take that thing apart, [laughs] and kids love to do that. It's a wonderful thing, give a kid a watch and a small screwdriver.

01-00:33:50
Burnett: Well—

01-00:33:50
Oldham: But those watches, of course, they're—you can't find them anymore, but they used to be watches you could take apart.

01-00:33:56
Burnett: But that's the thing, right? I know you said kids loved to do that and it—that's maybe the question, is it universal? Is it specific to a time or a particular work culture or a particular set of technologies that are visible? We're going to eventually talk about integrated circuits and stuff that you can see with an electron microscope, but otherwise, you're out of luck in terms of actually

engaging with it. So you grew up with this intense appreciation and involvement in the workings of things, looking at how they work and how they don't work, and an intimacy with objects. Is that fair to say?

01-00:34:46
Oldham: Yeah, it's fair to say, but I think it's—engineers are pretty famous introverts, right? And so you get absorbed with things and you do—your friends are things I guess, I don't know, somewhat as a kid. I mean you still have friends, but they're usually other nerds, anyway, your good friends I mean. I had friends who were not at all into that who were completely different, but mostly you were—you nerds gather together and do nerdy things together. And I don't know, part of it is doing things, but I think it's beyond that. You raised this thing; I'm just thinking in my own experience. Like for instance, I'm a pretty good cyclist, okay, and what it is, is I like—and I'm a pretty decent golfer, I can beat my age at golf, okay? What it is, is I really like to be with somebody who's better than me. So I learned cycling because I joined a club and there were some racers in that, mostly women, who I just follow them and just—and so I became a pretty good cyclist because I just admire somebody who's better than me. I want to be with somebody who's better than me, right? Some people are more competitive, and they just want to be better than everybody and so they don't want to be near anybody better than them, right? When I think about it, I'm gravitated towards people that are better than me because you watch them and just do what they're doing, right?

01-00:36:42
Burnett: Mm-hmm.

01-00:36:43
Oldham: So part of that is in this—in the electronics and all that stuff, but part of it is just part of in general, right?

01-00:36:52
Burnett: Yeah.

01-00:36:52
Oldham: I'm sure in your field, you love to meet these great authors and great thinkers. It's just fascinating to see them and then you maybe don't consciously, but you definitely imitate them, right?

01-00:37:10
Burnett: Yeah. We're interested in the ingredients of what makes up somebody, you know?

01-00:37:19
Oldham: Absolutely, absolutely.

01-00:37:20
Burnett: It's not to objectify people, but it's not like taking apart a watch, but what makes someone tick, right, that phrase, that expression, what makes somebody tick. There's that. Now, the way you describe it, it could be, oh, that sounds

cold, like I wanted to be around people who were interested in the same things, but not for them as the whole person and all of that. But there's a converse to this in that in your later life in your career, the boundary between social world and the work world, is that somewhat blurry? Because you talked about friendships as being this kind of—through the instruments or they were the instruments to get to the things, right? Is that somehow also part of engineering culture later? You don't have to answer this now, but it's just as I'm thinking, is there a blurriness around engineering culture where the people you work with are your friends and you're friends with the people you work with?

01-00:38:34
Oldham: No, I think that's overdone. You have friends quite independent of that; although I think it's really important to be friends with your colleagues. And as I'll say later, one of the marvelous things I found at Berkeley was—I was friends with almost everybody, not everybody but a large fraction of the people in my department, and that really makes a difference. It just makes you want to go to work. Not only do you like the work, but you like the interaction with the people so that's a marvelous thing. But friends outside, that also happens, it's just how you meet them. For instance, people who are very religious, they go to church and so meet all those people through their church and other people meet them through their kids. And you have kids, so you go to—you meet them at the schools and all of that stuff. So you have friends quite distinct from your work, and they become very good friends, so it isn't that exclusively. But nerd like other nerds, I mean I like to sit down—now that I'm old, all you do is you talk about illnesses, right, when you're old, but what's more fun in a day to sit down and talk about what's hot in integrated circuits? [laughter]

01-00:40:00
Burnett: Absolutely, absolutely. So eleventh grade, you're sixteen, seventeen, sixteen—fifteen, sixteen?

01-00:40:10
Oldham: Yeah, sixteen, yeah.

01-00:40:12
Burnett: So you're sixteen and so mid-fifties, '54, you end up going to Chicago, and you land there, and you said it's a different story. So you had to kind of start over socially?

01-00:40:29
Oldham: Yeah, socially you start over, yes, and you don't have the school. Like I had the school knocked, and I could do anything I wanted to around the school because I knew who the important people were. So you start over, and I started—you have to start innocent again, right? I always said in education, it was always—I always was amused by—in education that there's always a freshman class whether it's in grade school or high school, college. The

seniors are these, well, knowledgeable assholes who just knock the—and make fun of and make life tough for the freshmen, right? Okay. In those schools where there's a junior high and a high, it happens twice. What amazed me was it happens—oh, and then the kids come in and they're naïve and plastic, they're plastic. The kids come in as freshmen, they're plastic, you can have them do things. Senior, you forget about it, you can't tell a senior anything. I don't care if it's in high school or college, you can't tell them anything, they know everything. What's amazing to me was they come to grad school, they're plastic again. These hard-boiled, tough kids who made life miserable for the freshman come in as first-year graduate students, and they're plastic again. It's just the most marvelous thing.

01-00:42:14
Burnett: Well, it's by design to a degree, right? I think there is this notion in terms of the structure of education.

01-00:42:21
Oldham: Yeah. So I came into the second school, and I had to start over. So I actually got on more of an academic track. I actually took academics seriously, math, and I did all that stuff in Detroit, but I liked shop better. In second high school, I went into chemistry. We had a good—a pretty good chemistry teacher, we had a really terrific math teacher, and a pretty good physics teacher, so those subjects were great. I always tell these kids, "If you get one great teacher, marvelous, that's all you need, you need one good teacher, especially if you get one every year, oh man, then your life is cool because—" but I had several so that made a big change, I was lucky. I mean that was one of the first of my many lucky coincidences that determined my fate.

01-00:43:26
Burnett: Do you think that it was not as good where you were in Detroit?

01-00:43:31
Oldham: Oh yeah, the high school was. I mean let's put this way of, the kids who went to that school in Detroit, probably, 30, 40 percent went to college or something. I don't know what it was in those days in the fifties. But in the school in Illinois in La Grange, probably 80 to 90 percent, they all went to college, so—

01-00:43:51
Burnett: So La Grange was a suburb of—?

01-00:43:54
Oldham: It was a suburban school, which is a good suburban school. It would be analogous to like the—where I live now, Orinda, those schools. It would be analogous to that.

01-00:44:02
Burnett: Right, right. And so your father got a promotion, things got better financially I guess?

01-00:44:10
Oldham: Well, I think he was in regional sales for Detroit area, Michigan and then he took over sort of the middle of—middle United States, so Chicago was the office. So it was definitely some kind of a promotion, yeah.

01-00:44:28
Burnett: Right, right, yeah, yeah, absolutely. Chicago is the center for the inland economy, right?

01-00:44:35
Oldham: Yeah.

01-00:44:37
Burnett: All roads, all railroads lead to Chicago in that important sense. So you get there, and you had a better education, and this is pre-Sputnik too, so there wasn't necessarily this big push with it.

01-00:44:51
Oldham: There was—no—yeah, that was not the thing. It was postwar economy, so it was good. Let's see, I'm trying to remember now, Eisenhower was elected in 195—

01-00:45:07
Burnett: Fifty—

01-00:45:07
Oldham: —fifty-two.

01-00:45:08
Burnett: That's right.

01-00:45:09
Oldham: Yeah, so he was elected in '52, so it was the Eisenhower years, so we were starting on this amazing building of the middle class. I think that's when the middle class was really built. That's when factory workers, the one time in America when factory workers became middle class.

01-00:45:27
Burnett: That's true.

01-00:45:27
Oldham: No longer true, but it was true then. They had strong unions and—yeah.

01-00:45:35
Burnett: Someone with a high school education could have a nice home with two cars, and kids going to college—it was this window of opportunity, you're right, absolutely. And so from your perspective, the fifties were—it sounds kind of idyllic in a way, right, that there was opportunities for you to explore and develop your passions? And so give me a picture of—by the same token, there wasn't necessarily this concern in the fifties with—your full life trajectory was not in front of you necessarily and clearly defined. But to the extent that there

was talk or thought about the future as you were getting close to finishing high school, what were you thinking about for a future?

01-00:46:46
Oldham: Okay. It really was a turning point. I can remember no thoughts or discussions about what I do after high school when I lived in Detroit. Now I'm sure I had them, and I had this model of the school newspaper going to Ann Arbor. We did an annual trip to Ann Arbor, and it was a great thing, and it was inspiring. So I probably thought I was going to go to college then, I'm not sure because I can't remember but that—moving to Illinois made the difference. See, the other thing that happened is that I was sixteen, and up to that age including the year we moved to Illinois, including my sixteenth year because I remember I could drive then. I was sixteen you can drive, and we were still in Detroit. I went to Canada that summer, it was the last summer I went to Canada to live with my grandmother. And when we moved to Illinois the next summer, which was the summer of my—I guess between junior and senior year, I said, "Well, I can't go to Canada" because all I did in Canada is I played golf. I worked some, but they were paying fifty cents an hour, and I says, "Yeah, I don't get it, my grandmother will give me a couple of bucks a week, what do I need to work for fifty cents an hour for?" I could pick up golf balls and sell them for a buck when we needed to buy some comic books, which was a major expense was buying comic books.

01-00:48:21
Burnett: Oh yeah?

01-00:48:21
Oldham: I didn't work and so I said, "I have to stay here in Illinois and work." That was one thing and so I introduced myself to the hard, cruel world because I couldn't get a job, there was no summer job. So I convinced my buddy to—that he—and I had a buddy already in Illinois, and I convinced him to make lawn signs with the numbers of your houses. Here you paint them on curbs, but in Detroit, they didn't paint them on curbs or in Illinois in this suburbia. So we made these fancy signs, and they could stick in their lawn what their house number. And then I got introduced to the fact that it's really hard to sell these things, marketing and all that, so I learned about the kind of things I was good at, which was making the lawn signs and developing a process to make a lawn signs fast and effectively. But selling them, that's like a whole different thing, and I realized I'm no good at that, and I hate it. I hate knocking on doors, I hate it when you go around and say, "Would you like to buy a lawn sign?" Oh, that was so hard for me, so I learned about that.

01-00:49:44
Burnett: You learned what you were good at and what you didn't like?

01-00:49:48
Oldham: Yeah.

01-00:49:48
Burnett: That's important, that's really important.

01-00:49:51
Oldham: So we were doing that for about three to four weeks, and my buddy's dad worked at Corn Products Refining Company, which is headquartered in Chicago. A couple of kids in Chicago who work there in the office in the summer, in the downtown office in Chicago, a couple of kids were working there, young kids, not so much kids, they're probably eighteen or nineteen, the office boy and all that stuff got thrown in jail for murder. They murdered somebody and—

01-00:50:31
Burnett: Who did?

01-00:50:32
Oldham: —a couple of kids working at Corn Products and so they were short a couple of kids in the central office and so my buddy's dad worked at Corn Products. I don't know what he did there, but he said, "Oh, well, I got a couple of guys who could come in and fill in," and so I got an office job at Corn Products and my other buddy did too. He was the mail guy, he ran around from floor to floor with the mail, and I replaced people who were doing this dumb office work that people do, matching billings, the ladings, doing—adding up numbers and then stamping them, and they go on, and they pay the bills and all that kind of stuff. Luckily I worked, we had a job, so I got introduced to—the first time, it was a real job. And actually, I worked at Corn Products the next summer in a lab, and they had a lab where they measured the properties of their starches, and again my buddy and I both worked at the lab. His dad was wonderful to get me. He called me a second son, so he was nice. So he set me up out there, so I had two jobs there. So my life really changed, I became interested in academics in high school and then I had some experience of the—what it is to work, although not in a kind of work I wanted to do but in the summer. It was a very lucky incident for me compared to just this thing I was doing in Detroit, which was not necessarily a good direction.

01-00:52:13
Burnett: Well, it was a childhood, it was a full childhood of comic books and rockets and coming of age and—

01-00:52:21
Oldham: Well, I always had two lives. The life in Canada was completely different to the life in Detroit, completely different, and just like now, my life in Maui is completely different than my life here. Here, I have a machine shop and I built engines for cars and I do that. Over there, I play golf, I volunteer, I bicycle, it's completely different. So I always somehow did that, but anyway, I got introduced to some things by that move that were really good for me.

01-00:52:53
Burnett: And you mentioned that this wasn't want you wanted to do, so you already had some notion, perhaps negatively, of a domain that you wanted. You wanted to go to college.

01-00:53:06
Oldham: Yeah. Okay, fast-forward a little bit here, about sixty years, my last trip to visit my sister in Detroit a month ago, I made contact with my two closest buddies from Detroit. I hadn't seem then since 1954, and these were the guys who were building the rockets, which became bombs and building bombs. And it turns out, they both became electrical engineers and successful, they're both retired. One of them had his own business, and they're both alive, which is also marvelous. I love to find my old friends alive, which you don't so often anymore. And very interesting that we both—we all had sort of parallel interests, so we were destined to become electrical engineers.

01-00:54:06
Burnett: It ends up being part of the age, right? I think the enthusiasm around radio, and I can't remember now exactly when the term "Age of Electronics" is coined, but there was enthusiasm around that. I think it became clear without even thinking about it that that was this—the frontier.

01-00:54:34
Oldham: Well of course, that had—I mean that's kind of a societal perspective. As an individual, it wasn't true for me. I mean I didn't have any desire to go into electronics at that point and my buddies neither. At that point, they weren't doing any electronics. I was fooling around, I made phonographs and stuff like that, but I didn't want to become an electrical engineer or anything like that. And it's just very curious that all three of us were—

01-00:55:12
Burnett: Did you have a mentor in high school who talked to you about college or your parents? Did you have conversations with your parents about college?

01-00:55:27
Oldham: See, my mother didn't go to college. My two sisters were much different. One of them, my oldest sister went to junior college, and she didn't get a push to just go to a real college and so she went to a local junior college, met a guy, got married. So she got her education ten years later or fifteen years later, and she eventually became a mathematician and taught math. My other sister went to the local junior college in Illinois, which was part of the high school, and then she went on to college and became a teacher. My mother was probably more interested in me going to college, although she never pushed, and my father was mainly concerned about the cost. He wanted me to go to some local college and all that stuff, and he says, "Oh, it's going to cost—you know," so. By the time of my high school years, I was—by then I had met a lot of people, and there was—recruiters came to our high school. I mean it was a good enough high school, recruiters came and stuff, so I was interested in going to college. And I was mostly interested in—I don't know—I think the ones I

eventually applied to were Caltech and MIT, and there was a Carnegie Tech, which was really a nothing school then, Carnegie Institute of Technology compared to MIT and Caltech. But there was a great recruiter who came to our high school and talked about it and then they hook you up with people to talk to and everything and local alumni, and so on, yeah. So, yes, so by then, I was determined I was going to go to college. I didn't know what I was going to be. Actually in the three different schools, I applied in different departments just because I didn't know.

01-00:57:31
Burnett: Do you remember which departments?

01-00:57:33
Oldham: I don't remember. I know at Carnegie, I was a chem engineer, Carnegie Tech, and I don't remember at MIT and Caltech what I was or how rigid they were about declaring a major before you come in. I can't remember but—

01-00:57:49
Burnett: I mean if you're doing ChemE, [chemical engineering], you come from Detroit, you work at Corn Products in Illinois, you have some familiarity with large industrial organizations, so that's somewhat on the horizon, right, for you?

01-00:58:09
Oldham: High school chemistry is a marvelous thing. I'm sure it's what high school biology could be and maybe is today. [coughs] Excuse me, maybe you turn that off because, see, I'm going to cough.

[break in audio]

01-00:58:28
Oldham: In my experience in the fifties, high school chemistry was the subject that was most inspiring in that—I mean if—I guess if you like formulas and stuff, math is inspiring because it's so logical and has this wondrous stuff. But chemistry, I remember the periodic chart when I really understood the periodic chart, I mean understood, I mean different meaning, but it really was powerful. You saw amazing things possible. And so chemistry is—was very attractive then as a field, math was pretty good too, and I had a good math teacher, so I was thinking about math too, but I don't think I applied in math to any schools but—

01-00:59:26
Burnett: Did you do calculus in high school?

01-00:59:28
Oldham: In those days, you didn't. Although my math teacher was a guy who would work with you after school and stuff, so he wanted me to learn linear algebra, I think, which I did just as a project on the side. He knew that calculus you get—when you go to college, bingo, calculus is the first subject, so he didn't

have to teach me calculus. He wanted to teach me some things I wouldn't learn in college and so—yeah.

01-01:00:06
Burnett: What do you think was helpful about learning linear algebra, and why was it not part of the basic curriculum, and what is it used for, let's say, to be crude about it?

01-01:00:25
Oldham: Yeah, linear algebra is the kind of thing—it's not as interesting. In engineering there's electrical engineering, on the one side there's communications, communication theory, all of that stuff, and on the other side is the physical side of electronics, building electronics. And one side use one kind of mathematics, we use differential equations, it's all differential equations. On the other side, they do all this—the other kind of math, which is state spaces and all this other kind of math, which linear algebra plays into that. So it's important, but it isn't one of the first subjects you get to, and you may never get to it unless you're a mathematician, yeah. So, yeah, so I was encouraged in that, but you don't know what you're going to do in those days. I was going to go to college and—

01-01:01:32
Burnett: And figure it out.

01-01:01:33
Oldham: —and figure it out. I guess money had something to do with it. My father really didn't want to pay any money, and in those days, he went to—and mind you, he went to a private school. He went from Canada where—well, his father was a tailor and had lost most of his money in the Depression, but that was after my father went to college, that's what happened. So he had some money, he had a very successful tailor shop in Sarnia, and my father went to the University of Pennsylvania, you think about that. My two daughter or two sisters went to junior colleges, he wanted me to go to a local school. He thought Evanston was perfectly good. Well, that's private school, and I had no interest in going anywhere near Chicago to college. And Carnegie Tech was $800 a year tuition, and Caltech was $600 a year tuition in those days, imagine, MIT was in that range too. So I was going to go to Caltech because it was $600 a year, then Carnegie gave me a half scholarship and that was—so it was only going to be $400 a year tuition—it's so stupid—so that's why I went to Carnegie Tech. I mean they had a good recruiter, and I had a good impression, but I went to and I visited. I remember I took a train out to West Lafayette, so I visited Purdue and some other schools, but I had no interest in going to Michigan or Illinois or any of those schools. I don't know why; I have no idea.

01-01:03:14
Burnett: Interesting.

01-01:03:17
Oldham: But you hear of these other schools and I think they—maybe they all had recruiters or something, I don't know. Well, Caltech didn't have recruiters. They take 200 students a year, so.

01-01:03:32
Burnett: So, yeah, it may have come down to conversations with recruiters, and they mentioned something that was attractive to you is the way they presented it. But that was—

01-01:03:40
Oldham: No idea.

01-01:03:40
Burnett: There are some amazing people have come out of Carnegie Tech before it became Carnegie Mellon of your generation, Nobel Prize-winning economists. It was not a slouch school at all.

01-01:03:54
Oldham: They had some centers of excellence and I don't know. And this silly department I was in, it was like fifteen faculty members, it was a hodgepodge. I knew them all, I knew every faculty member there, which is not true at Berkeley in electrical engineering. I don't know two-thirds of them now. [laughter]

01-01:04:16
Burnett: And you worked there.

01-01:04:17
Oldham: But I've been retired for eighteen years. There were some really good people who came out, yeah, there were some really good people, so that was a good thing. That was one of the good fortunes, and I regard Carnegie as a good fortune, and it would have been true at Caltech, too, simply because of the size. So they let you do things there. I had the experience in high school because I was always photography or something that was critical—I think I did photography in Illinois too—so I kind of got the run of the place and able to do some things I wasn't able to do. And at Carnegie Technology, it was just such a place, I knew all the faculty, and the department chair, I knew, so I'm going to the department chair's office and say, "I'd like to take this physics course instead of this other course," and they would let you do things like that. So this flexibility of letting you do—it made sense—do things was a really good thing.

01-01:05:30
Burnett: I also read about the Carnegie plan, which was put in place in 1938, and it sounds a little bit like R. M. Hutchin's plan for the University of Chicago. But the idea was that they wanted well-rounded engineers, and they had a requirement for humanities and social sciences, so there was a real emphasis at Carnegie Tech on cultivating the intellectual and humanistic side of the students. Did you encounter any of that, did you—or you were just self-

directed, you were going out and saying, "I want to do this, and I want to do that," and they let you. Do you think that was maybe part of it that—

01-01:06:16
Oldham: Well, you realize in those days, most schools, engineering schools had a very set curriculum. You had if you were lucky, you had one—what do they call? One course a year, you could choose what it was. It's an elective, they call it elective.

01-01:06:34
Burnett: Sure.

01-01:06:34
Oldham: As if that the very concept of naming it an elective meant that everything else was rigid.

01-01:06:44
Burnett: Right.

01-01:06:44
Oldham: Right? And that's how it was, so, and that was true everywhere, that was engineering. You had to take freshmen physics, calculus, chemistry, first year, all that stuff. But Carnegie, you could talk them out of it, you could. And the humanities, yeah, to answer your question, I didn't find a big difference when I came back to Berkeley and was teaching here about the requirements for humanities here versus there, completely different than Europe. In Europe, it's totally different when you go into engineering, you do engineering, no taking classes in history. You learned that in high school because they're way ahead of us in their high schools, way ahead of us.

01-01:07:30
Burnett: Right, so as—

01-01:07:31
Oldham: We catch up in college.

01-01:07:33
Burnett: Right, right, right, that's interesting.

01-01:07:35
Oldham: I mentioned in preparing for this that I had a number of things that I thought were lucky, good fortune things, which steer your career in a direction, which is—turns out to be good, and that was one of them. That was a fact that the particular chair we had, Rod Williams, let us do things, which were—I mean later on for instance, when we—I had two good friends who were undergraduates there who also stayed there for graduate school. And the three of us went into his office and said, "Well, you have this exam, why do we have this exam at the end of our first year for a master's degree, a comprehensive exam and then you have another one a year later called a qualifying exam?" He says, "I'll tell you what," he says, "if you guys will take

the language requirement course—" you had to pass a test in translation. "If you'll do that then you can take the qualifying exam at the end of your first, so you eliminate one whole exam." That was not in the books, that was not written down anywhere, the department chairman there—you can't do that at Berkeley by the way, the department chairman does not have that kind of authority, but anyway, you did there and so we said "Big deal."

01-01:09:20

So we started, in the morning, we'd go in at 6:00 a.m. and translate German from 6:00 to 8:00, the three of us. We just get the dictionary out and get some articles and translate it into English, and we did that for about—every morning for about six months. And then two out of the three of us passed the exam and then we skipped the whole—so we're able to then take the qualifying exam in our first year. So it was the kind of thing you could do there, it was—it's marvelous.

01-01:09:56
Burnett: Now when you were asking to take particular courses, you had some idea, what was governing those choices, what you were thinking of?

01-01:10:09
Oldham: Well, it's just talking to other kids who—and then you look at the course. We still had some courses here, not so much at Berkeley, but we still some when I came here that were silly requirements, I mean that were, let's say, historical, and they hadn't yet gotten rid of them. Only a few years before I came here did they get rid of surveying. Everybody had to take surveying, I mean what a silly thing so—

01-01:10:39
Burnett: So its roots were in civil engineering and—yeah.

01-01:10:41
Oldham: And there used to be a drafting requirement and all those kinds of things, and those are required. Well, there was a course at Carnegie called—I don't know what it's called—something about materials, but it was not a modern materials course, so I says—and I had some friends who were physicists, and they had this atomics physics course as sophomores, which was really the introduction to modern physics, you know. And I was able to take that instead of the materials course, so it was fabulous and again the department chair said, "Okay."

01-01:11:15
Burnett: So you're maybe on the cusp of the—of engineering education evolving into what it would become, and you took the initiative to say I want to do what's the new stuff is on offer, and I want to take advantage of that?

01-01:11:33
Oldham: Yeah, it wasn't so much new, it's just—yeah, I thought, I don't know. I guess the word "interesting" doesn't say why it's interesting, but it was definitely interesting. It wasn't about sex, which would have been way more interesting.

01-01:11:52
Burnett: Right, so—

01-01:11:52
Oldham: It was about—

01-01:11:53
Burnett: —the number two slot. Yeah, yeah, yeah.

01-01:11:55
Oldham: But anyway, yeah, it was more interesting stuff.

01-01:11:59
Burnett: Yeah, okay. But you were learning, you said, your introduction to modern physics, and we talked about the chemistry, which was huge in the fifties. It's the atomic age and so chemistry and the chemical industries are important.

01-01:12:21
Oldham: Yeah. So they had a great freshman chemistry course. It's one of those giant courses of a room full of people. At that period, all colleges in engineering and sciences, you—as a freshman, you took the freshman chemistry course. They had this huge hall at Berkeley where they used to offer that course, I don't know if they still do, I think they still do. And it's a marvelous subject, I mean it just follows and you learn about. It's taught incorrectly in that they're—in the old days, they used to teach—I don't know how they do it today—they teach—well, we used to take biology first and then you would take chemistry and then you would take physics, and it's just totally wrong. I mean you should take physics and then you take chemistry and then you take biology, that's how it should be. But biology, in those days, was all just memorizing stuff and I just—I never took it in college. I only took it in high school and said, "Not for me."

01-01:13:30
Burnett: It wasn't cognitively or intellectually challenging.

01-01:13:35
Oldham: Well, it's challenging, you had to memorize all this stuff—

01-01:13:36
Burnett: No, but yeah—

01-01:13:37
Oldham: —I hated it.

01-01:13:38
Burnett: —memorizing is just kind of a—

01-01:13:40
Oldham: But yeah, yeah—

01-01:13:39
Burnett: —lower-level function.

01-01:13:40
Oldham: Now modern biology is just—it's about electrons, you know?

01-01:13:47
Burnett: Yeah, right.

01-01:13:47
Oldham: And the word *electron* did not come into biology in those days, yeah.

01-01:13:51
Burnett: No, that molecular biology was being formed when you were in college, and it was only being done at Caltech for example. You would have had to go there, and you might have had a different trajectory if you'd gone there. So the chance occurrences shaped the range of options for you?

01-01:14:15
Oldham: Yeah, and another chance occurrence, a silly one, when I went to Carnegie Tech, I took a train, I think. I think I took a train to Pittsburgh. I don't think I flew, and then I had a small suitcase, and my father was going to come with all my stuff. I walked from downtown Pittsburgh up to Carnegie Technology, it's about three or four, five miles, I don't know, dragging my little suitcase because I didn't know how the transportation worked, and I didn't need them, I could walk. And then I was met by these fraternity guys. It turns out there was something called fraternity rush; I didn't know anything about it. Nobody had told me about that, what fraternities were and all that. I met and I joined a fraternity.

01-01:15:03
That would turn out to be a marvelous thing because immediately, I had a group of similar guys who were going to be freshmen, who were going to be abused by the fraternity and made lifetime friends. They're still friends today. We have a very good group, and it provided a structured living situation and then opportunity for leadership. By sophomore year, I was treasure of the fraternity and then of course I was the president in junior year, and so on. So, it turned out to be just a terrific experiment. I hate to see what has happened in that whole world of fraternities—they become centers of drugs and all that stuff. The fraternity I was in was thrown out of Carnegie Tech at some point—

01-01:15:57
Burnett: Oh, no.

01-01:15:57
Oldham: —because of drug abuse later in the sixties. That's another lucky thing, drugs came five years later, I was very lucky because that really messed up a lot of kids, so—

01-01:16:11
Burnett: Yeah, and you were teaching by then, and we'll talk about that when we get to that period.

01-01:16:16
Oldham: Anyway, so just that. The other big thing, and you mentioned already, is Sputnik. Sputnik happened when I was like right then in—I don't know when it was in the—just in college or just late high school, I think in college. When was Sputnik like '60—?

01-01:16:34
Burnett: Fifty-seven.

01-01:16:36
Oldham: —fifty-seven, yeah, okay. I was like a sophomore in college. It totally changed things, the whole orientation towards technology. In particular, they gave a lot of money to universities, and Carnegie got a lot of money from them. Later on, I got a four-year fellowship as a graduate student because it was a Sputnik-based fellowship inspired by Sputnik, and again because of knowing people there, I talked my way into that. Anyway, that's another thing, but that determined actually one of the factors why I stayed at Carnegie because I just had four years of support, with other things, but it was just an accident that. Although it turned the world to looking at the importance of technology, right?

01-01:17:42
Burnett: Mm-hmm.

01-01:17:44
Oldham: And it didn't make me—I never understood that. Really at that point, I can't claim to have understood that this was going to be this growth opportunity and all that. Not many people did actually understand where that was going. Gordon Moore did, Gordon Moore did, right, a little bit later?

01-01:18:06
Burnett: Right. Well, for Carnegie like for a lot of the engineering schools and the universities, these regional centers often had centers of excellence. So University of Cincinnati had aeronautical engineering that became aerospace engineering, and there was that tie-in with NASA. And Carnegie—

01-01:18:29
Oldham: Caltech had JPL.

01-01:18:31
Burnett: Right. And so Carnegie is industrial, and I imagine it's materials, but with an emphasis on oil and gas and steel and chemicals and that kind of thing. So it really—kind of what is today Rust Belt industries.

01-01:18:52
Oldham: I think they had a good materials science department. I didn't know what that was and didn't—it turns out I'm a materials guy. I didn't know it then; it dawned on me much later in my career that I'm basically a materials guy. So I had no attraction to materials science there, yeah.

01-01:19:15
Burnett: So the National Defense Education Act is passed in '58, and I imagine that's where a lot of the money comes from to build out these programs?

01-01:19:23
Oldham: New labs—

01-01:19:25
Burnett: Tech, tech, tech.

01-01:19:27
Oldham: —and research money. Research money was really important because then the faculty could do interesting things, provide interesting tools for their graduate students, yeah.

01-01:19:41
Burnett: So in the undergraduate years, it's this exposure to the different kind of parent disciplines that are going to be instrumental in allowing you to become the engineer you're going to be?

01-01:19:58
Oldham: Yeah.

01-01:20:00
Burnett: A lot of people do the four-year degree or five years if it's the certain kind of programs and then you're an engineering and you go at engineer things and you go to work for industry or go out as a consultant or whatever. But is it because you had the funding to go through that you were like, no, graduate school is what I'm going to do?

01-01:20:28
Oldham: I don't know the answer to that. I don't know how that process even worked in me. I know that for instance, I was a chemist—chem engineer coming into Carnegie Tech, I was one of the stars in freshman chemistry. I still have today this book called *Handbook of Chemistry and Physics* from that year of '56 or '57 edition. It's this wonderful book, it's a fabulous book, it has every thermal conductivity, every melting point of all the materials, all the chemistry. All the interesting chemical data are in that thing. And they gave that to the top five students in chemistry, okay, so of the class of, I don't know, a few hundred

kids. I got that, I mean I was a good chemist, but I said, "This isn't for me." At the end of that year, I says, "Look I'm not a to do this because there's organic chemistry," and it's like biology, you have to memorize all this stuff. Organic chemistry was presented as a memorization exercise not as how the electrons resonate in certain bonds or something like that. It was just done wrong, and I said, "Forget about it, I'm not going to do chem engineering." And there was this other department of electrical engineering, and I went over and talked to them, and I switched that year to electrical engineering. So I didn't have any career objectives, I didn't, I'm just a student still stumbling along. Of course, then, in electrical engineering, they had this wonderful, small faculty. I got to know them, I did research as an undergrad, I met my thesis advisor Arthur Milnes, so my senior I—he had me doing some projects. I don't remember exactly what they were but—

01-01:22:31
Burnett: Well, let me ask you about that in terms of engineering pedagogy, right? And it might be a clue in explaining why you found something interesting as opposed to, and there are now two examples where you've said, strict memorization is boring for you. You're bored by that because it's just—

01-01:22:50
Oldham: Well, it was also hard. It was difficult; I'm not good at it.

01-01:22:57
Burnett: Well, we're inching towards what you are good at, and I think there's an engagement with—maybe problem solving is too reaching. But that you're learning tools, or the veil is being lifted in these domains when you're learning physics and chemistry. So part of it is being exposed to the organizing structure, the mathematical structures, and the mathematical relationships among physical things in the world, right? Because it's engineering, were there examples, was there talk about application even in a strict atomic physics course?

01-01:23:47
Oldham: No, in general, no, no. But it was logical, and you were learning about—a little bit about how the world works. I just listened last week to—I like these books about the twelve most important advances in physics or something like that, and I get these books, mostly books on tape. And it's very interesting what's happening in astrophysics and in all these things. So that part was really good, it's inspiring, and it's done in a logical way, so you don't have any problem remembering that one thing follows the next, follows the next, so that was a periodic table in chemistry to me. The periodic table made chemistry make sense, it just made sense, and once it makes sense, you can't forget it. You don't have to memorize anything. Maybe you have to memorize what the symbol is or is it gadolinium or you have to memorize the name or the symbol, but the whole thing makes sense. And so that's what bothered me about organic chemistry, I never saw that it made sense, and it was going to be too much work to learn all that crap, so I said why should I do that. And I

talked to electrical engineers, and they had a totally different philosophy, which they talked about—they called it part of the Carnegie Plan or something. But they constantly introduced exam problems, which were not covered in the homework, which were not covered. They provided you with some tools, some analytical tools and then they asked you the most absurd questions on exams. And so the sophomore course was like a revelation like that, and it was actually fun.

01-01:25:48
Burnett: Hmm.

01-01:25:50
Oldham: Whereas 90 percent of what we do is we—if you look at all the home problems for the last six weeks and then you're going to take the midterm, you know it's similar to those home problems. It wasn't at Carnegie Tech, I don't know why, in electrical engineering, they give you some problem and then you can start to attack it with those tools. I like that, I don't know, I like that.

01-01:26:22
Burnett: And to return to the fraternity, it doesn't have to be the fraternity, but in terms of the social side of it, and we've talked a lot about this already, this sense of a culture, right? Did that play into it as well that there was—you get together and talk about the exam and how you engage with the problems? Was there a culture of talking about applying the tools to fix problems?

01-01:26:53
Oldham: No. [laughter] The fraternity was a social organization, and there was nobody. There was one guy Hugh Young who was a—had been in that fraternity. He was now as a young professor at Carnegie Tech. And he was kind of a model, mostly because he came—he was also a musician, and he came back and led us in Greek Sing, he was the course leader in Greek Sing. But he taught physics at Carnegie Technology, that was his career, and he was the world's greatest teacher, he had the greatest textbook all that stuff. I never had him as a teacher, and I can't sing as the leader of the chorus, but he would identify the voices, "Now, you just be a little quiet there, and you louder." [laughter] That's how it was done. But in the fraternity when I was there, there were no other scholars. There were no—I'm trying to think, in—definitely not in electrical engineering and I'm trying to think in engineering. All the guys in there were in lighter subjects, so the worst one was printing. They still had the school of printing management, which was one of the old—

01-01:28:16
Burnett: Like typesetting, that kind of thing?

01-01:28:18
Oldham: They actually had a freshman course where they did typesetting. Carnegie Tech was a trade school, and then became—but they still had this niche where all the fathers in the world who had printshops had to find a place to send their sons to college, they send them to Carnegie Technology. I think in my class,

we had like twenty pledges that year and maybe at least six were printers, we called them printers, and it was a Mickey Mouse curriculum. They had a special math course, which was worse than the high school math and they had—it was a Mickey Mouse thing. And they learned the printing management they called it and so they had some really low-level management courses and stuff. And so those guys who were the important guys for running the parties and all that stuff; they had a lot of time. So I was one of those guys who—I just came in there. On Monday, we got our assignments, and I just spent Monday and Tuesday night, did all my homework for the week, got that taken care of so then I could be one of the fraternity guys for the rest of the week. And there was no studying there, no studying except—well, I just went into my room. Yeah, there was not.

01-01:29:39
Burnett: But it was an important socialization experience.

01-01:29:44
Oldham: Oh, yeah.

01-01:29:44
Burnett: If you're still in touch with these people now, it tells you something about what happened there.

01-01:29:52
Oldham: Not one of those printers went back to their father's shop. They all grew up in college. All their fathers sent them there, so they come back to their father's shop, not one went back, very interesting. One of my good friends, he became an English professor at University of Oregon. He's still up there and lives in Eugene. And he got out, and he said, "Pff," he's not going to become a printer and so he went on and gradually became—got his PhD and became an English teacher. So they were not dumb people, but they had a pretty low-level curriculum at Carnegie. So that was not important. The important part, like you say, was the social and the opportunity for doing leadership there, and we had some good, stressful times, and we had a lot of fun and so, yeah.

01-01:30:47
Burnett: Yeah. It was part of the—master's is folded into the whole PhD thing, right?

01-01:30:57
Oldham: Yeah, in those days and it's still true today, the bachelor's degree is one place you can leave college and do something. You can't be a much of an engineer. I always said that you learn as much in the one-year master's degree about engineering or more than you did in the four years before. You easily doubled your usefulness as an engineer, easily in any field because it's all this prepared—all the math and physics and humanities stuff you're taking and getting ready to really learn the hard stuff. And the master's degree, you learned useful skills, useful skills.

01-01:31:46

Also, did I mention another thing that was again a lucky—I think a lucky thing because I had worked at Corn Products for the end of my junior year in high school and at the end of my senior year. So between high school and college, I was in the lab. And then I switched to electrical engineering, they didn't let me work there anymore, they didn't want electrical engineers. After my freshman year in college, I can't remember which year, anyway, I did work one year for National Capital Parks, in Washington, but then my junior year, I got a job at IBM in New York, and that was again a very lucky experience in many ways because they taught me about electronics there. At Carnegie Tech, they were still teaching us about [vacuum] tubes. My senior year, they did have a course with transistors. You think about this back—there was no integrated circuitry, nothing about transistors, but I learned about that at IBM. When I went to IBM, they took their vacations en masse so that it was closed, but a few engineers were around. And so I went in, and there was a couple of engineers, and one guy says, "Well, what do you know about transistors?" I said, "I don't know anything." So a couple of days, he taught me about transistors one-on-one and then that's how I learned about transistors. And so when I went back to school, I was ahead of the game, and it was just again a lucky thing.

01-01:33:48

So that then allowed me to do things differently, and it's just one of those—and then I went back there after my senior year too at IBM because once you go to a place if they like you and you like them, then you went back. So after my senior year, I went back to IBM, and those are great experiences for a kid in college, those industrial experiences. You see how it works, do you want to be doing this or not and everything and so I had no interest in going out then after that. I knew what engineers did, and I had no interest in that level of engineering, so I definitely was going to go to graduate school.

01-01:34:38
Burnett: And that's an informal process? It's just engineering schools have relationships with industry, but it's not a formal work-study program.

01-01:34:49
Oldham: No. They do have those. I didn't know about them. I'm not very good at that kind of thing and so I didn't know about that. But somehow, I don't remember how I got my job at IBM, but probably talking to somebody who knew somebody there, you know how it works, and then I got it. So, yeah, so that determined that I was going to go to graduate school, and as I say, the graduate school determined by—pretty much by $400 a year in scholarship.

01-01:35:27
Burnett: And it took care of that, yeah, yeah, yeah.

01-01:35:30
Oldham: Four hundred dollars a year, right.

01-01:35:31
Burnett: Well, that's not nothing in those days.

01-01:35:35
Oldham: Yeah.

01-01:35:36
Burnett: So tell me a little bit more about some of the people that were intellectual mentors or the great teachers that you had at Carnegie, especially as you were working in graduate school and—because you have to think up a thesis topic right, a dissertation topic. Talk to me a little bit about the people there.

01-01:36:10
Oldham: Yeah. So when I was undergraduate, Carnegie still had a lot of sort of—I don't know what you call them—temporary faculty. They had like probably—I don't know what the numbers were—let's say ten fully fledged, tenured professors of various levels, mostly associate and professors. But they would hire people and have them three or four years and so there's a lot of young guys and so some of those I don't remember. There was one young professor, Ángel Jordán, so Angel Jordan is what people called him and one senior guy, Arthur Milnes who were ethe faculty in semiconductor electronics. And Arthur Milnes had recently learned it himself. He, of course, was a magnetics guy, that had changed him. Carnegie Tech was a big center of magnetics, and they still are. They had this guy Finzi who really knew magnetics well and so they were the center of magnetics expertise. And Milnes came in there as a magnetics guy and realized that this is not where the world was going. He was smart enough to figure that out, and he taught himself electronics and then he was a guy who first taught the transistor courses there and so on. And then he was later of course my thesis advisor, but at that point, I was able to just get an undergraduate relationship with him. He would give me little assignments in the lab and I would—he says, "Well, you know. " I went off to Western Electrical in time to learn a process there that he wanted in his lab and stuff like that so that was a great relationship. He was a very reserved Englishman but actually had this deep sense of humor, and he was a good guy. The other guy Ángel Jordán was only five years—three or four years maybe even then from his PhD and so he really was a young guy. And it was a small place, he knew all the students, we knew all the faculty. It was very—a good environment.

01-01:38:53
Burnett: Well, moving into the space of electronics, can you talk a little bit about, what, the kind of moment if you can where you hit upon this area that you wanted to cultivate for your dissertation?

01-01:39:20
Oldham: Oh yeah, yeah. How it's done is generally students have an interest—when we're trying to get a graduate student here, some students apply and they're interested in some broad range of solid-state electronics usually. And then we

look at their backgrounds and maybe make them an offer of a research assistantship or something. It's done with money, right?

01-01:39:46
Burnett: Mm-hmm.

01-01:39:46
Oldham: It's done with money. The best students, I'm talking about the best students. Some students, they just want to get admitted, and they'll worry about paying for it after they get there, but the best students, there's this negotiation. I learned about enough that I decided that semiconductor electronics was going to be what I was interested in in graduate school, but other than that, I didn't know, so Arthur Milnes. And the process of finding a grad school, I don't know if you want to talk about that, but how did I get to Carnegie in graduate school is a question that partly it was again money because—I did have a fellowship offer at Stanford. I can't remember, I didn't even apply to Berkeley because Berkeley required two foreign languages and that was the—again foreign language is you're talking about memorization.

01-01:40:53
Burnett: Mm-hmm, interesting.

01-01:40:55
Oldham: And I had no interest in languages at that point. I didn't understand that it was really fun to learn a foreign language, I had no clue, [laughter] and so—

01-01:41:05
Burnett: But you got a fellowship to Stanford.

01-01:41:08
Oldham: Yeah, yeah, I had a fellowship in Stanford, an offer, just that one year. They offer you—we always do that, you offer them a big, luxurious, one-year fellowship. And then the assumption is that second year, you be the associate of some faculty member, and they'll support you, you know. But my wife wasn't admitted to Stanford. She was a biology [major], bacteriology, and she was admitted to Berkeley, so that was an issue. I don't even think I applied to Berkeley because I saw those two foreign languages, so we had that problem. I went to Rod Williams again. I said, "Rod, you got these four-year national defense fellowships, and I think you have six or eight of them for next year, and you're offering them to all the top students around the country, but you got some students here, Bob Gregory and myself, Don Scharfetter, you're not offering them to us." And I said, "I've got a fellowship at Stanford, so I'm thinking of going there" and then he offered me one. [laughter]

01-01:42:23
Burnett: That's really interesting that they just assumed that—yeah I don't know, I don't know what they assumed but—

01-01:42:30
Oldham: Well they really wanted to collect, and they did get a great bunch of students, these guys were good guys. I was trying to think of their names. How do I remember their names from these years? But some people are better than that, but I'm getting to that age where you forget things, and so. I remember Art Riben, and he went off, he was a professor at Connecticut; Joe Charleston went off, a professor at Missouri; and there were other ones. Some of them went to IBM, and so on. Industrial labs were very, very attractive to go to, you know?

01-01:43:08
Burnett: Yeah.

01-01:43:10
Oldham: They were successful students, but he had a strategy. He says, "I can get the guys here because I'm just going to offer them one year." He offered us some fellowships, and we knew we'd be taken care of, but the idea. So that determined, that finally determined it again, so it was money again that I chose how to determine my career.

01-01:43:33
Burnett: Well, not only because you've mentioned a wife.

01-01:43:38
Oldham: My wife, yeah, and it's a package deal.

01-01:43:40
Burnett: So you got to back up here. Tell me about your wife.

01-01:43:46
Oldham: Well, I met her at Carnegie Tech, she's same year as me, and we decided to get married at the end of our—get your bachelor's degree and then both the parents were—they're okay with that. And my parents knew I was financially independent anyway at that point. For one thing, I had a small inheritance of I think $5000. Well, that was a lot of money then.

01-01:44:11
Burnett: It was, yeah.

01-01:44:13
Oldham: When I got that, I was twenty-one, so end of my junior year when I got that, and that was the end of financial support from my family. But it turns out, we didn't need financial support because my wife and I both had financial support in college, so we actually saved money in college, you know?

01-01:44:34
Burnett: Right.

01-01:44:35
Oldham: But, yeah, so we both had to find a school to go to—

01-01:44:38
Burnett: Together.

01-01:44:38
Oldham: —and it wasn't clear. We hadn't negotiated if she was going to do a PhD or not or this or that, I don't know, and eventually she decided not to do a PhD. So she just did one year at Carnegie; she could do it there too—

01-01:44:51
Burnett: Yeah, and that was—

01-01:44:51
Oldham: —so—

01-01:44:52
Burnett: —biology that she did?

01-01:44:53
Oldham: She did—I forget—I think it was called biology. She was a bacteriologist, but I think it's some—they were—Carnegie Tech was still a trade school then. When she went, she went to the Margaret Morrison Carnegie College for Women, they called that Maggie Murph, and that had things like home economics and things like that, so it was a place for women to do that. But in that, they had some science-based departments, and she went to bacteriology and got interested in biology—bacteriology. So she was actually a legitimate trained in bacteriology and then—I can't remember. She did some graduate work at Pitt, at the University of Pittsburgh, but she got her degree, her master's degree at Carnegie, yeah.

01-01:45:54
Burnett: Okay. So you were assured of support through the full—

01-01:46:05
Oldham: Yeah.

01-01:46:05
Burnett: —graduate program? Well, maybe we should leave until next time the discussion of the thesis and the interest in the particular subject matter. Are there other people that you wanted to mention or friends who are—? I mean Rod Williams was in charge of the department in ChemE or in electrical. And I think off-camera you mentioned a Feucht?

01-01:46:41
Oldham: Oh yeah, well the faculty there were the new, young faculty member. They brought him in about that year, Don Feucht as a new young solid-state faculty member because really, they only had at that point as regular faculty Milnes and Jordan—and Jordan, and that's kind of thin in that area. And so they brought Feucht in that year. They had a couple of other guys who were just kind of flowing through, and they were PhDs, and they'd keep a couple of years and move them on through, so there were some other people. And then

about that time they brought Dick Longini in from Westinghouse who was a local. He's a very knowledgeable and experienced guy in—I think probably trained physics, Dick Longini, I'm not sure but he was from Westinghouse Labs.

01-01:47:38
Burnett: Out in New York, is that right?

01-01:47:40
Oldham: No, Westinghouse was in Pittsburgh.

01-01:47:42
Burnett: In Pittsburgh, okay.

01-01:47:42
Oldham: Westinghouse was a Pittsburgh company, and it was the major employer for Carnegie Tech both in materials and in electronics. Yeah. Yeah, so Dick Longini, he was a faculty member. I can't remember. I had a couple of really close buddies from undergraduate school—well I had many but a couple of—a couple three close ones, Don Scharfetter who was an undergrad in electrical engineering with me; Bob Gregory, undergrad in electrical engineering with me; yeah, and Bart Alexander, undergrad in electrical engineering with me, and all three of us decided to stay on at Carnegie Tech. Bob because his wife was a junior, his would—future-to-be wife was a junior, and he couldn't get married till she was a senior, so he stayed there, and I stayed there. And Don Scharfetter, he was a guy who's pretty much figured he could get in two or three years if he stayed there, and he did. I think he did his PhD from his BS in two and a half years. And Bart Alexander stayed as a psych major, he decided to switch fields, he was in management, and they were close friends. It also plays a role, right, it also plays a role. All of them are dead by the way, all of those, my buddies, and that was—that happens. And not—because I'm eight-three, it was a cancer one ten years ago kind of thing. But—

01-01:49:28
Burnett: Did you smoke?

01-01:49:30
Oldham: I didn't. No, they didn't either, none of them smoked, no, but just it's the—

01-01:49:38
Burnett: It's the actuarial reality, right?

01-01:49:40
Oldham: Yeah it's—yeah.

01-01:49:41
Burnett: Yeah. Well, it's interesting, this moment at the end of the 1950s, the National Defense Education Act, the Sputnik concerns, the Cold War, the shift from valve electronics to solid-state, and that's right at the cusp. I mean Westinghouse, they made tubes, right?

01-01:50:08
Oldham: Yeah they made tubes, they thought they were going to be in the transistor business too at that point.

01-01:50:13
Burnett: I bet they did, yeah.

01-01:50:14
Oldham: Like what did they call it? Oh, they had a name. Molecular electronics, they invented their new name for that technology, and they were going to do this technology, and they had a research lab. It was the days when companies had research labs. They had a good research lab out there. That's probably where Longini came from, I don't know, but like most of them, General Electric and all, they were unsuccessful in electronics, most companies were.

01-01:50:44
Burnett: Yeah. Well, we should talk about the evolution of the industry as we go through and maybe musings and reflections on why that is, why was these dynamic, newer companies out west that became so important.

01-01:51:05
Oldham: We could do that because it was close to that.

01-01:51:08
Burnett: I bet, right, right. Well, why don't we pause for now, and we can take up next time?

01-01:51:15
Oldham: Okay, good.

01-01:51:16
Burnett: Thank you.

Interview 2: July 22, 2021

02-00:00:13
Burnett: This is Paul Burnett interviewing Dr. Bill Oldham for the University History Series, and this is our second session, and it's July 22, 2021, and we are here in the Oakland Hills. Welcome back.

02-00:00:28
Oldham: Thank you and thanks for the coffee.

02-00:00:29
Burnett: Yeah, you're welcome. So the last time we talked, we were discussing your graduate education at the Carnegie Institute, and some of the faculty, and some of your experiences. I'm wondering if you can tell us a little bit about settling on a dissertation topic and the work of doing the dissertation and the path that that led you down?

02-00:01:03
Oldham: Okay. As I think I said earlier, I had contact with Arthur Milnes who was going to become my thesis advisor as an undergraduate and did some work for him as a senior. And then I started graduated school, and the first year is mostly you just take a lot of classes, but you start your research program. And I can't remember what it was, but he had some things he was interested in and suggested to me, and I looked at them, and I didn't have much interest in them frankly, it was kind of dull stuff. And we were intensively reading the literature a little bit in the coursework but just—you just get into that then. And there were some hot topics—this was very birth of the transistor and integrated circuit era—so that hot topic then was heterojunctions, heterojunctions. And all that it is it just means—there was something called p-n junctions, that's the basis of all transistors, the p-n junction. And heterojunction just mean a junction between dissimilar materials, so germanium and silicon or whatever.

02-00:02:47

And about the same time—well let's say the actual discovery was a few years earlier, Professor Welker in Germany who was at that time I think working—he was working at Siemens, he discovered these III-V compounds were semiconductors, so-called III-V compounds, which are well-known today because all these LED lights are—that's gallium nitride, that's III-V gallium, three nitrogen, five, III-V compound. At this time, the hot material was gallium arsenide and indium phosphide and materials which were somewhat similar to silicon and germanium in their properties but superior in electron transport so that's why they were exciting. And so I was more interested in that stuff, yeah, and it was interesting because Arthur had a research program in heterojunctions, and he had a couple of other students working on them. But he had—in a research program, you have, of course, some positions to be—to—that are paid for and then you don't have any more and you're fresh out of ideas for topics, and so.

02-00:04:21

But anyway, I got interested in that, and I puttered along that first year. I don't know what exactly I did that first year frankly, but I puttered along and then I took a summer job at Bell Labs and met a remarkable fellow at Bell Labs, Carl Frosch, bless his soul, he was really a genius. I think he started at Bell Labs working on telephone poles, better creosote for telephone poles or something like that. But anyway, he became the guru of silicon and had a lot to do with major inventions in silicon, silicon dioxide and so on. And he was growing gallium phosphide, a III-V compound, in a very strange way, which we didn't understand. And so I wasn't working for him, I was working for another chap, Art D'Asaro, but at Bell Labs in the summer, they let you do what you want and so I attempted and did duplicate Carl Frosch's apparatus and tried to reproduce his results. And it was a very interesting time, discovered some interesting things, finally figured out how it even worked because he didn't know, but it worked. He was just a genius at making things happen; he had no clue how it really worked. It turns out it was a rubber hose he had bringing the hydrogen in and oxygen was diffusing through the rubber hose and—

02-00:06:04
Burnett: Wow, just kind of an accident.

02-00:06:06
Oldham: That trace amount of oxygen was actually responsible for what was going on, but anyway. So I got interested in this transport process, and when I came back to Carnegie, I duplicated that and did some more work on that and was reading literature on other ways and built a number of apparatuses both closed—so-called closed tube where you make a reactor out of a quartz tube and then you actually close the ends with—as glassblowing technique and then you have this reactor in a bottle like a ship in a bottle. And then you do the reaction in there, get it done, and then you open it up and—anyway, it's a very interesting method. I did hundreds of those and then I did a lot of open tube and so I just got into making stuff like that, materials.

02-00:07:07

And my thesis ended up on—it was called, I don't know, "N-n Semiconductor Heterojunctions," but I did just a lot of fabrication of junctions. And then you explore their electrical properties and then you try and figure out why they behave the way they do, and that was the subject of my thesis. But there's a lot of material in there that I never finished and published. I just got a copy this week in preparation for this, and I was looking at it again, and it was very cool. That was age where tunnel diodes were discovered and so I actually made some tunnel diodes that were heterojunctions, and it was really cool stuff, very enjoyable. That was my second year I was doing that and had a lot of success. And I remember Arthur saying to me, "Bill," he says, "you're not supposed to be working on heterojunctions," and I said, "Yeah, but I am, and it's very interesting," and he had no problem with that.

02-00:08:19
Burnett: Right. Well, he recognized that if you're enthusiastic about it, and you had that exposure. You said something earlier about taking a summer job at Bell Labs. Can you talk a little bit about Bell Labs itself and its function with respect to the education and growth of talent in American science and engineering?

02-00:08:48
Oldham: Yes, Bell Labs is pretty well-known, of course, as a pretty famous research institution, but you realize at that time, RCA Labs was really amazing. They did amazing stuff on III-V compounds. When I was a student, they used to produce these reports because it was military funded, and those were the hot stuff. When those reports came out, I was on them because they were really doing cutting-edge stuff, RCA Labs, GE Labs. R. N. Hall of GE Labs was a coinventor of the semiconductor laser. IBM Labs, when Fairchild was started out here when the five or six guys left Shockley and formed Fairchild, they set up a research lab. Gordon Moore was director of research. So every big company had a research lab, and this was the era of research at companies and was—it was just a fabulous era. I think that it's why the US was preeminent in semiconductors for the next thirty, fifty years because they did all this work and trained all these people and got it going. You wonder today when none of those exist anymore. They all—

02-00:10:15
Burnett: Well, that's—

02-00:10:15
Oldham: —one by one died, and there's not a significant research lab left.

02-00:10:21
Burnett: That's what I want to explore with you, what are the consequences of the shifts over time that take place in terms of the evolution of institutions? One thought that's been bandied about in talking to people about Bell Labs is that a lot of that talent that came out of and through Bell Labs migrated to leadership positions in the research universities. There was a modeling exercise: they took elements of Bell Labs, what worked at Bell Labs or what they thought worked at Bell Labs and changed what happened at the research universities and took on some of those functions. If there are no grand industrial laboratories anymore, where else is this research being done except at NSF-funded or department-of-defense funded research that's going on at universities, or privately funded research? Is that partly what you think might have happened, or is there maybe another explanation for it?

02-00:11:33
Oldham: I don't know the role of universities modeling their research programs after the industrial research. I never thought about that, so I think my thoughts about that would not be coherent.

02-00:11:54
Burnett: Okay.

02-00:11:56
Oldham: But I know some of the Cal campuses, particularly Santa Barbara, benefited very much from the collapse of industrial labs. In San Diego, they hired these people in, and they became preeminent. Herb Kroemer at Santa Barbara, Nobel Prize winner. Herb was, of course, German. I remember his papers very much, he had a theory of negative effective mass, which was just fascinating. And then later when I was a consultant at Fairchild, I met Herb Kroemer, and I found out he's just a human being. And he then migrated from Fairchild research to Santa Barbara, and Santa Barbara hired a number of really good people that way—I won't be able to come up with all the names—and San Diego too. And so what happened is they were good research institutions, but in the field of like semiconductors, they really benefited. But I think it was as much just the people as I don't know if the style or the mode of the research was a gift from the laboratories or—that I don't know.

02-00:13:23
Burnett: Yeah. I think it was definitely a people transfer, and you described it as a collapse, it was sudden.

02-00:13:30
Oldham: I almost went to Bell Labs myself because these were marvelous places. In my summer job, it was really great. I'm out there, I could do a lot of other things, but on Saturdays, I was in at Bell Labs because there was fun to be had. And you could do what you wanted and it was just a great place, and I said, "Boy, what's wrong with this?" One of my good college friends went to Bell Labs, and of course that worked for about ten years and then as they just started to disintegrate, it became a very bad place. They kept changing the rules. For a while, it was very strange. At Bell Labs, of course, they had the research area and the development area, and they competed, which was really a wonderful, healthy thing, they competed. Then suddenly in the development area, they said, "Well, if you publish, that's against your record. It will just delay your promotions." This was really an amazing thing, and let's talk about changing the rules. Before if you published and you were famous, you advanced, and now, it's the opposite, and so there were these—I don't know exactly all the internal pressures, but it has to do with this, as we've seen in the US, the corporate ethos was to make money above all and to grow, grow, grow. I can't remember in that period because—maybe because I wasn't alert to the financial situation, but it seemed to me that the idea that a company has to grow 5 or 10 percent a year or nobody wants its stock, it seemed to me that wasn't the case. It seemed to me people bought stocks because they made money and a grocery store was fine, it made money every day—you know? But if it wasn't growing now, I mean in the last twenty years, then it's not valued, and I think that was probably what happened and so everybody focused on growth.

02-00:16:04
Burnett: With a certain timeframe too, so a shorter turnaround.

02-00:16:08
Oldham: Growth, growth, growth, and I think they found these labs were, in the short term, expensive. I don't know. But it's very interesting. One by one, the labs—There was a classic—GE bought RCA, as you know, and they really bought it for their—what do you call their software? They bought it for their—

02-00:16:39
Burnett: Intellectual property?

02-00:16:40
Oldham: —movies and that part of it, because RCA had this big—I forget what it was, is it or was it NBC or something? Anyway, they had enormous numbers of films and programs that were their source of actual profits. And so GE bought RCA and just took it apart and sold it off, the brand. They sold off the name, and they sold off this and that, and so of course the labs disappeared. And GE Labs were pretty good then. As their senior people got older, they didn't hire the younger people to replace them, and they disappeared. IBM was probably the slowest to totally shut down their laboratory research, but that's pretty well done now.

02-00:17:37
Burnett: This was an enormous resource for research, for training? I hadn't thought as much about the fact that you had graduate students going through the labs in these summer positions, and that provided you exposure to—you got ideas about directions to go from being at Bell Labs.

02-00:18:02
Oldham: And more than that, you got models of maybe effective ways to do research. I'll talk about that at some point, but this method of using your colleagues, not competing with them is really important to me—especially in my later career, but we'll talk about that. But, at Bell, Labs what was wonderful that I saw was—it was this hallway, Bell Labs was this horrible hallway. It was because they had put air-conditioning in later and so it was really barely—your head barely cleared the ceiling of this hallway. But all these, there would be a room off of it with a person in there and their little experiments and another one and another one, but these people walked from room to room and talked to each other. So if you had a problem, like I was doing some electron or some x-ray diffraction work, and there was—the expert was there, so you walked down the hall, and you walk in and say, "You got a minute?" And then you're talking to the top person in the field, and you can make real progress, and that's how it worked. That was important, and it didn't sink in on me then as much as later with later industrial experience—I had later industrial experience—and how important that is—the culture of sharing.

02-00:19:46
Burnett: Yeah. I read that there was kind of—I don't know if this is true or not but there was design that way, there's design to force people to interact and set up the way the—architecturally.

02-00:20:00
Oldham: Bell Labs was—there was no architect in Bell Labs, that was just a dreadful building but—

02-00:20:07
Burnett: The Murray Hill campus—

02-00:20:08
Oldham: —it turned out that way, yeah, in Murray Hill.

02-00:20:09
Burnett: Okay, it wasn't—[laughter] It was a modernist—[Burnett was thinking of the Holmdel Complex, designed by Eero Saarinen].

02-00:20:14
Oldham: It was just this long hallway with these rooms off it. Each of it had their little fume hoods, and it was like a whole bunch of chemistry labs all strung down a hallway, and that's how they did labs then. I mean Siemens was the same way. When I went to Siemens in Europe, it's the same way.

02-00:20:35
Burnett: Well, I want to talk about that as well because that was a brand-new lab at the time that building that you went to.

02-00:20:40
Oldham: No, no, that was later at Siemens. I've been at Siemens several times.

02-00:20:44
Burnett: Oh, okay, got you. Well, we do want to talk about that too. So you're getting inspiration for the subject matter, for improving what you're doing, and the methodologies for going about things, and contacts too, meeting people—

02-00:21:06
Oldham: Yes.

02-00:21:07
Burnett: —getting back to that social connection. So there are these compounds instead of just straight-up silicon as a semiconductor. There would be like gallium phosphide and are these—so you're interested in the particular properties of these materials, but you're also making them and growing them. Is there a part of that research that you're more interested in or the actual practice of making these materials, or you're actually really trying to understand? Is there a kind of quest around it and that like in an alchemical sense, are you looking for a new substance, a new compound that will have real advantages or potential advantages, or is more just straight-up curiosity?

02-00:22:24
Oldham: I don't know the answer to that. I was pretty naïve about silicon. I think most people were—about why silicon was destined to be the material that all of technology relied on for the last fifty years, and it had to do with silicon dioxide. At that point, the MOS [metal-oxide semiconductor] transistor was

not yet a functional—I mean the concept had been around for twenty years, the field-effect transistor—but the MOS transistor was not yet an item. And in fact, the research that was being done that I read suggested that it could never work. And so I had friends who were interested and had heard about it and were going to work on MOS, and I tried to talk them out of it. I said, "Look, it's never going to work, and here's why." I showed them the papers and what the measurements were and so on but—

02-00:23:43

So anybody who worked on III-V compounds then, and RCA Labs, as I said, was preeminent in that, and they were doing it because it was a government contract, not because they had a technology in mind to make RCA money. There was a government contract available, and some people regarded that as a huge mistake, a way to guide your research. Don't guide your research where the money is, guide your research where you want to go, right, and find the money. And RCA was one of those that took government money, but they were doing this marvelous work, and there were marvelous properties, but it took me years to understand that silicon had this huge advantage of this oxide where the interface, the surface of the silicon was passivated, where it didn't have bad electronic properties. The surface of all materials have bad electronic properties fundamentally because if you just take a surface, you interrupt—you interrupt this wonderful, orderly structure. A crystal has this periodic structure, and it's that periodic structure which gives rise to the electronic properties. If you terminate it, you really create a mess. And silicon had this unique property that silicon dioxide would passivate that and make that a tolerable surface, and none of the other materials did, and I didn't understand the importance of that nor did most people at that time, okay.

02-00:25:26

So I worked on these other materials, and they were way more interesting because other people didn't have access to them. I could make them, I couldn't make silicon and buy silicon. I could actually grow silicon, epitaxial growth, and I did a lot of that too. But these other materials just—it was just fun. You can make these things, and they had wonderful properties. I did things like p-n junctions, p-p junction between two materials, n-n junctions, and their properties are unknown, it was kind of cool. So you looked at them and—

02-00:26:09
Burnett: So what turns out to be the—your basic transistor is typically a PNP or an NPN, is that—?

02-00:26:17
Oldham: In those days, bipolar transistors ruled because, as I say, in the fifties, they did not have stable interfaces. There was no way to make a stable interface, so it was really—let me see, when did MOS transistors become stable? People were making them already in the early sixties, but it was really late sixties, so probably ten years later. It took maybe ten years to solve the problems of the silicon interface because the silicon—the MOS transistor, which is all

transistors today, there's almost no bipolar, I mean there's a little bit, but no, the NPN transistors, those—they're oxide, oxide involved. And those things took over by the mid-seventies. There were still bipolar guys until the eighties that thought they could still do it, IBM in particular, but of course they had no chance, they had no chance whatsoever.

02-00:27:32
Burnett: There was just so much more efficient and so much better—?

02-00:27:35
Oldham: Well, it has to do with the fact that we went from circuits, which a computer was built of individual transistors, so there was thousands of transistors in a computer. Well today, there's billions of transistors in a computer, and that means they're pretty small and have to be packed together, and they can't dissipate any significant amount of energy and that's—only can be done with MOS. But nobody—I mean I wouldn't say nobody, but most people did not envision that we were going to have by the eighties a million transistors—

02-00:28:16
Burnett: On a single chip, on a single—

02-00:28:17
Oldham: —on a chip.

02-00:28:17
Burnett: —chip, on a single surface.

02-00:28:18
Oldham: Most people did not envision that; there were people who did.

02-00:28:25
Burnett: Yeah. I guess the [Gordon] Moore article of '65 where he talks about that doubling time. There are so many avenues to explore, and I do want to talk about your 1977 *Scientific American* article in another session maybe because it's such a great pulling back the veil of the process of manufacturing semiconductors, or integrated circuits rather. You talk about making substances, can you give us a very brief kind of cooking lesson in how you make a substance? What were the ingredients that are involved in the processes in those days for you?

02-00:29:14
Oldham: So we knew if you want to make a semiconductor, the classic way was to chemically refine the ingredients. This germanium, you take some germanium compound, it's very—first of all, you're going to make a crystal of germanium and silicon, you refine it as a chemical first where the chemist had wonderful methods like distillation. Like how do you make alcohol? You separate the alcohol from the water, distillation. And so they had all these wonderful ways to purify materials too and so that's what happens. So you do that, then you turn that into a crystal, so they reduce it to some kind of a crystal, then they continue to refine it. In both the germanium and silicon case, so you grow this

ingot of silicon, but then they did this process they called zone refining where they melt a little zone in it and move it through, and the impurities go with it and that kind of thing. So anyways, there are all these methods of getting pure, and purity was everything. This was a new age of purities where purities used to be parts per million of things. Then you had when you bought some—you went to the chemistry store and bought chemicals, it was parts per million of stuff in it, and now it had to be parts per billion, it was like a different thing because of this electronic sensitivity to impurities. And so it turns out that early on in the business, somebody—and I don't know who invented epitaxial growth, but there's this process called epitaxial growth, and it's a wonderful, big word. It's kind of like the physicians do, they have big words to talk about simple things. [laughter] They use Greek here, epitaxial growth.

02-00:31:29

So all it is, you have a perfectly good crystal of something, but you want a layer of it to have higher doping or opposite doping. One's n-type and the other one wants to be p-type, or so on. Instead of diffusing an impurity into it, which it can only increase the impurity levels, you can grow a layer of it on top of another. You might think you could just evaporate, just heat it and evaporate it, and it turns out that's a very dirty process, and you don't do it that way, you do it chemically, and that's—they call it an epi-growth. So typically, a halide, silicon chloride or a silicon that was typically one of the chlorides of silicon that you would reduce to grow silicon on silicon. And then it turns out the halides of the group III elements are also very favorable for this, so you could use, for instance, gallium [chloride] to transport gallium in the vapor and have it reduce itself to gallium, and the chlorine goes off pretty easily in a vapor form and so that's what we did. You could move the group V element, the phosphorous or the arsenic, whatever it is, as a vapor in a tube or in a reactor. But the group III element, which is a metal like gallium or indium or—you move that as a halide.

02-00:33:17

And so through the literature, you see how people do this and then you just go and build that reactor. It's a little bit like science almost where you see somebody else do something, you say, "Hey, I'm going to reproduce that and see." And you do that and then, immediately, you think of four better ways to do it and then that's where you go, right?

02-00:33:40

Burnett: Well, yeah, there's that—the communalism or the openness of science is operative in that sharing the knowledge leads to this—they call it the marketplace of ideas, I suppose. But instead of it being a closed market where someone sells something for profit and its proprietary and secret, your goal is openness, you want to maximize openness.

02-00:34:04

Oldham: And that's right, and it was open then. When you think about it, a lot of the papers we were reading came out of industrial labs. Part of it because they took contracts. RCA took government contracts, so they had to publish. They had to publish reports. Some of it came in the literature, but they had to publish government reports, which you could get, but a lot of it was in the open. IBM published an awful lot of stuff in the open literature and they had a publication. They did that for patent protection too because once you publish it, somebody else couldn't patent it. And they didn't know if it was going to be any good, so they couldn't keep it a trade secret because they didn't know if they're going to use it, so they just publish it. It was very interesting and so a lot of the ideas of how you do growth came from that.

02-00:34:55
Burnett: My memory of history of Bell Labs is fuzzy, but I think that—wasn't there something about a dollar or 1 percent of every long-distance bill went to the fund for Bell Labs? As a public utility, it had certain kinds of public responsibilities, and I'm wondering if that was part of the openness piece of those kinds of things? I don't know.

02-00:35:26
Oldham: I don't know, I'm skeptical.

02-00:35:29
Burnett: Yeah, they were fairly proprietary?

02-00:35:33
Oldham: One of the things that that I saw at Bell Labs was they had this research and so they—like you say, they have a public duty to do some research or something, I don't know. They had a research division that was—what was that? It was Area 1, they called that Area 1, and then they had a development group division and that was Area 2. When I was there, I was working at Area 2. Well, Area 2 competed with Area 1. They wanted to show they were just as good or better, so they were publishing like hell to show that they were just as good as—it was a very healthy—I mean from the point of view of the world, it was a very healthy situation. I don't know if it's healthy for AT&T, but it was very healthy for the world because these two groups were competing and publishing. So it was great. I mean the journals then were just so good.

02-00:36:36
Burnett: Oh, yeah. Well, the change might have come later where Bell Labs got more interested in—I think there was the tiny bit of code that became Berkeley Unix, and they sued the University of California because "that's us and that came from us." I don't know if that's a turning point where they became more interested in getting a piece of what was coming out of Bell Labs or making sure they got their piece.

02-00:37:05
Oldham: I don't know. The relationship was pretty good all through that. Even though they was maybe a lawsuit, that was all still pretty good. I really don't know the story on that.

02-00:37:18
Burnett: Well, in any case, it's fascinating to talk about the process of the work and the spirit—I think you've used the word *ethos* of the work—and what your goals are and what the ground rules are for research. Why are you doing this work? And that's something I'd like to talk about throughout, but you're saying there's an openness at that time.

02-00:37:49
Oldham: There was. It was very, very positive to publish and people were—that summer at Bell Labs was important because not only did I—well, I met these great guys. Carl Frosch, he was just such a great guy. It's wonderful to meet these really legendary people, and they're just ordinary people, and they treat you well, and it's just like you feel good about yourself, and you want to stay in that field. You don't appreciate it so much at the time; it's just—I just look back. At the time, it was just, okay, I don't think about it, but later on, I look back and say that's really important.

02-00:38:42
Burnett: Yeah, being civil, being kind.

02-00:38:45
Oldham: Okay, so I had a great supervisor that was a young guy, Art D'Asaro. I used to commute with him actually into Bell Labs daily, so we'd have these conversations. He would let me do whatever, and he suggested some things, and I got going on them and then I met this Carl Frosch and got going on those experiments. But I had my official boss, which was Art D'Asaro's supervisor was Friedolf Smits, and Friedolf Smits played some role in my life also, so it was a good thing.

02-00:39:35
Oldham: Friedolf Smits came along later because—Sandia was run by Bell Labs, and he took a period at—they used to ship these Bell Labs managers up to Sandia, and he was a manager there. And so he made me come to Sandia for an interview out in Albuquerque, and I did that, and actually from that, I convinced one of my friends. I didn't want that job out there, but I convinced one of my friends this was a place to interview, and he went there. And so then later in my life in '66, I went there for the summer and that played a role, so. It's all from that Bell Labs contact, all these things happened, you know?

02-00:40:27
Burnett: Right. And so you finished your dissertation, and what year is that, that's—?

02-00:40:36
Oldham: That was '63 and so in '60–'61, I was just a student. Sixty-one–'62, I was really doing the bulk of my thesis, and in '62–'63 I was mainly writing papers and writing my thesis. I was going to finish in '63, and that was important that in my life that my advisor, Arthur Milnes, this Brit said, "Well, why—?" And I was going to go to Bell Labs probably. I mean I had been at IBM too, but Bell Labs was the most immediate thing, and it was just a great place, but I had

interviewed at [UC] Berkeley. I guess I had given a paper at this big summer conference, which was the device conference, the conference in our field, and a fellow from Berkeley had been there and then invited me out there for an interview. And I also had a contact with somebody, Tom Everhart, who was spending the year at Westinghouse in Pittsburgh, and because I did the interview, then Tom Everhart contacted me and tried to recruit me to Berkeley. And I was noncommittal, and I didn't know what I was going to do except I'm probably going to go to Bell Labs.

02-00:42:19

And then Arthur Milnes said, "Well, why don't you take a year and go to Europe?" He says, "I bet you I can get a job in England," Arthur Milnes and so he did. He was a Brit, and he had good contacts in England, and he got me an offer at one of the famous labs—what was the name—Hillsom's, Hillsom's Lab. I don't know what it was, but it was for—I think a thousand pounds a year was the salary or something like that. It was just amazing. And it was not, let's say, on the cutting-edge of what I was interested in. It was a great lab, and these are great people, I don't put anything down. But at the same time, we had another faculty member, Dick Longini, who had come from Westinghouse, and Westinghouse had close contacts with Siemens, and Dick Longini says, "oh, you're thinking about that?" He says, "I bet you I could get you a job in Germany at Siemens," and I said, "Oh." And sure enough, he got me a job offer at Siemens Research. And I had met at conferences a fellow from Philips and who turned out to be a very famous guy later, Kooi, who was the inventor of the selective oxidation, which has profound impact on the field. He offered me a job at Philips, so I had three job offers in Europe. I mean it was amazing, and I ended up going to Siemens for which my thesis advisor never forgave me. He hated the Germans having been bombed by them, he hated them. But I went to Siemens because among other things, they were the inventors of III-V compounds, and that was the lab, so I went there.

02-00:44:28
Burnett: Erlangen, wasn't that a fairly new lab though, that one?

02-00:44:32
Oldham: No.

02-00:44:33
Burnett: No, it wasn't?

02-00:44:33
Oldham: No, it was a research lab for Siemens-Schuckert, Siemens then was several companies, but the Siemens-Schuckert lab had a classical research lab, and they always had a research lab, and Welker had his own lab. He was so famous now that he had his own lab I think in a place—I think it was Pretzfeld, but I don't know. But I never actually met Welker, and I never got out to that lab. I didn't know what I was going to do when I went to Siemens, but it turns out there was a guy who was doing growth of gallium phosphide,

and he was interested in starting a different project, and he had this setup and so I just took over his setup, it was just fabulous. I mean it was just like—

02-00:45:30
Burnett: It exactly fit with what you were doing.

02-00:45:32
Oldham: Oh, yeah, it's not exactly the same, so you learn something new, but it was right in my—

02-00:45:41
Burnett: Wheelhouse.

02-00:45:41
Oldham: —right in my wheelhouse as far as being the kind of stuff I liked.

02-00:45:47
Burnett: As far as you could tell because you were just there a year, right, how was the culture different from, say, Bell Labs?

02-00:45:57
Oldham: Well, the culture was different in a way that had an impact on me. Those folks—you know, you always hear the unions in Europe are parts of the company, and they're not real. They don't have strikes in Germany like they do in Italy and France, and the unions were—they're not respected as much as the unions here and those other ones, but they had negotiated working hours. So a working day at Siemens was—well, the working week was 40.36 hours or something, it was a very German concept of [time]. And by God, the lab doors opened at a certain time and everybody came in, and they closed at another time and everybody went home, and then it was locked up, and it was locked up Saturdays and Sundays, and it was all based on union hours. But the members of the technical staff like I was, you would think they would let them come in. No, they didn't want to come in, they wanted to go do the rest of their life, and this is what was different there. I mean when you went in, you worked, and it was a great research environment, I had great experiences, wonderful people I was with again, I was so lucky. Again, I had a boss who just let me do what the hell I wanted, you know. And so he handed me this apparatus, which was functional, and it was supportive. But those people believe that there was more to life than work.

02-00:47:57

And the other thing that was profoundly different from Bell Labs, they had vacations, I mean four weeks of vacation. It was only four weeks then but thirteen paid holidays, so that was really like six weeks plus they'd have three or four American holidays we have. That kind of got to me over the year, I didn't appreciate it, I wasn't interested in vacations, but then after experiencing that at the end of the year, I decided to call Berkeley and see if they had a job still, but I didn't want to go to Bell Labs. They had two weeks' vacation a year.

I thought, that's kind of crazy, what, two weeks as year? What if I want to take a couple weeks off and do something? You can't even do that.

02-00:48:53
Burnett: Right.

02-00:48:55
Oldham: That actually was the biggest impact on my career. Research direction was good, but the big impact was just understanding a little more about the how to live your life.

02-00:49:11
Burnett: Yeah, work-life balance, which is something that is remarked upon all the time in other countries about the United States. They just don't believe how hard—not necessarily how hard—but how long Americans work, how much space work takes up in a life. And so you saw a different way of being, and certain kinds of academic environments facilitate something like that, a greater flexibility, and so you saw that at Berkeley as a possibility.

02-00:49:51
Oldham: Well, yeah, Berkeley, there's no vacations, it's you set your own. You have to get stuff done, and all that matters is what you get done, right?

02-00:50:01
Burnett: Right.

02-00:50:01
Oldham: You have to teach your classes, and you have to have a really good research program, that's the requirements at Berkeley, and how do it? That's up to you.

02-00:50:12
Burnett: Yeah. Well, maybe we should just pause for just one second?

[pause]

02-00:50:18
Burnett: Okay. So you arrive at Berkeley, and is it the '63–'64 or '64–'65, is that your first academic year?

02-00:50:31
Oldham: Summer of '64 we arrived in Berkeley.

02-00:50:36
Burnett: Right. Can you talk a little bit about that, getting settled and arriving in California? That was also a new change for you. What's the difference in speaking of work cultures, the difference, say, between the Carnegie Institute and Berkeley when you got there? What was your understanding of how things were organized and if that was a bit different from how things were at Carnegie?

02-00:51:10
Oldham: That's an interesting question; I hadn't thought about that. I think things were very similar with respect to how a faculty member has this combination of teaching and research. The people that faculty members I knew at Carnegie were all probably dedicated to teaching and good researchers. For success, that's what you had to be and so I think that was very similar. I can't even think about teaching loads and all of that; I'm not quite sure.

02-00:51:59
Burnett: Yeah, and that's very specific, you don't need to detail that.

02-00:52:04
Oldham: But it was not unexpected. I knew from being close to my faculty at CMU, what a faculty member did. At CMU I did teach a course. I had a fellowship, I didn't have to teach, but I requested to teach a course there just to find out what it's about. I don't know why I did that, I still can't figure that out, but I did, and I taught the sophomore electronics course and enjoyed that. Very interesting at that point, which is going—we're going back up a bit, I used to argue with my close buddies who were—Don Scharfetter who was determined to go to Bell Labs or a place like that, and Bob Gregory who said he was going to be a teacher. And I said, "Bob, what on earth would you want to do that for, you've got these great laboratories?" and we used to argue about that, well he said, "Well, the thing is to go and be a teacher." Well it turns out, I went to Berkeley and became a teacher. He went to Sandia to a laboratory—

02-00:53:24
Burnett: That's—

02-00:53:25
Oldham: —and it's so very interesting.

02-00:53:27
Burnett: You switched places a little bit.

02-00:53:28
Oldham: I guess, I don't know. Anyway, I had taught a course and so that experience was positive and probably played some role not—in being able to make that choice to go be a faculty member.

02-00:53:41
Burnett: Right, right.

02-00:53:42
Oldham: Anyway, yeah, so you come to Berkeley. Until I went to Europe, I was not a travelled guy. I had been to California once to interview for Berkeley, and it was February, and I came out of Pittsburgh. And I remember walking up through the campus in about the second week of February, all the trees bloomed here, all the cherry trees and all those flowering trees in Berkeley. And it was all in bloom, and it was warm, and the girls were walking around campus without big coats on, and I'm walking up through, and I'm thinking,

you know, there's something different about this campus than ours, and I couldn't figure out what it was, but I liked it. [laughter]

02-00:54:34

So anyway, I came here now in the summer, and I had another good—two college buddies who lived in San Francisco, and I asked them to find me an apartment, they find us a house or an apartment or something, and one of them did and so I had that to come out here. But when I got here, I didn't like it and so we didn't take it, and we moved in with those guys for a few weeks in San Francisco, which was very enjoyable. So I was commuting from San Francisco, but mind you, it's still the summer. I came like in July to try and get things going and set up whatever I'm going to do in the lab and all that. That was a good recruiting year for Berkeley because there are several other people among them, a person became a good friend and a coauthor Steve Schwarz and Elwyn Berlekamp came that year, a very famous, famous guy, different field.

02-00:55:45

Burnett: Yeah, combinatorial mathematics, right?

02-00:55:47

Oldham: Yeah, yeah. He was just a killer mathematician. Anyway, they were that year, and I remember them because I met them at all these parties that the faculty would have. The chair Lotfi Zadeh who I hadn't met before because he was not chair when I interviewed two years before. His wife was just a gracious person and so the new faculty, they had them over and that—the person who was the director of our research organization or electronics research lab, Diogenes Angelakos, "Diog," his wife was also just this very gracious person, and they had us over. And so you're meeting not only the new, young faculty, but they would invite strategic other senior faculty over and so it was just positive. And then we found a place to live down on Francisco.

02-00:56:55

Burnett: So it was a good work culture. So many things are happening in that—in and around that year and maybe the year before in electrical engineering and on campus, so we could take that in any order you like. But I understand that the late fifties that Berkeley engineering was trying to modernize itself and get into these areas that were growing, strengthening in control theory, they were getting into that, and the communications stuff, and building up electrical engineering. And in '63, is the microelectronics lab.

02-00:57:48

Oldham: That's when Don Pederson decided, he and Tom Everhart and Bob Pepper. Pepper left just when I got here, but he [Pederson] and Tom Everhart decide to create this integrated circuits lab, which is unheard of at a university. "They're going to build integrated circuits," and "you can't do that at a university," and all that stuff. And Don who was not a fabrication guy at all, Pepper was closer to that, and Tom, not so much either, but they just knew it was important. And they were going to put a lab together, and they did, and I got here, and there was a laboratory, which had furnaces in it and had space where you could do things. They had evaporators and stuff, so you could actually make small transistor chips, small integrated circuits. The integrated circuit had been invented by then and so it was known that you could combine some transistors on a chip and not just have them separate. And so that's what Don was going to do, and he pulled it off. They put together this—I mean it's extremely primitive by today's standards, but it was a functional lab, and the guys like [David] Hodges and these other, Bill Howard, they built chips there.

02-00:59:22
Burnett: Can you talk about—you said it was unheard of, like "you can't do that in a university." Why? Is it because fabrication is so complicated, or because it was so new, or it was something that was really an industrial process?

02-00:59:38
Oldham: Yeah. It's a process which requires very—first of all, it's a so-called clean room, and it wasn't very clean then, but dust particles bother you. It requires chemical processes that—a variety of them, not just one, it's not just like one or two things, a whole variety of processing. And the concept of a foundry did not exist, that came much later. And so it was something that company did—a company designed a circuit and then a company built it. They had to know what the circuit needed, so they would have a process for that and so on. It was something just—so anyway.

02-01:00:38
Burnett: With the government as a customer. I understand that there was no real commercial market for integrated circuits at that time. It would've been the military.

02-01:00:50
Oldham: No.

02-01:00:50
Burnett: No?

02-01:00:50
Oldham: Let's see. I'm trying to think when Fairchild [Semiconductor]—Fairchild was a going operation then, and Fairchild was producing small integrated circuits, and they did not do much government work. There was government work, and like I say, some companies got sucked in by it, like RCA in particular, but Fairchild didn't do much. I don't know how much they did, but I know when Intel started, now that's '69, they had a philosophy that under no circumstances were they going to do government work because that's going to take them in a direction that the government wants but not where the company needs to be.

02-01:01:36
Burnett: I think definitely later, but what I read from the history of integrated circuits, and it could be totally wrong, is that the major if not exclusive client for

integrated circuits was the military until the early sixties, early to mid-sixties. There was nobody else who needed it for anything—

02-01:02:02
Oldham: Yeah.

02-01:02:02
Burnett: —you know?

02-01:02:03
Oldham: —maybe to early sixties. But see, I'm talking '63 when I came there, there was a commercial market, there was a commercial market of integrated circuits, and Fairchild was on top. Now, Texas Instruments was big-time funded by the government. They really used government funding to develop their whole technology.

02-01:02:31
Burnett: Right. So if you're thinking about markets, it would be business machines, it would be smaller, because one of the chief advantages is miniaturization, of course?

02-01:02:44
Oldham: Yeah.

02-01:02:44
Burnett: So it would have been in that kind of domain that there would have been a commercial market for that that's outside of the government?

02-01:02:54
Oldham: Yeah, miniaturization, all of the things that go with it. With miniaturization, it's simplicity, reliability, all the things that go with it. Yeah. I'm not an expert on this because I wasn't focused on that at the time.

02-01:03:18
Burnett: Well, I am interested in your understanding, in the conversations. Of course, they want you to flourish and do what you do, but to the extent that there was conversation about common objectives for the department, the trajectory for the department. I mean sometimes with department meetings, there would be a narrative of the chair of the department about direction, "Five years out we want to be doing this." Were you privy to those at the time, or does that come later for you?

02-01:03:56
Oldham: Oh well, once I was a member of the department, there's nothing secret, but it was not very directed. I got to bless these people because Don Pederson wanted to make this integrated circuit thing work. They had one faculty member who was productive in devices, Professor Wang but definitely not a circuits guy, definitely not a circuits guy. He was more of the technology, a physicist, a physicist doing electrical engineering kind of thing. Don recruited me, and I was really not an integrated circuit guy. I was a device guy, a device

guy because my—what you published, you would publish this device and then you'd publish an analysis of how the device worked and its electrical properties. And, of course, part of that was how you made it, and that was a part I was interested in, but I did the device stuff. And I was also using computers then to do the analysis, which was a new thing that was happening where you do the analysis of your device with a computer because remember, computers were just, just getting available in the late fifties.

02-01:05:29

Anyway, Don hired me to do that, and of course, I eventually didn't do that. I didn't see the light that—how important the integrated circuit because I never did any circuit research except when I went to Intel. But I did device and technology of integrated circuits, and they put up with that. And there wasn't a lot of department direction. Department wanted to be good in what they're—whatever they're doing. They did want to do everything, but they didn't want to miss the major future fields, and that's still the case today when we have these meetings about who to hire. It's not about you're good at something, it's not about keeping that tech—that expertise. It's about where is the big fields of—that are going to have impact worldwide going to be and are we going to be in that. We do that, and I don't know how much they did that before I got there, right, of course I don't.

02-01:06:36
Burnett: It sounds to me from John Whinnery's oral history that they were planning in the late fifties, and there were three major areas. I'm blanking on the third, but one was control theory and the other was electronics, and they wanted to grow in those areas. And I can't help but think that you must have been part of that plan in your—in hiring you.

02-01:06:59
Oldham: Yes.

02-01:07:01
Burnett: And you said you're a device guy, but you're a materials guy.

02-01:07:06
Oldham: I am, I figured that out later. [laughter] I thought I was a device guy then.

02-01:07:13
Burnett: Okay, let's be—

02-01:07:13
Oldham: But I was doing materials work.

02-01:07:16
Burnett: Let's be historically accurate. At the moment, you thought you were a device guy, okay, great, we've got that for the record then. It's about these elements and the compounds. You're researching compounds that have interesting electrical properties that are in some ways better, much better in their particular electrical properties than the other kind of—than—

02-01:07:48
Oldham: Well, yes, yes. [tentatively]

02-01:07:50
Burnett: Yes and no?

02-01:07:51
Oldham: Yes, but it turns out, I'm not researching the materials and their properties. It turns out, I'm researching the processes to manipulate these materials, it turns out, I didn't know that at the time, that's what—but that's what I was good at, and I evolved to that. And then you'll see later in the eighties that's really what we did. But at the time, I thought I was a device guy at first and then to make devices, you have to do some processing and so I did the processing, you know?

02-01:08:28
Burnett: Right, right.

02-01:08:29
Oldham: And that's how I was hired, as a device guy.

02-01:08:35
Burnett: So you're getting started, and you're getting your lab up and running, and when you have a lab, what does that mean? You get assigned a space and a hall, and you have graduate students, and you get going. How did you set it up—

02-01:09:01
Oldham: Well—

02-01:09:01
Burnett: —if you recall?

02-01:09:02
Oldham: —actually, I didn't fully appreciate how—the culture at Berkeley because at CMU, we had a very good culture in that we had a good facility. We had a very good facility there. We could make whatever we needed, and measured the electrical properties, and if you needed a different kind of instrument, you put in a request, and you would eventually get it, so it was very good that way. And I came here, and luckily Don Pederson and Tom Everhart and the colleagues decided that we were going to do things a little different. It's not going to be that a faculty member has a laboratory and graduate students are in it, and they all work as a team. That's typically how it is in most departments. I mean like take chemistry or something, Professor X has a—he may have a collaborator or not, but then he has the students, and they have these rooms, these laboratories they do their research. We set up this common integrated circuit lab that Don Pederson did and then I built the second generation of the same thing. But it was to be a common facility that we all shared rather than Professor X and his students in the lab, and that's really important.

02-01:10:36

It was really the Pederson culture and I think led to not only—it led to certain openness in sharing ideas, it led to a huge advantage because you have a lot of people helping you with your ideas and your problems and so on. There were faculty members who didn't do that. I won't say any names, but there were faculty members who told their students, "Don't talk to any other students because they're going to take our ideas," and there were people who didn't get it. And then what happened at Berkeley, and it was independent of Pederson, like it happened in computer science too. They came up with these major projects, like you've heard of RISC [Reduced Instruction Set Computer] and so on, that was the first. There were other ones, the RAID [Redundant Array of Independent Disks] project and so on where you have a team of faculty members and a larger team of students and you attack a major problem—

02-01:11:43
Burnett: Together.

02-01:11:44
Oldham: —together. And that became a norm, and that developed independently over there from us, I think. I don't think they somehow learned from us, but it turned out to be a more fun way and a more productive way to do research, and we benefited enormously from these kinds of things.

02-01:12:07
Burnett: I wonder about the long arm of Bell Labs, because in the late fifties when they were doing this planning, Don Pederson was on the department's executive committee even though he was an assistant professor, which is interesting, right? He had come from Bell Labs as a Stanford graduate, Whinnery recruited him, then Whinnery rather recruited Ernie Kuh and Charles Desoer—Desoer?

02-01:12:41
Oldham: Desoer, yeah.

02-01:12:41
Burnett: Yeah, Desoer, away from Bell. And so you had this population that had absorbed something of the Bell Labs culture, and someone who came from Bell Labs, hired people from Bell Labs or talked about hiring people from Bell Labs was also setting up a new lab. So it stands to reason that there must have been some kind of impact from the experience there. And since you were there as student, maybe it resonates with you a bit as well? I don't know.

02-01:13:23
Oldham: Yeah, it could be. I mean I haven't thought about that.

02-01:13:25
Burnett: Well, yeah, and you were a student and you hadn't been there. It was a bit of a different experience to be there as a graduate student, right?

02-01:13:34
Oldham: Yes, as opposed to a member of staff? Yeah.

02-01:13:38
Burnett: Yeah, okay. So we'll leave that as a question, work for historians to explore in the future. But at any rate, there is common space, common pool of resources, common equipment for everyone who's working in microelectronics. Would you say you were microelectronics person at that point?

02-01:14:09
Oldham: Absolutely.

02-01:14:09
Burnett: Okay, even then when you graduated from—

02-01:14:12
Oldham: Yes.

02-01:14:12
Burnett: —university? Okay. And so you're participating in this new experiment at Berkeley that becomes important. Not to derail things too much, but another thing that was happening in 1964 when you think of—

02-01:14:34
Oldham: Free speech movement.

02-01:14:34
Burnett: —Berkeley, yeah. So, do you have any words on that? Other people in engineering have said, "Well, I was off on the other side of campus and pretty busy."

02-01:14:48
Oldham: Actually, just before the free speech movement, there was the recall elections of the Berkeley council or something like that going on. Mind you, I was a nonpolitical person when I came to Berkeley. I was in the lab; I was not out on the street during—I didn't understand anything about the Civil Rights Movement. I didn't even know what was going on in civil rights; I wasn't sensitive to that. But I got to Berkeley, and, my goodness, there were all these amazing meetings. I used to go across and listen that they're going to recall—there was busing going on, and people were upset about that, and there were these meetings going on. I remember that Carol Sibley I think was a member of the schoolboard being recalled or something like that. I can't remember exactly what the meetings were. I used to go to that and then within a few months, we had the free speech movement and so it was very interesting. I was over there when Mario Savio climbed up on the top of the car.

02-01:16:00
Burnett: Really?

02-01:16:00
Oldham: Yeah, I was there because it was very interesting. I was not on one side or the other or anything, I was just—because I'm so naïve politically, I'm just watching this and just amazed by the whole thing and the amazing intensity of these people. And then we had faculty meetings probably every week, sometimes several times per week of the whole campus. They would have these giant faculty meetings where we would argue about free speech and what to do, and there was people that thought these students should be dismissed and got rid of and other people who said, "No." So it was really very interesting, a very interesting time and I did not—it was not very emotional for me because I wasn't, as I say, political but—

02-01:17:00
Burnett: Yes, but you were witnessing it and—

02-01:17:05
Oldham: I was witnessing it.

02-01:17:05
Burnett: —in those meetings and at the faculty senate meetings.

02-01:17:11
Oldham: Yes. And the other thing that was going on besides that was by the end of the year, there was major anti-Vietnam stuff going on.

02-01:17:25
Burnett: By end of '64.

02-01:17:27
Oldham: Yes. During '64, there were major anti-Vietnam happenings, so, during that, I learned about Vietnam and then I did become political because Vietnam was clearly a disaster happening. And then of course, the draft and then we're all threatened by draft that—so it's actually personal, but—

02-01:17:59
Burnett: Well in—

02-01:18:00
Oldham: So all that was happening, but mostly, I was in the lab.

02-01:18:03
Burnett: Well, the draft impacting graduate students that you might have?

02-01:18:07
Oldham: Well, and drafting me.

02-01:18:09
Burnett: You were eligible?

02-01:18:10
Oldham: Oh, yeah. Yes, see I was like twenty—when I came to Berkeley, well I came in—let's see in '68, I would've been thirty, right?

02-01:18:19
Burnett: Yeah.

02-01:18:19
Oldham: So I came to Berkeley when I was like twenty-six or something, twenty-seven.

02-01:18:24
Burnett: Twenty-six was the limit I think, I think. I think twenty-six, you couldn't be drafted after you were twenty-six, I don't think. I'm not entirely sure about that.

02-01:18:33
Oldham: I don't know. I had to get deferments, I had to get deferments. I used to go to the—

02-01:18:38
Burnett: Really?

02-01:18:37
Oldham: —department office and they would write letters and—

02-01:18:41
Burnett: As a standing faculty member—

02-01:18:42
Oldham: Yeah, I mean—

02-01:18:42
Burnett: —you had to get deferments?

02-01:18:42
Oldham: —but you could get a deferment as a faculty member though.

02-01:18:45
Burnett: But you had to apply?

02-01:18:46
Oldham: Oh yeah, oh yeah. And then at the end, I was eligible when—they finally gave up the deferments and said there's a lottery, and I had a pretty good lottery number, so I was okay. But yeah, we were still—

02-01:19:04
Burnett: It was personal.

02-01:19:06
Oldham: Yeah, and by then I was so much against the war, it was really a problem. I thought, what would I do and would I leave—go back to Canada or something? I didn't know. I really hadn't fully thought it out, but I was not likely to go to Vietnam. I knew enough about what was wrong.

02-01:19:30
Burnett: Right, right, and that—and those conversations were in the air, people were talking about it.

02-01:19:37
Oldham: Oh, absolutely.

02-01:19:38
Burnett: And in '65, things get—I was interviewing someone else, and they were talking about '65 is the year when things kind of turned at Berkeley. It's '68 to '69 is when things go off the rails I suppose, and you remember that as well.

02-01:20:10
Oldham: Oh, man, that was really bad times that, it was awful times. I mean helicopters overhead dropping tear gas on you, and all that stuff was going on.

02-01:20:19
Burnett: And you're going to campus to do your work.

02-01:20:21
Oldham: I was trying to cross campus, I had a sabbatical in '68 and be trying to cross campus to go over to Dwinelle Hall and listen to the German tapes, and you have to watch because there's these helicopters, and if they see more than four, five people they dropped tear gas on them. This was when Reagan was governor, I think.

02-01:20:44
Burnett: Yeah, well, he had it in for Berkeley, that's for sure.

02-01:20:45
Oldham: Yes, so it was really bad times.

02-01:20:48
Burnett: Oh, my goodness. You were listening to German tapes or you were—?

02-01:20:51
Oldham: Well, I was taking a sabbatical in '70, I was going back to Germany, and I wanted to improve my German a little bit. Yeah.

02-01:21:04
Burnett: Wow, so in amongst all of this technical work, there is this larger context in which the campus has become a flash point for all kinds of political conversations and political activism.

02-01:21:19
Oldham: Yes. It was very interesting. I was not a big participant in the political activities, but I was a strong observer. We're drumming ahead from this time, but a little bit in that period of the late sixties or maybe it was—when did we have the incursion into Cambodia, Laos, Cambodia where we—?

02-01:21:52
Burnett: I think that was—

02-01:21:53
Oldham: Seventy?

02-01:21:53
Burnett: —seventy.

02-01:21:55
Oldham: Seventy-one maybe?

02-01:21:56
Burnett: Yeah, that sounds right. [April–June, 1970]

02-01:21:57
Oldham: Okay, so it's a little bit later but then I did get involved, and it's interesting. I helped some students. The whole campus is on strike including engineering; they had just had it. And of course there was this other whole world: "What are these people doing, they, what are you, the anti-American and you're—these—for these communists and all this stuff. And there was a conference going on, an Electrochemical Society conference in LA that I was supposed to be at, and so I asked some other students. I said, "Look, you guys are all on strike here, you want to—I'll pay your way if you want to come down to the Electrochemical Society meeting and talk to the people there and tell them what we're doing." What a crazy idea I had. So I arrived there, and I said, "We want to set up a little table and just have these students here, and people can talk to them about why all the students are on strike." And they quickly convened the people running the conference and said, "No." And so I said to the students, I said, "Well, they said no, but you can still do it. It's an open hallway, it's in a hotel," and so they did. And I'd go by every now and then, and the students would be arguing with somebody or talking with—depends, there are both types there.

02-01:23:45

And then I got this note that the Electrochemical Society senior directors wanted to meet with me. [laughs] So I got called in, but it turns out the president of the Electrochemical Society was Professor Tobias, Charles Tobias from chemical engineering, and I didn't know him real well, I knew him a little bit. He was a cool guy, a Hungarian guy, electrochemist. I remember this meeting, and he said, "Well, Professor Oldham here, he's a good man and—" and they said, "But we told you, you couldn't do this and you did it." I said, "Look, they came all this way," I said, "they're going to do this," and they said—you know. But Tobias stuck up for me. I mean they couldn't do anything to me anyway, but they can really—I don't know, they can write a bad letter to something or whatever they wanted to do, I don't know. But anyway, he stuck up for me. And so I went back to Berkeley, I took the view that at that point we had done our job. I mean there had been several hours of talking with the people there, and we went back to Berkeley.

02-01:25:05

Well, Tobias is a cool guy and then he later married Katalin Voros. She did a master's degree with me and then took over our lab and ran our lab. That was her job after graduation, and she was a fabulous manager, Hungarian management. Anyway, Charles Tobias married Katalin Voros, and he actually wanted me to help get her into Berkeley when she was going to do her master's degree because he had met her in actually an Electrochemical Society meeting, and his wife had died and all this, so it was a very interesting connection.

02-01:25:47
Burnett: Oh, wow.

02-01:25:49
Oldham: But he was just a terrific person and he had an espresso machine in his office. If you went to his office, you had an espresso.

02-01:25:58
Burnett: True civilization.

02-01:25:59
Oldham: Yeah. A very cool guy.

02-01:26:03
Burnett: Wow. So it's not the first story I've heard of engineers and scientists as activists in small ways and large ways. It's a sign that the political world had encroached on these halls of academe and were affecting people, and that was part of the landscape at that time and subsequently. So you set up your lab?

02-01:26:41
Oldham: So let me say a little more about these—and I said these, we had these really good people who welcomed you here. You felt it. You come in, you're welcomed. In those days, you're expected to teach—it was a semester system, three courses a year, so two courses one semester, one another. And they gave me these two courses, and of course the courses here were much better than I had at Carnegie Tech, they were much better. They were just—I wouldn't say much better courses, but they were in subjects which were farther advanced in those areas than I had had, in particular in circuits, because Don Pederson is sort of the father of integrated-circuit teaching, and he really was. And so he had these courses, and they had me teaching one of those. They had me teaching another course, which was solid-state physics for semiconductors, and that was an area that I was quite familiar with. I've never had a course in it because we didn't have one at [Carnegie] Tech, but I could do that. And so I

suddenly looked at this and says, man, I got two courses which are pretty tough to do and so I convinced them to give me two sections of one course rather than these because we had multiple sections of courses. And so they were flexible that way. They let me do that, so I wasn't overwhelmed with the teaching while you're trying to set up your research, you're trying to recruit some graduate students.

02-01:28:36

A lot of things happened there. Bob Pepper had left, and he had a graduate student, Bob Holmstrom, who hadn't finished his master's degree and was still looking for a—and so I instantly had a graduate student, and this guy is terrific, Bob Holmstrom's terrific. So I had him, and that was great, and we had this staff. At that point, there was money for staff, so we had a terrific staff. We had a machine shop which had like—I don't know. There were actually two machine shops, one for the electronics research lab and for the department and so we had a dozen machinists.

02-01:29:29
Burnett: Wow.

02-01:29:31
Oldham: Good guys.

02-01:29:32
Burnett: They could build apparatus for you, they could build—they could bring in equipment?

02-01:29:36
Oldham: Because the kind of stuff I did, you had to make the equipment for. You couldn't buy the equipment for it. And Don had set up a lab staff. He had hired one of the secretaries, Dorothy McDaniel, to be the head of a lab because she liked that, and she just stopped doing the secretarial stuff and started running this lab. And there was glassblowers. John Whinnery had started this program in lasers, and lasers in those days, a lot of them were made in glass tubes, so they had glassblowers, so they had a couple of glassblowers. Don Rogers was the chief glassblower. They used to make microwave tubes, so they had another guy George Becker who was just a brilliant machinist, absolutely brilliant—

02-01:30:37
Burnett: So bespoke—

02-01:30:38
Oldham: —machinist—

02-01:30:38
Burnett: —microwave valve tubes?

02-01:30:41
Oldham: Yeah. Because they were making this big—these are big tubes full of—

02-01:30:46
Burnett: Oh kind of like the klystron—

02-01:30:48
Oldham: Yeah, those kind of things, traveling wave tubes, I don't know, all that kind of stuff. That's what he had done, what John Whinnery had done as a researcher both in industry and then at Berkeley and then he switched and decided to start quantum electronics, lasers because lasers had just been invented. And so we had a glassblower, and he was at Bell Labs the year I came, and he was away. He finished as dean and went off and so he came back and started quantum electronics and hired Steve Schwarz that year and some other people. Anyway, they had that staff, and another glassblower Bob Hamilton, he was another glassblower and assisted Don Rogers, and he later became one of our staff members in our microelectronics lab. And Don Rogers ran the lab before my student Katalin Voros graduated and took that lab over, but these were all great people.

02-01:31:59

The number two guy in the machine shop, Wil Zeilinger was an Austrian guy and I immediately—the head guy was a German running in the machine shop in those days because all these Germans come over and they were really well trained. And so the head guy was a German guy, and I've forgotten his name. But the number two guy, the assistant head of that machine shop, Wil Zeilinger, and I just met this guy, and we were like friends right away, and he was the number two guy. He eventually was the number one guy. Eventually, he took over running the whole staff of Cory Hall, and he's a very talented guy. So we had this terrific staff. It was as good as any industrial facility you see. So if you had something that you needed to get made or done, they could do it for you, and it was not expensive then. Nowadays if you hire a new faculty member, you have to give them $50 million start-up money or something, some start-up money, so you can get the research going, right?

02-01:33:08
Burnett: Mm-hmm.

02-01:33:08
Oldham: I had $2000 then and so I'm supposed to build all my stuff and pay the machinists and buy the equipment and so it's peanuts, I mean, but then it was okay.

02-01:33:21
Burnett: Because in part it's all in common, there was a common investment in hiring those staff, so their salary, they're there.

02-01:33:30
Oldham: Yeah, they're there.

02-01:33:31
Burnett: And you don't need to purchase time so much.

02-01:33:33
Oldham: That's right, yeah.

02-01:33:34
Burnett: You're booking time with these machinists, and they do the work, and the $2000 is for materials and things like that?

02-01:33:40
Oldham: Pretty much.

02-01:33:41
Burnett: Got you.

02-01:33:41
Oldham: Pretty much, yeah. It was very little cost of machining.

02-01:33:46
Burnett: It was in Cory Hall, the microelectronics lab?

02-01:33:51
Oldham: Yeah, it was up on the fourth floor, which was the top floor. And there was this—I don't know what that lab was before. But anyway, Don took over this one area and built that lab in there. And it was not like it was a clean room, but it had some hoods, which were sort of clean, and there were some furnaces where they had—I don't know. I don't think there were laminar flow over any of the equipment at that point. But you had to wear a lab coat in there, but a lot of people didn't.

02-01:34:33
Burnett: But no hazmat suit with the, you know—

02-01:34:35
Oldham: Oh, no, no, no, in fact—

02-01:34:36
Burnett: —protecting your—?

02-01:34:37
Oldham: —I can remember in those days—

02-01:34:41
Burnett: Not a hazmat suit but a—

02-01:34:43
Oldham: —it was—

02-01:34:43
Burnett: —dust suit I guess. [clean room suit]

02-01:34:44
Oldham: I knew all the students who were in the lab then. I knew them because I was in the lab all the time, and I remember Erich Ippen, a pretty famous faculty

member at MIT was a graduate student of John Whinnery's. I remember him in the lab—he always wore a suit and tie, he was the East Coast guy, always wore suit and ties. In the lab, he took off his jacket, and he's in the lab with this shirt and tie on, and he's lapping some material. He's going to study some material with a laser, and he's lapping this material in the lab. I said, "Erich, you should take your tie off and wear a lab coat, you're going to ruin your shirt" and so—

02-01:35:26
Burnett: So what is lapping, just for—what?

02-01:35:28
Oldham: Lapping is when you have a surface that you want to make flat and polish to do something on and so it's done with successively finer and finer grit. It's how you polish glass, how you make a mirror, you lap it to a shape and then you use a finer grit and take that out and finer and finer and finer, and finally, it's like a mirror, right.

02-01:35:55
Burnett: But it's dirty in the sense you get stuff on you?

02-01:35:57
Oldham: It's very dirty, it's very dirty, yeah, and we are allowed to do that in the lab, so it was not a real clean, clean room but it was okay for the time.

02-01:36:09
Burnett: Now is this at the point at which for the making of bespoke integrated circuits for experimental purposes, do you have maskers, is it lithography at that point like—?

02-01:36:24
Oldham: Yeah. Well, this famous guy, George Becker who was this brilliant machinist, a man of all skill, trades who was the guru that made all of John Whinnery's microwave tubes really, he and the glassblower would make all these things. George Becker designed a so-called step-and-repeat camera. You want to make a mask, integrated circuits are—in those days were made by having a glass mask, which has the patterns on it black and white. You put it against the silicon with a photosensitive material, and you shine a light on it. And that transfers the pattern to this sensitive material on the surface and then you can get the pattern into the silicon. Anyway, you need this mask, and how do you make that mask? Well, you have a camera that you make a large thing. In those days, it was called Rubylith. It's actually like a plastic sheet, which has a peel-off part of it that's red, and you can scour it with a knife and peel off the red in some areas and leave it in others. There's going to be this integrated circuit, which is a little chip, but you make it much larger because then you can mechanically make it and then you photograph that and shrink it down.

02-01:37:59

And George Becker made this little—this camera where it was very clever. You put this piece of glass plate in one place on this template and you take a picture, and then you move it somewhere else and you take a picture. Anyway, you end up with a glass plate, which has maybe ten copies because what you want are hundreds of copies of the circuit. In those days, so maybe one of them works, but now just to make a lot of circuits for little money. For us then, it was just you hope one of these doesn't have a defect on it. And so George Becker made that equipment. It was there when I was there.

02-01:38:47
Burnett: So shrinking things down, so when they made microdots in the spy service, they would be able—they would use cameras to shrink things down?

02-01:38:58
Oldham: I don't know about microdots.

02-01:39:00
Burnett: And then aperture gate masking is a technique in film where you have—where you're masking, you're exposing one area and masking the other. So there are these techniques that are around in other areas that get adapted, and there are these craftspeople, these technicians who are able to take techniques used in other areas to this brand-new area, right? And they are saying, "Well, we could do this and import these things?"

02-01:39:29
Oldham: The technology evolved primarily from the printing industry. In the printing industry, they were called lithographers. They took aluminum plates and etched patterns on them and then you smear ink on them. Then you make a print and that was called offset lithography, instead of setting individual little letters. So they did that with photography, and the chemistry of that was something called photoresist. So what it is, is it's a photosensitive material that you could coat on a surface. If you shine light at it—there is positive and negative resist—but let's just say you shine light at it, and at that place, that will wash away in a certain solvent, and where there was no light on, it won't wash away for instance, okay. So you coat this material on, you shine light on one place, then it washes away. Now you have some varnish-like material on the surface that has holes in it where you shone light. And then you can use that to etch patterns. You could put acid on there and etch patterns and all that. That's photolithography, and that same technology, including the photoresist, were taken over from the printing industry. All the resist we used in the sixties were ones which were developed for printing in the printing business. It was only later that they developed them especially for us.

02-01:41:16
Burnett: Right.

02-01:41:16
Oldham: That was probably late sixties they had special resist for us.

02-01:41:23
Burnett: But also camera people, right, there were camera folks involved. People who worked at Zeiss would come over, and they were—their specialty was lenses and that kind of stuff. And Fairchild semiconductor was Fairchild Camera company. [Karl Heinz Johannsmeier, trained at Zeiss, developed masking technologies in this time period]

02-01:41:36
Oldham: Yeah, but there was no connection.

02-01:41:38
Burnett: There was no connection?

02-01:41:39
Oldham: No connection whatsoever.

02-01:41:40
Burnett: Okay, well that's good, that's good to clarify, just—I was just curious. I just thought that might be an interesting connection. So the point is that there's a whole group of people with diverse talents or diverse specialties who bring a suite of technical expertise and technologies to bear on this new lab to make it the equal of industrial labs that are interested in doing this kind of work.

02-01:42:14
Oldham: Yes, and this idea that we all share the lab, this was really the key thing so that we all use the same lab and then you have some person who tries to maintain—and that was Dorothy—trying to get people not to leave a mess, right, because you can leave a mess and somebody else has to inherit that, so that kind of thing. Whereas at Bell Labs, you did most of things in your own little lab and did it by yourself, so it was even better than that. Now later on, Bell Labs built these kind of laboratories, but that was after we did. They built little, special labs where they did fabrication.

02-01:43:06
Burnett: So Berkeley's was the first true microelectronics lab as a research—

02-01:43:13
Oldham: At a university—

02-01:43:14
Burnett: —at a university, but that had this kind of experimental research function?

02-01:43:20
Oldham: Yeah I think so, I think that's the case. because they used to come in. I remember the Stanford guys come in and take notes and then they'd go make theirs.

02-01:43:29
Burnett: Yeah, Stanford and MIT I guess were the next in line to do it. That's interesting.

02-01:43:35
Oldham: And, of course, we sent them students or faculty members, so they had models, you know.

02-01:43:41
Burnett: Right. Well, tell me a little bit more about the research that you're doing in the 1960s and some of the larger contexts for that research.

02-01:43:52
Oldham: Well, that's an interesting story because I came here and I had to start a research program. And I was very interested in this particular process called epitaxial growth because it was the key to, for me, making interesting devices. In the industry, it's key as part of the integrated circuit process. Then it was all bipolar transistors, and all almost all of them were made on so-called epitaxial wafers, which were heavily doped substrate with a lightly doped layer or a special heavily doped layer deposited on these wafers of silicon. By the way wafers of silicon were that size when I started. I still had some from Fairchild, which were this size, one-inch diameter wafers. And now, they're—as you know they're this size.

02-01:44:57
Burnett: So in '65, how many transistors did you have on a wafer that size?

02-01:45:01
Oldham: I don't know the answer to that. Anyway, I was trying to get research going. I had seen in the literature some work and it was especially in England on doing this in a vacuum where you have a very high vacuum. We call it vacuum; it's really not a vacuum. It's still full of molecules bouncing around, but so-called high vacuum is, okay, I'll give you a number ten-to-the-minus-sixth Torr is the high vacuum, but you're still—every square centimeter still has like ten to the fifteenth molecules hitting it every second. I mean there's still a lot of stuff in there. But there's ultra-high vacuum, and now we're talking. Ultra-high vacuum, maybe it's ten to minus nine Torr, well that's much harder to achieve, but then you can keep a surface—a clean surface clean for a while and then you can deposit a material on it. In a so-called high vacuum as opposed to ultra-high vacuum, in a high vacuum, you get a fresh material and before you can deposit what you want, it's coated with all this stuff, which is water. So you have to go to ultra-high vacuum and ultra-high vacuum then was build it yourself, so I had a machine shop. So I said, look, "This is the way to go, I mean then you're not dependent on all this chemistry. You can deposit the materials, and we will be able to do it." And there were a few papers, English papers showing you could do epitaxial growth that way, and it was just high-vacuum epitaxial growth. And later on by the way, that got a name it's called MBE, molecular-beam epitaxy, and by the seventies, you could buy equipment. You could buy commercial equipment to do MBE, which is ultra-high vacuum evaporation. But then we—that name hadn't been invented and the equipment wasn't available, so I was building that stuff.

02-01:47:26
Burnett: So that's one piece of equipment we didn't talk about is vacuums.

02-01:47:31
Oldham: Yeah.

02-01:47:32
Burnett: So these are high-pressure devices, right?

02-01:47:34
Oldham: High-vacuum.

02-01:47:35
Burnett: High-vacuum, oh yeah, the inverse.

02-01:47:37
Oldham: So ultra-high vacuum, and it takes special pumps. It isn't like the usual vacuum pump, pump, pump, not that kind of—special pumps and—

02-01:47:47
Burnett: And energy.

02-01:47:48
Oldham: If you open this to air, then water goes in, and coats everything, twenty monolayers of water are coating everything. And water sticks, and you can't get it off. So if you pump it out, the other—the whole wall provides an—basically an infinite supply of garbage that's going to hit your clean wafers, so you have to bake it. You have to pump it out, and you have to heat it to get all the stuff desorbed off the walls. I mean it's a process, ultra-high vacuum is a process, and so, but I've read this and that and there were available methods of sealing because you have to open it up and then how do you close it? You can't use an O-ring for instance. You think of an O-ring or a rubber seal, that O-ring will supply infinite amount of garbage forever. So you have to use metal seals, you have to have to, like an aluminum or copper gasket or gold or something where you crush it and so on. So all this technology.

02-01:49:02

So I thought I could do that, and I spent two years building those things and debugging them and chasing vacuum leaks, and that's another whole thing of finding the leaks in your system, and virtual leaks, that means something inside the system that's just supplying [contaminants]. So I spent two years doing that. I really had no results after two years just chasing leaks. But luckily, we had a computer—and I'm still reading literature and so I was doing some other things too luckily, so I was publishing in this analytical instrument. We had one, we had an antique ellipsometer, which is a—it's a device, it's an optical device for measuring the properties of surfaces. You shine a light on something, bounce it off, and you analyze that, and you can learn amazing stuff from this. It's called ellipsometry, and it's very widely used now. It wasn't then but—and so there was interesting problems. So I published some stuff on that because I could do some measurements and then

I could do some analysis and somewhat use computer simulation, and we had a pretty good computer here at Berkeley, so I could run over the computers then with these decks of cards.

02-01:50:35
Burnett: Yes. That's right.

02-01:50:38
Oldham: So I published some other stuff. So I came in '64 and I—we also had a nuclear reactor across the street in Etcheverry Hall. NSF decided in the sixties to populate the United States universities with nuclear reactors, so they had these Triga reactors. They had half—I don't know, half a dozen or a dozen of them around the country at universities, and they had one at Sandia, which I used there too. These were pulsed nuclear reactors, so you could get some big neutron—pulses of neutrons, and this was a cool thing, you get these pulses of neutrons. And the military was very interested in radiation effects and so there was money available there, so I says, "Well, okay, maybe I'll work on that for a little bit." And one of my close buddies had gone to Sandia because I introduced him to Friedolf Smits who was my supervisor, and he was from Arizona, Bob Gregory, and he just loved the southwest. So he went there, and Friedolf Smits was a terrific boss, so he took the job at Sandia, and he was there. And I had another friend, again a college friend, Don Scharfetter, who was at Bell Labs who was by then doing simulation of electronic devices. So he went and I went the same summer in the same lab as Bob Gregory to Sandia for the summer. I took that job just to really get up to date on radiation effects in devices. And then I learned enough about that, that I did research on that and probably had half a dozen graduate students do their PhDs on radiation effects in devices, which is kind of worthless in terms of advancing the state of the art in integrated circuits, but it was interesting, and—

02-01:53:01
Burnett: Well—

02-01:53:01
Oldham: —there was money available. I needed money.

02-01:53:04
Burnett: It's useful if you're shooting an integrated circuit into space.

02-01:53:07
Oldham: Yeah, it was important for that, but the military had their other reasons for just wanting that. They just wanted to know if they—how close to the H-bomb can they have on electronic circuit that still works and all this kind of stuff.

02-01:53:21
Burnett: Sure.

02-01:53:21
Oldham: But we were not doing anything like that. We didn't do any classified research; we never would do that. We just did basic stuff, understanding. I

was just looking through my students. I probably had half a dozen students that did their PhDs on—and their primary direction was radiation effects on devices, but sometimes they did other stuff on the devices, which was also very interesting. So I got my research going that way because you had—

02-01:53:55
Burnett: Right, multiple tracks.

Oldham: Because you have to be producing something, yeah.

02-01:54:00
Burnett: And you don't want to put all your eggs in one basket.

02-01:54:02
Oldham: Well luckily and finally, I just shut this thing down and threw this piece of equipment out because I said, "Look, I do not want to chase leaks the rest of my life." I would go in at night and spend five or six hours trying to find out where was this leak, which was ruining my vacuum, and so basically, I was chasing leaks for two years.

02-01:54:25
Burnett: Can I ask about that, because, what was the parent technology that you were influenced by? Is that in chemistry or electron microscopy where they need high-vacuum?

02-01:54:39
Oldham: No, I needed high-vacuum to be able to cleanly evaporate one material onto another. I saw this was going to be—it was a very flexible way to be able to make—not [mass] production—but to make circuits and make devices. And like I say, it hadn't been named yet, and now it's named MBE, and it's very important. I mean it became a very important way to make all kinds of devices especially photonic devices but also electronic devices, but not for high-volume manufacturing. You figure out another way to do it in high volume, but if you're going to do experiments and you want to make a device, it was the way to do it.

02-01:55:36
Burnett: Do you know where and when that MBE was developed or—?

02-01:55:39
Oldham: Well, it was in the seventies when it was all over and people started to realize. Once people started making the high-vacuum equipment that was reliable, you could open it, close it, pump it down, and it actually pumped down. Once that was possible, then you could do all this stuff, but I could never do that. I closed it and then I bake it and then I pump and I say, "Oh man, I've got a leak here, I can't get—" And then I have to find where that is, and you have these leak detectors, and you put helium around, and, oh, it's over here and so you say, okay, so that seal is bad, so you replace that. Oh! [Expression of exasperation]

02-01:56:20
Burnett: Right, so are vacuum, not necessarily high vacuums, but are vacuums used in the clean-room spaces of foundries?

02-01:56:28
Oldham: Always, always. Vacuum was used a lot. Like when you're depositing metals, almost all metals were deposited in those days by evaporation. So typically, you would have a little—like aluminum was the conductor of use then, it isn't so much now. And the way you did it is you either had a filament, which was coated with aluminum that you heated, or you shine an electron beam at a pallet of aluminum, anyway, it then just went off and evaporated. And it didn't matter if there was some oxygen at the interface. The aluminum ate it up, and you're not interested in electrical properties there, it was the aluminum and it's stuck. It's been always used and it's still used, evaporation. Ultra-high vacuum evaporation, not so much in production. It's used a little bit. IBM later on developed exactly the process I had in mind, but it was twenty years later, a way to do a certain kind of epitaxy at a very, very precise high-vacuum way. Anyway, so that was just a dead end. You have some dead ends, and I had two years of a lot of waste. It doesn't matter.

02-01:57:57
Burnett: Right, that's part of the research career, it's inevitable.

02-01:58:03
Oldham: Yes, it's pretty rare you don't have—and I had this ellipsometry work, and I had radiation effects in devices, pretty much was the kind of work I could publish. Because of that and because of what was happening outside, I got interested in semiconductor lasers, which had come on in the sixties, simultaneously invented in three different laboratories around the country, it was marvelous. And I got more and more into lasers. Looking back at my students, I had a half a dozen students do their thesis on various kinds of semiconductor lasers, and I got very interested in exotic lead salt lasers for the deep infrared, so I got more and more—I realized by the early seventies that I'd gotten off the main track. Here I am making infrared, deep infrared lasers and studying that, and I'm not a real laser guy. My buddy Steve Schwarz who I work with and did the book with, he's a laser guy. I'm not a laser guy, and I was having all my students work on lasers, I said, "What am I doing? I'm supposed to be an integrated-circuit guy," so that's when later on I went back and reeducated myself at Intel, yeah.

02-01:59:42
Burnett: Well, maybe that's a good point to pause?

02-01:59:45
Oldham: Yes.

02-01:59:46
Burnett: And we can start up with our next session next time.

02-01:59:50
Oldham: Okay.

Interview 3: September 15, 2021

03-00:00:04
Burnett: This is Paul Burnett interviewing Bill Oldham for the University History Series, and it's September 15, 2021, and this is our third session, and we are here in Oakland, California. Welcome back from Hawaii, it's been quite a trip, I'm glad you can make these trips to do this set of interviews. The last time we left off, we were talking about your efforts and casting about in these research programs, and you were getting nowhere with this high-vacuum work. Can you tell me at what point you decided to abandon that when it was clear that that was going nowhere and then how you sought out new—a new research program or a new topic to pursue?

03-00:01:01
Oldham: Yes, okay. We discussed a little of this in the last time in problems of the high-vacuum epitaxy work. And I don't remember exactly, of course, the date when I just plain got tired of spending my nights trying to find leaks, and I mean I was doing some other things at the time. What we had here at Berkeley, we had a big computer center with—it was an old-fashioned one where you used punch cards and all that, but you had a real computational capability here, so I could do some computations, which I couldn't do before. In the lab, we had some equipment that was interesting, and I could do some analysis and experiments on. I had this chap, I can't remember if I mentioned him before, Bob Holmstrom who was my first student who had been a graduate student with Professor Bob Pepper who left simultaneous with my arriving at Berkeley. And Holmstrom was a very capable experimentalist, and he was interested in similar things to me, but he was doing chemical epitaxy. Of course, I did a lot of that as a graduate student, but he was interested in that and so we had those kinds of opportunities available. On the side, I was doing computations and calculations, and I had Bob doing experiments, and we got into some actual device work, which was what I was hired to do, [laughter] and we did that.

03-00:03:07
Across the street, they just put in this reactor. NSF built all these TRIGA reactors [Training, Research, Isotopes, General Atomics]. And so I had that capability, which was a pretty cool experimental capability and—

03-00:03:35
Burnett: So it would help with visualization or measurement of the properties of the materials that you were working with?

03-00:03:43
Oldham: With that reactor, you could bombard the materials and create defects in them, and defects play such an important role in semiconductor devices. And there was a large interest in radiation effects on semiconductor devices at the time and there was funding available so that sort of—and I had a close connection with the chap who was running the research program at Sandia on radiation

effects on semiconductor, my former boss at Bell Labs. And one of my close college buddies was working there, and so it made sense to look into that and so on. I call this opportunistic in the sense that you make use of the facilities, the money, whatever is available in interesting problems in something where some students have some interest because if the student, not interested in the subject, there's no point in doing it. So that's why I moved into that direction.

03-00:04:58
Burnett: Well I think we should touch on teaching a bit more on an ongoing basis I suppose.

03-00:05:08
Oldham: Yes.

03-00:05:08
Burnett: At the time, you're an assistant professor, how does it work when graduate students come in? Are they applying to work with someone, do they apply because they're coming to Berkeley and they will find out when they get there? They know they want to work in electronics, but how does that dance work between the professors, the faculty, and the students, the graduate students, and in particular with you as an assistant professor, how were you approaching graduate students as part of your work?

03-00:05:47
Oldham: Oh, that's a good question, and it works in all the ways you mentioned and some more. You could imagine that any sensible graduate student would only want to work for the most famous professor in the field, right? Yet, the assistant professors were able to—I was just thinking of my close friend Steve Schwarz who was in quantum electronics, and he was getting some terrific graduate students. In fact, I directed one of them to him, so other colleagues are directing students to you. There's many ways as you—sometimes you look through applicants and say, "Oh, let me ask this guy if he's interested, maybe I can fund his research" that kind of thing. So there's all kinds of ways where you—this dance, as you correctly described it, to attract graduate students to your work. But you have some idea of their interest, and their interests are generally what's hot in the field, that's most generally because if they're not into it yet, they don't know, kind of, where the bodies are buried.

03-00:07:07
Burnett: [laughs] Well, I could see the junior faculty in fields such as physics and engineering almost being more attracted because they're more likely to have just graduated in the hot area. Is that a fair supposition, or is it partially true, or not true at all?

03-00:07:31
Oldham: I could imagine that too, but I don't think most students think that way. I think they're probably more attracted to people whose names they read in the stories and papers and stuff that—although some students are just plain trying to get

into Berkeley, and they'll write ten faculty members and say, "I really want to work for you," so it varies—

03-00:07:59
Burnett: It varies.

03-00:07:59
Oldham: —a lot. And so somehow, out of these, somehow, you—a few come to you, and you accumulate these interesting people.

03-00:08:15
Burnett: Yeah, and they're game for what you've got going on? When you're trying to work on something that—?

03-00:08:20
Oldham: One of the things I should mention, I was thinking about this in preparing for these series lectures, this, what you don't mention is sometimes, some of the really pleasurable students to work with are those who really don't have much interest in what your interests are. They know what they want to do. I had a few of those, and it's a wonderful thing to have a graduate student come in and say, "You know, I'm going to research this, and is that okay?" And some of them, two of them I had, interestingly enough, the two that went off to be faculty members, one at MIT, one at Stanford, those two guys came in not only with what they wanted to work on but with their own funding. They said, "Oh, my—" I think that HP [Hewlett Packard] was funding both of them, so they had funding. They had their own research ideas, you didn't have to tell them what to do every week, they'd come in and tell you what they were going to do, and so on. Those guys are just such a pleasure, but they're the exception. Most students you are sending on the idea, and they come and need help as they go along, yeah.

03-00:09:37
Burnett: Mm-hmm, and so there was industrial research funding, or is this the foundation?

03-00:09:41
Oldham: It was always a mix, it was always a mix, and in the—fairly early in this program—I forget when MICRO came along. MICRO came along in the seventies I think, before the end of the seventies, micro. And that really pushed the industrial side of the funding, this California MICRO program, which encouraged companies to put some money in and then was matched by the state and so that side, no, but some companies, IBM in those days and I'm trying to think what other companies, not so much but Bell Labs, the military. One of very first students was funded totally by—I think he was air force, and he had enough money to do his PhD. I mean I have to provide for the research cost but he had—I didn't have to pay him; whereas normally in sciences, you pay the students, so they can live.

03-00:10:49
Burnett: Right, right. So it would be like RCA?

03-00:10:54
Oldham: Yeah, RCA, they never really funded much at Berkeley. They were—

03-00:11:00
Burnett: Because they're East Coast.

03-00:11:00
Oldham: —eastern companies, but certainly—and the start-up companies here took a long time getting going and funding, they eventually did. The Intels, it took them a long time before they were funding anything directly. Like this MICRO, that's what made a lot of that happen, and they could have some say in what the research was on, that's what they liked. They could say, "I'm going to fund research in such and such," and so on, so that was their interest in that.

03-00:11:32
Burnett: Right, right, and as you said, the military too, there was a lot of funding from—?

03-00:11:38
Oldham: Well, the military, the military labs in particular were funding—we had this program, Joint Services Electronics Program. Even when I came to Berkeley, it had been started. It was run by the director of ERL [Electronics Research Laboratory] which was—I think it was called JSEP, Joint Service Electronics Program. All three services put money into that and then each year, we would propose what we're going to do, and they would say, "Oh, oh, that's interesting," or not. And after I became director of ERL, I ran that program for about six or seven years till it—I think it finally ended in around early eighties.

03-00:12:22
Burnett: You're getting students in the late sixties, early seventies, and you mentioned Holmstrom. Were there other graduate students from that time who stood out to you as—?

03-00:12:39
Oldham: Well, yeah, I had mentioned this guy, Reid Samuelson, who was the military guy. He stood out because he said, "I have three years, I got funding for three years, I want to be in and out in three years." I was all for that. A lot of colleagues or my colleagues are not so desirable getting their students through real quickly because they don't get enough work out of them in that way. [laughter] But I myself, I did my work in three years, and I appreciated that you can, and there's no reason not to. So see, Samuelson was unusual in many ways and very productive, did a very interesting series of papers, research, which we never published till I had another student who was I would call him the cleanup guy, Paulo Antognetti, another very interesting guy because he would look around and say, "You've done this work, this is interesting," and

then he would—we would publish that. So he has coauthored a number of publications, which wouldn't have been published otherwise.

03-00:13:53
Burnett: So he was refining and polishing stuff that was existing or work that you had worked on?

03-00:13:59
Oldham: Yes, I mean he did his own work too, but he just saw. Because we work as a group, we're very friendly as a group, so everybody knows about everybody else's research and he saw like—I don't know if Samuelson, he was gone, I think by the time Antonietti came in but said, "Hey, this—" In fact, I had him doing some research, which was a follow-up of Samuelson, so we went back and published Reid's work and so on. So, yeah, there's so many interesting students with different sets of talents. You don't appreciate it at the time; it's only when I'm in—looking back at this now that I see this different set of talents.

03-00:14:44
Burnett: Does it help when graduate students graduate and they go on to other—to the academy, to work in other universities, or to Bell Labs, or to industry? Is there a kind of larger EECS community out there so that when new graduate students come in and say—you can say, "Hey, you should talk to So-and-So, my former student." Is there a larger EECS family?

03-00:15:14
Oldham: That's another good question, not explicitly, nothing. Your question, I have to think it through, so it's not so common that I say, oh, yeah, that's how it is, no. I mean that exists to a certain extent, but a lot of my students—well, we would get together when we're here. We even went skiing together, we did this and that, but after they left, I paid no attention to them at all. I'm terrible that way, but they themselves would get together. So they had their own—

03-00:15:58
Burnett: Cohort I guess.

03-00:16:00
Oldham: —cohort, and of course, some of those students got together, and they were the ones who funded this fellowship for first-year graduate students. They got together and raised money and funded a fellowship to support first-year graduate students. I didn't suggest that or anything. They just one day said, "Okay, that's what we're going to do." That's a good example of them because they themselves realized how important that first year is. You come in with funding, everything is good on your first year, and after a year, you can figure out what you're going to do.

03-00:16:41
Burnett: Kind of a soft landing and get oriented?

03-00:16:45
Oldham: Yes.

03-00:16:47
Burnett: I imagine. So I guess the famous thing about engineering schools is this prescription of core courses, so much of it is not electives, right? You have to do this, this and this and proceed to the next sequence. How did it work with respect to teaching at EECS and—? This is undergraduate engineering that, then they specialize and so on, when you become a graduate student and you're entering EECS, is there a core teaching curriculum that they need to do in order to proceed to the next level? What is that first year like in that sense?

03-00:17:50
Oldham: As the undergraduate did, that changed over the years. There were a limited set of courses, let's say, in the fifties and the early sixties, very limited set of courses. So if you're interested in electromagnetics, it was like three courses, every electromagnetics student took those three courses. Or in semiconductors, they took—we had a device course, we had a sort of solid-state physics of devices course, and we just had a few courses in the beginning and then every student just took courses. They're not required courses. You had exams, and the exams were in certain subjects, so you knew you had to take courses in those subjects.

03-00:18:44
Even as an undergraduate, Berkeley was quite a bit better than the average engineering school, which had a fixed curriculum. I had like one elective a year when I was an undergraduate. I think I'd mentioned that I had a great experience at Carnegie that they let me substitute other courses. I would go and say, "I don't want to take this course, can I take that course?" and they were very liberal with that, but you had a set curriculum. Well at Cal, it was quite different. There were enough courses that all that was required was a few certain courses. There were a few key courses and then there's a bunch of courses you could take after that. So it was I think closer to the liberal arts idea that there's a few things, and after that, you take a set of things that are in the field and they make sense for that field but not prescribed, rigid.

03-00:19:53
Burnett: Right. So when you were teaching, I imagine as starting out, you were assigned teaching, is that how it works, as a junior faculty, did you get—?

03-00:20:09
Oldham: Yeah, I think I had mentioned, maybe we mentioned in one of the other interviews, I was assigned several courses here that I wasn't too comfortable with, and they relented and let me teach two sections on one course and so on. There's a person in charge of scheduling who scheduled the courses and then there's—again, the dance goes on where the faculty say, "I want to teach this," and the department needs to teach that," and that's all worked out.

03-00:20:41
Burnett: In the department meetings?

03-00:20:43
Oldham: Well no, it's worked out with the scheduling officer basically, which interestingly enough in—when I was still an assistant—no, I became an associate professor in about '68, and I was named vice chair of scheduling, which is a ridiculous thing. Ernie Kuh, Professor Kuh, another one of our really great people who was here when I came here, he became department chair, and he named me back in '68 or '69, as scheduling, which is very interesting because I'm this junior guy and I'm trying to tell these senior—negotiate with these very famous and opinionated, let's say, [laughter] senior guys of what they're teaching and questions come up. Like this guy wants to teach three courses, each of which has six students—that feels not too popular at the moment—and another guy is teaching three courses, each of which has forty students, and is that an equal teaching load? And this kind of questions come up and you get into arguments, so yeah. But there was—the dance goes on, and we worked that out. It's a marvelous world that I could do that as this nobody and I could actually—at the end of the day, we got all the courses scheduled and everybody was happy.

03-00:21:59
Burnett: We wanted to talk a lot about culture and we did that last—in the last couple of sessions or the last session. Was it a fairly flat culture in terms of it wasn't hierarchical so much or—?

03-00:22:35
Oldham: Apparently.

03-00:22:37
Burnett: Okay. [laughter] It seems to be a mark of great departments and departments where a lot is accomplished; there's often an insistence on informality and that kind of thing. Was there a changing of the guard that you—or had that already happened? I read something and talked to some folks about how there was some more senior, European guys who are used to the kind of ETH [Eidgenössische Technische Hochschule Zürich] thing, which is more formal. MIT again would be more formal, more hierarchical, a lot of egos. And they described a kind of culture that was a bit more like that. That was gone by the time you got there?

03-00:23:23
Oldham: That was interesting; that was just in the process of changing. What happened is up to—certainly through the fifties, if you became department chair, you didn't want to give that up and you stayed department chair, and if you became a dean, you're a dean for life, right, and all that. And that's still true at a few schools, not so many anymore. That changed in the early sixties at Berkeley. Like Ernie Kuh—let's see, who was department chair? Lotfi Zadeh was department chair, and I was amazed after four years, he gave it up. When Ernie Kuh became department chair, '67 or '68, he—after three years he said,

"Okay, I've done it," and I was amazed and that then became the standard. And we never had a department chair more than four years and usually three since then, and that's very healthy if you want a flat culture. Because you got to be back with the troops, so you can't mistreat the troops, right? [laughter] You're just back to an ordinary citizen and that—these guys also set that standard for the deanship. Now the deanship sometimes, they go two terms, they've been up to six years since then but absolutely. The campus paid attention to that, and the campus now has really gone to reviewing deans and not letting deans be deans forever, which was not the case in the late fifties or early sixties, so yeah, and it's very healthy.

03-00:25:07
Burnett: Yeah, and more a sense of an identity. Obviously, a scholar is an individual, right, but is there more of an identity that I'm part of this group, I'm part of Berkeley EECS, and we need to do things as a group even though you're working on your projects with maybe one other professor or two other professors and a bunch of graduate students. Is there more of a sense of—that there's a trajectory, for example, conversations about where we need to go in the next five years? Is there more of an ongoing conversation about trajectories and outcomes and that kind of thing?

03-00:25:54
Oldham: Yes, over the years, that's certainly been the case. We discussed again this once before, but I would say now, there's no question, but everything is done with the—not with the whole department trying to be optimized. It's such a huge department, we had a hundred faculty members or something, so you're trying to optimize each field, maybe AI or maybe integrated circuit design or something. You're trying to get—keep that at the top of its field, and you worked not as individuals but as a collection for that. And certainly, all hires are done, and that's amazing that in the end, even the EECS which is this impossible large department with very divergent interests, that we come together and make the final decision on hires as a department of course. So, yeah, no, it's very healthy over the years to see that evolve, and it pays off because UC Berkeley, it's a good place, and what's good about it is there are very few weak departments. Most departments are very good and some are just the world's best, and we have the largest—certainly the largest number of, say, top ten departments, and it has a lot to do with this kind of thing. And, of course, I say it has a lot to do with the faculty-run decisions as opposed to administrative-run decisions.

03-00:27:43
Burnett: It's a kind of shared-governance model?

03-00:27:46
Oldham: The shared governance, yeah.

03-00:27:47
Burnett: It's a real force.

03-00:27:50
Oldham: It's real, and deans don't have any power, and that's the greatest thing, you know, that's the greatest thing. Deans can't hire their friends.

03-00:27:58
Burnett: Interesting.

03-00:27:58
Oldham: That's very healthy.

03-00:28:00
Burnett: [laughs] Wow. A flat culture, and I just mean that it's nonhierarchical, there's a shared sense of purpose even though you're each working on your different projects, but there's an interest in the overall health of the group, right? I was going to ask something further along about that, and maybe it has something to do with the ERL, so the Electronics Research Laboratory, which I want to clarify, is the larger unit of which the Microlab is a subset, is that right? So the ERL was created in the fifties, and the Microlab is a smaller group, is that right?

03-00:28:53
Oldham: Oh, yes.

03-00:28:53
Burnett: That was started in the early sixties by Don Pederson. So tell me about the function of the—in this larger group of EECS, how—what is the ERL as an institution within EECs in those years and how does it—? It's obviously a laboratory, but what is it as a force in terms of making decisions about the direction of the department as a whole?

03-00:29:26
Oldham: You know, it puzzles me exactly how this ERL in particular got started because it's not a department, it's not who's the boss of ERL, is it the department or is it the dean and so on. And the answer is it's a mixture; it's a strange thing. But what happened somehow in the fifties is that—and by the way, Don Pederson was director of ERL for a short period of time there when the integrated circuit lab [Microelectronics Laboratory] at that point came about, and he made that happen. But, yeah, somehow, somebody felt the need, and I don't know the history of that, but somebody felt the need that we need a research organization independent of the department whose primary function is to administer, foster healthy research, administer it for you, know how it's done with respect to both the campus needs and the sponsors' needs, which was largely military in the fifties, that there was military money, and so how do you do that?

03-00:30:50
And so they created this organization, ERL, and Don was one of the first—probably, he wasn't the first director, I don't know, Sam Silver—I can't remember because I wasn't here. But Don was director when I got here and

then very shortly thereafter he took a sabbatical, and Diogenes Angelakos took over and he was ERL director—

03-00:31:10
Burnett: Yeah, a long time.

03-00:31:11
Oldham: —a long time till he stepped down in '84, and that's when I was ERL director. It was really not trying to direct research at all; it was trying to facilitate research by administering it properly, and it was so successful in EE that it took it over for a short while for some other departments. So people in materials science, not in physics I don't think, but in materials science and some other departments in the college actually administered through ERL. And then ERL vanished in this larger organization ERSO [Engineering Research Support Organization], which has basically the same function as ERL, which is to foster research by administering it well.

03-00:32:04
Burnett: And that's 2008 or something like that?

03-00:32:08
Oldham: I don't know when ERSO happened. Yeah, it happened—

03-00:32:10
Burnett: Late two thousands?

03-00:32:11
Oldham: —yeah, probably, just about the time I was retiring.

03-00:32:14
Burnett: Okay, okay. It's a large administrative force in addition to physical space.

03-00:32:24
Oldham: Well, it had to have some space because you had to have a lot of people doing grants, administrators. It had a whole shop of its own. ERL had a machine shop with half a dozen machinists in it. Who were their bosses? Well, there was one head machinist who their boss is. How did that work? I don't know. It was there, and I mostly did my work in the department machine shop, but I did some work in the ERL machine shop in the beginning. And then one day it disappeared because ERL funding was reduced to support that and so the machine shop was one of the things to go.

03-00:33:06
Burnett: And in terms of the space on campus for EECS, EECS' home is Cory Hall.

03-00:33:12
Oldham: At that time, it was Cory Hall, yeah.

03-00:33:15
Burnett: Okay, but you're also doing work in Etcheverry Hall, which has the reactor and—

03-00:33:19
Oldham: Yeah, but that's just anybody could do work at that reactor, you know?

03-00:33:24
Burnett: Right, right. Tell me about computing?

03-00:33:27
Oldham: And computing was in the basement of—well first of all, it's in Campbell Hall and then they built Evans Hall. They built Evans Hall in the early sixties and then they put—they moved computing over to Evans Hall. I believe maybe math was in Campbell Hall before that, I don't know where math was, it must have been in Campbell. So somehow, the computing was somehow always associated with math. Although it has very little to do with math, it was somehow always associated. Anyway, went in the basement of Evans Hall and so that we all trucked with our boxes of cards in and out of the basement of Evans Hall until later on in the—I don't know when we got some other alternatives to that in the late sixties or early seventies.

03-00:34:14
Burnett: Yeah, it sounds about right. Computer science is '68 and then there's this—there's computer science and then there's a computer science program in EECS and then they're kind of merged I think later. So these are mainframe computers in the basement?

03-00:34:36
Oldham: I think it was a big old CDC 6800 or something, the biggest sort of non-supercomputer, but it was a supercomputer by its function, and it was the CDC series. They had a couple of them in Evans Hall there, so we trucked over there to that. Then what happened is in the seventies—just to follow that theme a little bit, in the seventies, Unix started happening, and Berkeley participated bringing the VAX Unix. Unix was on smaller machines than the VAX initially, PDP8s, I think. But our students started learning about Unix, and they dragged us into Unix, so my students taught us about Unix. Andy [Neureuther] and I, in running this program, were getting some computer-savvy students to do this really good programming work, coding of simulation, and they dragged us into Unix.

03-00:35:51
Burnett: I think we were talking about this off camera, but there's this interesting—you and your colleagues are working on devices and the hardware of integrated circuits, which are integral to computing. And to do that work increasingly as the complexity and the size of the number of circuits on a chip increases exponentially, they're too complicated to—you can't—obviously, you can't build a breadboard for them, so you need to have modeling capacity. And so you're increasingly using computers to chase the innovation in the hardware that is used in the computer—that comprises the computers. So I'm wondering if you could talk about that? You said that students dragged you along into, say, the newer programs like Unix, but you were working in the older machine languages like FORTRAN, for example. Can you talk a little bit

about developing modeling software for the processes you were interested in? And maybe to get there, we need to set up the kind of processes that you were investigating and looking at, and to do that, I think we need to talk about your period in the early seventies where you're beginning to latch on to new things and looking for a new research program. Can you talk a little bit about that search in the early seventies for something new that you could be interested in?

03-00:37:47

Oldham: I mentioned already that—and this is relevant to your question—this is somewhat opportunistic, in that if some tools are around, like computer is a tool or an analytical tool just like ellipsometer. If tools are around, and there are some unknowns related to those, but they can play a role in your—in the future of the field or in your research, then you're motivated to work on them. So it's like that. We didn't have the idea of building better transistors so we could have better computers so that we compute how to make better transistors so that we could—but it does bootstrap itself, and we're not totally aware of that.

03-00:38:43

I can give you an example where—let me give you—I think this is a very interesting example. This happened a little bit later. So one day, we invited Gordon Moore to speak at Berkeley. This is probably in the mid-seventies, maybe late seventies, and he was giving a seminar at Berkeley, but it's largely attended by folks from computer science and electrical engineering and so on. So my colleague [William Morton] "Velvel" Kahan from computer science who's an interesting character, Velvel sticks up his hand and asks, he says, "Dr. Moore, one thing I don't understand," he says, "Intel has all these big factories and working on building chips." He said, "Very clearly, all the advances are made in software, why isn't Intel working on software?" Now, the answer to that is, of course, dude, you can't execute your software if you don't have any chips and we're making the chips, and Gordon didn't say that. He said, "Well," he says, "I personally have a lot of money invested in factories, maybe hundreds of millions of dollars, and I would like to recoup that investment, so what I do is I make chips." [laughs] So that was the answer.

03-00:40:17

But I think the real answer is you can't do your software if you don't have—and this is really true. As we make cheaper chips, you can do faster software and make faster software then you're going to be able to design with these unbelievable programs today for designing the circuits, designing the chips, designing what we do, the processes to make the chips. All of that is done through this very intensive computing. Your question relates to how you do decide on the problems to work on?

03-00:40:59
Burnett: Well, let me make a very precise question because that was a rambling question. Tell me about why you need programs for the processes. What processes are you looking at, and what do you hope to get from the modeling that you can't get from doing other things?

03-00:41:26
Oldham: So what we used to do is we used to say, "Well, gee, I want to make this kind of transistor, and it requires maybe a junction this deep, and it needs this structure." They're really three-dimensional things, they're not really one-dimensional, but you mostly work on one dimension because it's easier. And so you do all these computations, and you say, "Well, I wonder how long I should do this oxidation for?" and so then you do an experiment. You do a bunch of timed experiments and then you take and measure the results and then you refine it and then you do it again. Well, all this takes weeks and weeks and weeks. So if you're able to compute that, then in a few hours or if it involves carrying boxes of cards to computer center, maybe days, but it's even shorter now, you don't carry boxes of cards. So in minutes, you can do that whole set of experiments virtually. So you really need to do that.

03-00:42:37
And the same way that in circuits, SPICE [Simulation Program with Integrated Circuit Emphasis] came about because once you got a circuit with more than, say, a dozen transistors in it, not even thinking about the transient response, the time response, just thinking about calculating the—just the static, what's the current and what are the current and all the voltages in all the nodes, it's a very laborious calculation. I mean you get dozens and dozens of transistors, it's really hard to even know if the thing is stable. Is it stable, and how much current is it running? Well, you can do that by hand for a few devices, but that's what drove these people to create this program in this series of improved circuit-design experiments, which led to SPICE. And the same thing with processing that we were—we had these ion implanters and so you send all these ions rocketing into the chip and then you want to know where they are and so you did all these experiments. Well, why not compute that? So there's a very strong motivation. It's just so much faster to compute, and you can make so much progress so quickly that computation is the way to do it.

03-00:44:10
Burnett: Is SPICE the first effort in that—at Berkeley in that effort? I think before that somebody built CANCER.

03-00:44:20
Oldham: Those things were all happening together. Yeah, CANCER probably as an—was a named program before SPICE probably, but that work was going on. [Ronald] Rohrer and Pederson were kind of competing in doing simulation work, yeah.

03-00:44:40
Burnett: Rohrer had a class, and he made that the assignment and—

03-00:44:44
Oldham: And I think Larry Nagel was in that class probably.

03-00:44:47
Burnett: He was in that class, and he said, "This is the assignment, I think you thought this was a course in something else, but it's not. The course is going to be building a modeler for integrated circuit design. And the grade is if you successfully build one, you pass; if you don't, you fail." [laughter] And then half the class left that day, immediately. So that was—

03-00:45:17
Oldham: You have to understand Ron Rohrer's personality to really appreciate how that was done. I mean it's not that—quite that simple but, yeah. So Ron Rohrer could pull that off. I mean he was—he's a—

03-00:45:30
Burnett: [laughs] He was well liked?

03-00:45:33
Oldham: Well, yeah, he was a charismatic guy and strong, opinionated, and everything. He was a human being and so he could pull that off. He wasn't some kind of a pedant or something. So, yeah, I could see Ron doing that. I'm not real familiar with that story at the time, but I've heard it since, yeah.

03-00:45:53
Burnett: Okay. [laughter] So that was a way in which the students were being brought into this innovation, and I think Rohrer was doing this at the behest of Don Pederson? You said that they were competing, but the idea was that the students would be enrolled in this project to create essentially a tool for students. It would help the students understand circuit design, so it had that pedagogical function. I don't know how that sits with you.

03-00:46:27
Oldham: I don't know the role of the pedagogy versus the role of being the first to have a certain kind of cool simulator. I really don't know the role of that. I know that Don and Ron were friends and kind of competing, and it's possible for that to happen at Berkeley at that time where this young guy—Ron Rohrer was—whose student was he? Oh, man, he may have been—I think he was a student, he got his PhD from another Berkeley professor I think, anyway. But he has—clearly lower on the hierarchy of—but it's possible. The beautiful thing was it was possible for two guys like that to have a friendly competition and say, "You don't know how to do that," and "You don't know how to do that." They could do that, it was really possible, and there were no consequences of—

03-00:47:29
Burnett: Right, right, right. It was just a spirited project.

03-00:47:33
Oldham: And completely different personalities, completely different ethics, completely different kind of characters, and that went on, yeah, with—it's great.

03-00:47:43
But back to your point, when I came back from Intel and to jump ahead a little bit here, when I came back from Intel, I knew for the first time in my life, I had run a program in design because I was doing both the design of the DRAM and the technology. My only time at Berkeley I ever did, I taught a course in integrated circuit design, so I did the same thing. I had students say, "Okay, you guys want to do IC design, in this course, you're all going to design a RAM, a read-only memory, you're all going to design a RAM, and that's what this course is about. We're going to start out, you're going to—you have to learn the process, so you know what the devices are like, and then you have to lay it out. You have to lay out a sense amplifier, you have to lay out a decoder and all that stuff and put all the stuff together. In the end, you're going to have a design." So I actually did that too, and the students loved that kind of work where—not everybody does—but the ones that you want to inspire with that love it, and they deliver.

03-00:49:00
Burnett: And it gives you a perspective, doesn't it? Doing it at that level, it's not as messy as the actual devices and the actual processes, but almost because it's simpler, it gives them the kind of—maybe bird's-eye perspective is the wrong metaphor or analogy, but that this—it gives them a workable perspective as a learning student. Is that fair to say?

03-00:49:33
Oldham: Well, absolutely, you see—you might think analog if you were a mechanical engineer and somebody says, "Okay, we're all going to design an eight-cylinder engine or something." Well there, students can design—you have no idea if it's going to work. If you go through this at the state of the art in '75 or '76 in—with the simulation capability we had, you designed a chip, that chip will work. Those chips could all have been sent out, they would've worked. It was that good, so it's really a realistic design. It's like I say if you—in the mechanical field, you would have to then have a foundry fabricate all that stuff, and you really wouldn't know if it's going to work until—because the finite-element design wasn't there at that time. You wouldn't know if that connecting rod is going to break. Today with fine-element design, you can almost guarantee that all the parts will work in the mechanical design because we have finite-element analysis now, but you didn't then. And whereas in integrated circuits, by then, we already could design circuits that were going to work.

03-00:50:53
Burnett: Hmm, and this is all—SPICE is like '71 I think?

03-00:50:59
Oldham: Well, in the early seventies, and every company had something. Intel wasn't using SPICE yet. They were still using their own program called Pulse but, yeah, you had to have that capability. You had to be able to design that program with the—that circuit with the program with the program to work.

03-00:51:20
Burnett: Well, I think that just this kind of thing circulated everywhere, and there were, yeah, proprietary programs that each companies use. The story about SPICE that I heard was that because it was open source and that Berkeley was this repository for it, so the debugging would come back, it improved, its core improved at a faster rate and so it started to be—to spread.

03-00:51:50
Oldham: Yes, yeah.

03-00:51:50
Burnett: And it became a kind of industry standard.

03-00:51:53
Oldham: Yeah, exactly what happened like with Unix. Unix was open source, and that's why it became really, really big, important at that time, no longer so much, but it's still around.

03-00:52:07
Burnett: Yeah, yeah.

03-00:52:08
Oldham: The open-source thing is really important and the Berkeley's continuing Berkeley support of it with Professors Ping Ko and Chenming Hu and these guys who supported it later. Don Pederson was long gone from interest in that. He didn't do that anymore, but the other folks did, and, yeah, it was supported.

03-00:52:35
Burnett: There were various iterations of SPICE but other programs as well that became important. Let's put a pin on that for now because we'll get to talking about the modeling work that you were doing when we get to that topic. But there's a couple of other things that you were doing and finishing up: One is this sabbatical leave, and you go to Germany again. Can you tell me about that? That's in '70—

03-00:53:13
Oldham: Yeah—

03-00:53:13
Burnett: —seventy-one.

03-00:53:13
Oldham: —nineteen seventy, seventy-one, so I had—I was doing this hodge-podge of different fields, a lot of—probably the—most people in radiation effects in semiconductors, but some of those just involved the devices themselves, and

some of them were radiation effects on devices. That started some of this laser work, and I was looking for—it was time for—it's a funny thing. You work for about five years here and you say, "Man, I've got to get out of this place," and I don't know what it is, and really sabbaticals really, really make a difference. So in—

03-00:54:00
Burnett: Getting recharged?

03-00:54:02
Oldham: —I don't know what it is, but maybe it's me. Some people can just keep doing the same thing all the time and I just—so I needed to get a refresher. I had lived in Germany a year before and so I was determined, that time I was going to go to France. I had some close connections in France with some work we were doing, and I was going to go there. And on my tour through Europe one summer, I used to go to Europe in the summer with my wife, and on one of those tours, I went back through Munich and happened to go to the—it was called the TH, then the—which is now Technical University in Munich, but it was called then the Technical High School. And I think Dick Muller may have been there on sabbatical, I'm not sure, but I went through there and met the folks there and stuff, and it was just so easy. I knew the language, I liked it, and my wife liked the area so much, so I ended up going there.

03-00:55:06
And there was this Professor Ruge who again became—he was the young guy there, and he became again another lifelong friend. And he said, "Yeah, come in and you—give you an office," that's all you want. So I was able to work on a number of things, wrapping up the radiation effects work and starting some other work with some—a couple of his students I got to know there and did a couple of things with them. And then it turns out that was later important because those students, a bunch of them went to Siemens, and when I went to Siemens later, some of them were there, I already knew them and what they were doing.

03-00:55:54
Burnett: So it was—

03-00:55:54
Oldham: And I also had the opportunity there to follow up. You mentioned teaching, I've had to follow up with Steve Schwarz with writing a textbook. We had talked in the eighty—in the sixties about the need for a textbook. Now very interesting, this is something about my colleagues, Pederson and Whinnery and another, a lecturer named Jack Studer had written a textbook for the introductory electronics course. They had just finished it, so it came out in '65 or something like that. And that was the textbook for this course, the introductory electronics course, which has—the number has changed over the years. But anyway neither Steve nor I liked this book very much, and it's funny, the guy who hired him there was John Whinnery, and John Whinnery

was the giant in electromagnetics and then became the quantum electronics leader, and Steve was hired in quantum electronics, and Don Pederson had hired me into Berkeley. Their textbook, we didn't like it, so we just said, "Well, why don't we just write another one?" never thinking that you shouldn't probably do this. [laughter]

03-00:57:13
Burnett: Well what—

03-00:57:14
Oldham: I mean it never even occurred to us or—

03-00:57:16
Burnett: Well, number one what was wrong with the first textbook, and number two, it's advanced electronics, which is changing rapidly so I can imagine that—

03-00:57:26
Oldham: It was not advanced, it was kinder—well, I call it kindergarten electronics. It was kindergarten electronics.

03-00:57:31
Burnett: Okay, so introductory electronics?

03-00:57:33
Oldham: Introductory, and so it had basic circuit theory in there, enough elementary circuit theory, so you didn't have to have an advanced circuit theory course. We taught them about Kirchhoff's laws and all that stuff, they could analyze circuits. And then we taught them about transistors, we taught them about transistor—elementary transistor circuits and a little bit on logic, Boolean logic and how you do that with circuits and all that stuff.

03-00:58:02

But, yeah, what was wrong with the textbook? Well, textbooks need to have two things: one is they need to be teaching the right subject, another thing is they have decent pedagogy. And this failed on—primarily on the second, but we didn't even like the topics that were in there because—well those—Don Pederson was a circuits guy, not a device guy; John Whinnery wrote the world's best textbook in electromagnetics, he was electromagnetics guy; Jack Studer was just a lecturer who they hired to help them with the thing and so they didn't really have somebody in the field. They had taught the course, they had taught the course, so they knew what was needed, but anyway, I think it missed the mark. So we didn't worry about the fact that we're writing a book that's going to put their book out of business, which we did, and there was no repercussions from that, I never heard one word [laughs] from—they didn't care, so. At least if they cared, they never said anything to me and they didn't.

03-00:59:19
Burnett: Well, so this is done through a publisher so was—what was the conversation about in terms of why this book was needed. That was it, saying the pedagogy was lousy?

03-00:59:28
Oldham: He and I were going to teach the course, we want to teach it the right way, so we just said, "Okay." And we outlined the topics, and I said, "Okay, I'll write a chapter on this, you write a chapter on that. And Steve was a very good writer, way better than me I would say and a very good critic, so I learned a lot about writing from him and how to do things like that. So we had tremendous interactions over that, very, very positive. But I took a sabbatical and he took a sabbatical in the period of about two years, so we both had time, you have some time to do these things and so I—that's why we did it. And then you typed these things, those days, you typed them on a typewriter and my wife could type, so I would write this stuff, and she would type it and then off to Steve and then would come back home, my God, it's—and then I have to rewrite it, you know?

03-01:00:30
Burnett: Wow.

03-01:00:31
Oldham: So I did that then. It was very good to do those things. I mean writing a textbook is a really good thing to do to get your thoughts straight on something and then you have to write problems, you have to do a lot of problems. Writing problems for engineering is a great exercise in itself, you know?

03-01:00:57
Burnett: Well, tell me about that.

03-01:00:58
Oldham: Well, you say, "Okay, we want to teach this certain concept in circuity theory" or something and then the way people learn it is to then be tested in it by solving a problem using those skills that you taught them in that lecture. I had a computer science professor when I was a student, Alan Perlis, the famous guy at Carnegie Mellon, and he said, "Well," he says, "you know, you guys think you learn something in a course, you take a course and then you think you know something." He says, "You don't really know that, you think you know about it, and you pass and test in that stuff." And he says, "Much better test of learning it is to teach it, so then you start to write a lecture on it, and you realize, oh, why is that true? Is that really even true and this and that? And then you understand it at a deeper level." And he said, "But you still don't understand it." He said, "The way you understand it is to write a program to do that, and a program is just a program. It can't think and correct errors and anything real, and it's just a program. If you write a program to do that, then you understand it," and doing problems is that. How many professors have written problems for exams, which can't be solved and then they discover during the exam? I mean that happens all the time—

03-01:02:33
Burnett: Oh, my God—

03-01:02:33
Oldham: —in engineering courses, oh yeah.

03-01:02:35
Burnett: —that sounds horrifying.

03-01:02:36
Oldham: And that's a classic, it's a classic. You write a problem, and you just do it at the last minute, and you put it on the exam and then up comes the hand in exam, and somebody will say, "You know, I don't understand this, how do you—?" And then you say, "Oh my God," you overperceived something or you've underspecified something, there's a lot. Yeah, so writing a problem set for a textbook is actually a wonderful way to learn the subject and solve the problems.

03-01:03:06
Burnett: Right, and does it also help to have a writing partner?

03-01:03:10
Oldham: Oh, absolutely.

03-01:03:13
Burnett: That you're absolutely able to have someone verify—?

03-01:03:15
Oldham: Well, especially if it's a good writer like Steve, I mean you have a good writer like Steve.

03-01:03:20
Burnett: Yeah, and the problems have to be keyed to the level of the students, too. I mean that's the—I mean you're—

03-01:03:29
Oldham: Oh, they have to be keyed? Well, the book—the subject is keyed to the level you want to teach, but the problems have to be keyed to that, to teach that, without bringing a lot of extraneous stuff, so yeah. So making up exams is a big chore. Making up a final exam in an electrical engineering course, that's a lot of work, and people don't quite realize and then you—so some people will tend to use exams twice or something. I would never use an exam twice because people are out there are going to have copies of all those exams and all that stuff, so you don't do that. But it's an enormous amount of work, and it's a good thing, anyway.

03-01:04:15
Burnett: Well, one more question about the—I mean it's a 650-page book, this textbook, and maybe it ends up that long, I don't know. So in the intro course, electronics course, do you—is it designed in a modular fashion so that this—whoever is teaching can choose units out of it or do you do the whole 650 pages?

03-01:04:39
Oldham: No, you don't do the whole thing. You do more because you have to write a textbook in a way that people with somewhat different interests, some with expanded, some with less interest than you can also use the book; otherwise you don't have any sales. So, yeah, the book is not a one-year—a one-semester course. The book could be used over a one-year course, but no one-year courses exist anymore, they don't exist in the world. They used to be, we used to have regular one-year courses, a, b, and you had to take a and you had to take b. It doesn't exist anymore. It really got bad in the—we had the quarter system for—well, that really became ridiculous when you have a quarter system and you—phoo, it's bad enough.

03-01:05:22
Burnett: You only have ten weeks to do so.

03-01:05:23
Oldham: Because the old days like the European system, it's a one-year course, right? And there's no problem sets and no test during the year in the old days in Europe, no problem sets, no tests, and then at the end of year, there's a set of exams. Well, the students goofed off all year long and then they cram for the six weeks part of the exam, and they try and pass the exam. That's why American colleges are able to—we have very inferior secondary schools, but American colleges, the kids catch up because we kill them in college. I mean electrical engineering, don't send your kid in electrical engineering because they're going to go nuts with the work, right?

03-01:06:05
Burnett: Mm-hmm.

03-01:06:06
Oldham: Yeah.

03-01:06:05
Burnett: Talk about that. Berkeley is a tough school, challenging I mean in that sense, and Berkeley engineering is tough in that sense. What was your sense of how the students cope with the workload? Are they working together, in groups, do they have study groups, how did it work, how did you survive?

03-01:06:30
Oldham: That concept of having the students participate in a way other than just doing problem sets and tests never occurred to me until later on in my career because it wasn't common then. Now, we have all these courses where students have groups and they'd solve things in groups and so on, it's very useful, I mean it's a great thing. I didn't even know about that; I mean I never did that, okay. That was almost twenty-first century as far as I'm concerned, not quite, but I didn't catch on to that one in my career, but it's very useful. I don't deny, it's a very useful teaching technique especially for certain kinds of kids who have different backgrounds. But nerds like me, nerds, real nerds, they learn, they figured out how to learn. Now with the internet, you can do—

you can get any information you need, but in the old days, we used to find the books and find the experts and solve the problems, right?

03-01:07:40
Burnett: Right. You just had to be—learning how to learn is the key, of course.

03-01:07:46
Oldham: One of my students [Charlie Sodini] who became a professor at MIT and then my daughter is going to go to MIT, and he says, "God, don't let her take 601," right, or whatever the—they use a number for departments there. So if you're going to be electrical engineer, it's like 601, or I don't know what the hell it is, they don't even call it electrical engineering, it's really weird, I mean talk about nerds. So he says, "Don't let her do 601, it's just impossible." He realized [laughs] how hard they work their students, right?

03-01:08:22
Burnett: Yeah.

03-01:08:23
Oldham: And it's true, it's true in engineering in general, [laughter] we work them hard.

03-01:08:30
Burnett: Yeah. So part of it is—because you're learning as a teacher—throughout your career, throughout your life, you're learning as a teacher, but it's a crash course at the beginning. And I imagine that writing the textbook was you coming into your own as a teacher, you and Steve Schwarz.

03-01:08:55
Oldham: Yeah, I expect that's true. One thing that happened I should also mention that happened here, which is a very positive thing—it's controversial now—was about second semester. So I was here, this student radical—remember this was the time of the students were rising up against the oppression of everything. One of the organizations, I believe it was called SLATE then—

03-01:09:27
Burnett: That's right.

03-01:09:28
Oldham: —decided to have students at the end of a course rate their professors. And they would go to the classroom as the students were leaving at the end of the semester and say, "Please fill out this survey." It was totally unsanctioned, and the university I think tried to suppress this, well, they couldn't suppress it. And so somebody from SLATE or so came over to electrical engineering and started doing that, and of course, the beginning courses were the ones which made the most sense to [review], and so in the beginning, I had my students—within a year or two, I had my student—they had surveys which were published. They didn't send them to me, I have to read about them in some—you have to go across campus and find some magazine or something like that. That was a really, really good thing. You know, that was a very good thing.

03-01:10:27

Now today, the controversy is about whether those are meaningful for faculty advancement and whether those kind of surveys should be used in faculty advancement because there's been a lot of research on the subject. It's a pretty thoroughly researched subject now, and there's a lot of data that say the results—the learning results don't correlate well with the surveys, this and that and the other thing, so there's a lot of controversy. But for the development of the teacher, it's a great thing to have your students tell you how you're doing I think. And it can be very negative because you can then pander them, and I didn't see a lot of that, some people did that, but I didn't see a lot of that. By nature, we want to—we're somewhat proud that our students can do this, you know? And to just give them all A's without them being able to do that is kind of against our nature. But there's this conflict of interest, which says, "Hey, if they're going to use this to advance me in my promotion, I want to get all A's, so I just give everybody an A and have a happy old time and we have coffee and cookies every afternoon" and all that.

03-01:11:53
Burnett: Yeah. I think the research was saying that the rating of the professor was highly correlated to the expected grade.

03-01:12:05
Oldham: [laughs] Yeah.

03-01:12:06
Burnett: Right, very highly correlated.

03-01:12:07
Oldham: Anyway, so there's—it's a controversial subject, but I'll say this, I think it had a very positive development on myself and on some of my colleagues who were not very good teachers. Some of them, by the way, couldn't learn, and those guys are gone. Well, some of them did survive the process, but they were for their whole lives lousy teachers, but most of people responded to that in a positive way, I believe. And we had that wonderful office—I forget what it was—that if you had low grades [evaluations], you could go there and they would teach you how to teach. We have that here.

03-01:12:46
Burnett: Hmm, like a center for teaching and learning?

03-01:12:48
Oldham: I forget what it's called at Berkeley. And I know of some faculty who are now, let's say, very famous and powerful faculty who were very poorly rated by the first semester and then they went over there and they got it. Because we're talking about smart people; smart people can learn if they want to.

03-01:13:14
Burnett: Yeah.

03-01:13:16
Oldham: And so back to teaching, the existence of those surveys was very important in the beginning, I think. I'm so glad that that happened.

03-01:13:29
Burnett: Yeah, I mean the emergence of undergraduate students as a constituency, which wasn't there before. You're not human until you're a graduate student, [laughter] you're not a human being. And all the attention is on the graduate students as kind of near-peers, right?

03-01:13:45
Oldham: Yeah.

03-01:13:47
Burnett: And some of those faculty who were not good teachers, they might have been good mentors, which is a different kind of teaching, right, and a different skill set. So it wasn't a net positive to have that. One of the nice things about the student movement was that, that emergence of students as a participant as you said in the process.

03-01:14:16
Oldham: Yeah, and that happened in the sixties, it was—yeah.

03-01:14:20
Burnett: So this textbook is an introduction to electronics, and that's your first text with Steve Schwarz, and it goes through multiple editions, right, and then there's one in the nineties.

03-01:14:30
Oldham: I was busy after that, and Steve wanted to write updates because we were—we did not—we did well at the schools like MIT and Stanford and so on, but we did not do well with the schools we needed to, the bulk of the schools, so we never had *huge* sales. And Steve was very interested in having big sales, so he said, "We've got to revise this book," and I said, "Well, you revise it," and he did, and of course then I said, "Okay, so now, you get a higher fraction of the royalties" and all that. We didn't make much money on that book. You get paid about ten cents an hour for writing a book like that. But you get—you educate yourself, and it's a very worthwhile thing to write a textbook but I never did anything in those second editions. Steve kept me on as a coauthor, as a—by the third edition, he just kept me on, and by then, I don't know what my fraction of royalties were, but it was real small.

03-01:15:38
Burnett: I remember in graduate school, you're—and this is in the humanities and history—you're thinking about the higher order questions and how to think about things and that kind of stuff. But the actual content is often missing because a field, it's huge, right? And you do something like teach an intro course and you start teaching and you start—have to iterate on them, you really have to master stuff that you're—have very little knowledge of. And you have to build up, and you actually do really learn a tremendous amount

from teaching. It's the way to go. That kind of I think jump-started or accelerated your competence not only as a teacher but also as an engineer and as a researcher. There are some folks that I think you wanted to highlight in this period and maybe a little bit earlier in this period. Mac Hopkin?

03-01:16:46
Oldham: So, yeah, there was a number of people we mentioned in earlier reviews, and a lot of those were just, I would say, the people that defined the department culture. Mac Hopkin was not in my field, he was not a top researcher, he had quit doing research long before I got here. Excuse me, he was in power electronics, but he was one of those people that like Angelakos, Pederson, and so on that set the culture of the department. Art Bergen, he was in power electronics and systems—systems, and he—again, these are the people—I sent you a picture. I sent you a picture of the wine taste on the top of Cory Hall, and if you look that people in that picture, they're all really important people in the culture. And then Steve Schwarz and I were the two young guys in that picture, I think the only two young guys. But, yeah, so—

03-01:17:53
Burnett: And David Sakrison is in that—

03-01:17:54
Oldham: David Sakrison who never I mentioned but just I had no, let's say, contact with Dave on any technical matters. His field was communications, and it's a field I know nothing about. I never had course in it, I should've learned about it, but you're busy, so [laughter] anyway. But he was a social—important social focus in the department. When this fellow we mentioned Rick Dill, I don't know if we mentioned him yet—

03-01:18:29
Burnett: No.

03-01:18:29
Oldham: —but Rick Dill was a visitor here in '68 from IBM and played an important role in that he came here. I had known him, he was a Carnegie Mellon graduate, I had known him at Carnegie, and he came here and so I made contact with him. But Dave Sakrison as just one of the social guys in the department and so we were—we did a lot of things together with Schwarz, Sakrison, Rick Dill, and so on, and then of course Rick Dill went back to IBM. And jumping forward, then Andy Neureuther went to visit at IBM for a year and worked with Rick Dill. And Rick Dill was working—by then, he was working in a different field then when he came to Berkeley. Well, he actually had started that work on photoresist. I was not yet interested in photoresist when Rick was here, and Rick was actually doing some of that important work, and I was not involved. But then Andy got educated in that at IBM and came back very knowledgeable in that, and that's how we started working.

03-01:19:48

But the other person in that picture of wine tasting on the roof of Cory Hall, which we did once every month or so, was Tom Everhart. And Tom Everhart I think we did mention, because he helped recruit me to Berkeley. He was living in Pittsburgh my last year at Carnegie, and he came over and visited me and tried to recruit me to Berkeley. But Tom played a very important part in my life in that one day, he said, "Look, I think—do you have any interest in consulting at this company called Fairchild?" and I said, "Absolutely." He said, "Well—" he had some connection with there and if I would follow up with so-and-so at Fairchild. So I went down to Fairchild, and Fairchild was the really important company in that period from 1965 on. They were making integrated circuits, small integrated circuits, and we had mentioned that earlier. So that was my contact with Fairchild, and that's how I met Andy Grove, Gordon Moore, other people there, Gene Meieran, all these people, which were later—of course, [Robert] Noyce, all those people who were later so important. Because later I went—they all left and—well not all of them, some of them went to Intel, and I had this connection to Intel.

03-01:21:31

But in general, they—these people were leaders in the business, and I was fortunate enough to go there once every few weeks, and they actually paid me to go in there and get educated. I'd go in there, and we'd talk about what their problems are, and I would give my opinions and this and that, and they—for some reason they put up with that. Once in a while, maybe I said something intelligent, I don't know, but I know it evolved into—and I told Andy Grove this thing back in just—he came here to give a lecture only a few years before he died, and I told that story at that lecture that—well, I used to go to Fairchild. And so we're talking about this in this period in the sixties, and it got into the mode of I would have lunch with Andy Grove and Ed Snow who was another brilliant guy was there and Gene Weckler, and they would save up a couple of problems and ask me about this problem. Well, it was like having a qualifying exam. It was a hard problem that they don't know the answer to, and they want me to somehow pronounce on this. So I would think about this, and we'd have lunch, and I'd talk about it, and I could've taken that as an, oh, my God, this is a scary experience, and I took it the other way, I said, "This is unbelievable." I mean they're actually wasting their time with me, and we're discussing this problem. And it was the most marvelous thing, and that went on for maybe a year of that mode where we'd have lunch to talk about difficult problems at Fairchild.

03-01:23:33
Burnett: What year was that?

03-01:23:35
Oldham: This, probably '67—

03-01:23:38
Burnett: Wow.

03-01:23:40
Oldham: —just before—

03-01:23:40
Burnett: Before they leave?

03-01:23:40
Oldham: —they're all gone off to Intel, '66, 67. And so having that experience with those guys is important both sociologically and technically, you know, making contacts, seeing the kind of problems they had. And I was mostly interested at that point in III-V compounds. At that point, I had worked on my thesis in III-V compounds not in silicon. I remember a conversation with Andy Grove saying, "Well, what do think we should work on?" he says one day to me in his office, and I said, "Well, you guys, there's a lot of problems in gallium arsenide, making this gallium arsenide work." He said, "Do you realize we're spending—?" And he told me something like, I don't know, some huge fraction, like 20 percent or something of their research budget on gallium arsenide. And I said, "Yeah, of course, there's no problems left in silicon," [laughter] I said, "1967," [laughs] so.

03-01:24:51
Burnett: And gallium arsenide, so the III-V compounds, are those the ones that become important for—later for solar and other technology?

03-01:25:01
Oldham: No not solar, for lasers, all the lasers—

03-01:25:03
Burnett: Or for lasers—

03-01:25:03
Oldham: —all the photonic devices. The ultimate fastest transistors are made in III-Vs; they have higher mobilities. Yeah, they become important, but they never made integrated circuits with them because, well, technological problems. They don't have an oxide that's stable and so you don't have surfaces like silicon dioxide, anyway, but—

03-01:25:39
Burnett: So in those days, did they have a—I mean it's probably anachronistic to call it a foundry but they were—were they fabricating the chips onsite in—

03-01:25:50
Oldham: What chips?

03-01:25:52
Burnett: At Fairchild semiconductor?

03-01:25:54
Oldham: Oh yeah, no, Fairchild was a manufacturer of the first transistors. They brought out the first transistor, then they brought out the planar transistor, which was made completely different than the old way of way of making

transistors. And then from there, it was obvious—well, there was a Nobel Prize involved, so not too obvious—you could make integrated circuits make all the things and connect them with wires and make a chip. They did all of that and, they made that there. Yes, they made it there, and they had a factory in Mountain View.

03-01:26:29
Burnett: And was there a clean room notion at that time?

03-01:26:34
Oldham: Yes, they knew for decent yields that you had to have a clean room, and there was rapid learning about that so that you get cleaner. They were not very clean then. I mean they're like—but they were clean rooms, you wore little white coats, sometimes a hairnet.

03-01:26:54
Burnett: Sometimes a hairnet. [laughter]

03-01:26:57
Oldham: But yeah.

03-01:26:59
Burnett: There was a documentary on fabrication in 1979, and they were talking about the clean rooms being—I think it was three orders of magnitude cleaner than a hospital emergency room or a hospital operating room. So there's hundreds of particles per cubic foot instead of whatever it was, 100,000—

03-01:27:25
Oldham: Oh, that's—

03-01:27:26
Burnett: —or 10,000.

03-01:27:27
Oldham: —we don't have time to go into my problem with hospital rooms. They are not clean, and they've done bad experiments to show that they don't need to be clean and so they're still not clean. It's really outrageous how many infections there are in the hospitals.

03-01:27:42
Burnett: Yes, sure, sure.

03-01:27:44
Oldham: And yet they're still—they're not clean and—but anyway, that's another whole subject we won't—

03-01:27:50
Burnett: That's—

03-01:27:50
Oldham: —get into.

03-01:27:52
Burnett: I think others like Paul Gray have talked about this kind of circulation of Berkeley faculty and Stanford faculty in and out of Fairchild, and I think Paul comes directly to Berkeley from Fairchild. He graduates from Arizona, he's at Fairchild, and then goes up there, and then he said, "They were going up and down to Berkeley all the time, and it's this wonderful—" We know that universities are important, we know that Stanford's important, but this idea that there are these private companies doing this innovation, and it's true, of course, it's all true, but it misses the point of this circulation. There are these circuits of knowledgeable folks who are learning from each other all the time, and you're part of that kind of, I don't know, ecosystem or circuit that's itself a kind of circuit of knowledge production, and that's a really key piece to the history of Silicon Valley.

03-01:29:05
Oldham: Absolutely. Anyway, so where we got there was I was talking about Tom Everhart, so he got me that consulting job. I don't know, I keep meaning to ask Tom. He lives down in Santa Barbara. I haven't seen him in a couple of years, but I keep meaning to ask him how did—why did I get—why did you—why didn't you take that [position]or whatever it is, anyway. But that was a wonderful thing because it really changed my life. I don't know what, maybe my other life would've been better, but I don't think so. [laughter]

03-01:29:42
Burnett: Well—

03-01:29:43
Oldham: Because—

03-01:29:43
Burnett: —you should ask him.

03-01:29:43
Oldham: —introduced me to those people.

03-01:29:45
Burnett: Right, right, and so that facilitated other subsequent sabbaticals that you went on? Because you knew these folks.

03-01:29:54
Oldham: Well, because I knew those folks, I got in deeper into that field. That's how I decided in—like I say, in '73. So here I am, I'm doing all this laser work in infrared lasers, not even visible, deep infra lasers because they're marvelous things. I mean technologically, I love this field where you could take a lead tin telluride laser, and by adjusting the ratio of lead and tin, you can tune the wavelength, then you can squeeze it, and you can change the wavelengths some more, and you can detect. A car is going by, you can detect all its emissions. These are very cool things, so I was very interested in that.

03-01:30:43

But then I just at some point said, "What am I doing? I'm going farther and farther from where the action is. The action is—it's starting to dawn on me, maybe the action is in integrated circuits, which was what I was hired to work on [laughter] at Berkeley." I called up Andy Grove and said, "Andy, how about bringing me in for the summer? I want to do some work in integrated circuits?" Andy says, "Are you kidding?" He says, "You'd come in for the summer," and he says, "you get everything, we get nothing." Andy is a very direct guy, and he said, "How about you come for a year?" I said, "Well, yeah, okay, so I agreed, and I took an industrial leave for a year, and of course it ended up being essentially two years. I had to come back and teach that second year, but I was only teaching. I was really very heavily involved there because I had a big program. Then they put me in charge of a big program, and I had to pull this big program off, and you can't pull a big program off in one year, but anyway. But that was the education I needed if I want to be in that field, right? If you want to be in that field. And so that was just because I had this connection to these guys, and they knew because I knew them all from several years.

03-01:32:16
Burnett: Right, right, and you've obviously kept in touch during that time, yeah, yeah.

03-01:32:19
Oldham: And we had other people, you know, Dov Frohman who is—

03-01:32:23
Burnett: Wow, yeah.

03-01:32:24
Oldham: Dov Frohman, a famous guy.

03-01:32:25
Burnett: Yes, of course.

03-01:32:26
Oldham: He was—

Burnett: Flash memory—

03-01:32:27
Oldham: —the inventor of the—not the flash but the—

03-01:32:31
Burnett: EPROM.

03-01:32:32
Oldham: —they called it FAMOS, but a floating-gate memory cell, which was the technology of flash but not the architecture of flash. He was a graduate student at Berkeley and he happened to be in the same lab I was and so you talk about this and that and the other thing. He was trying to do what we called MNOS

memories, which is a nitride-based storage, and that was going to be the memory, never was. He was at Fairchild and had a big project on that, and I helped him with that. In fact, I loaned him an instrument that he could do his experiments on. It was an instrument at Berkeley, and I get permission so he could borrow this thing. So an instrument from Berkeley goes to Fairchild, he works on that, and then he gets the idea for a better idea for memories, and so on. And again, Dov then of course migrated to Intel. At that point, he was at Fairchild when he first started that, I'm not sure if he had already moved to Intel.

03-01:33:51
Burnett: Okay.

03-01:33:51
Oldham: I guess he had invented that memory at Intel, so he must already have moved to Intel when he did that, so it must have been in the early seventies. It must have been like 1969 or '70, yeah, anyway.

03-01:34:05
Burnett: That sounds right to me. So tell me more about this interim period in the early seventies. Andy Neureuther goes off to IBM and comes back and is energized. He's leaving an area too because he was in antennas and electromagnetic waves and that kind of stuff and so both of you are kind of recharging. Can you talk a little bit about how that comes together for you both and what you start working on?

03-01:34:38
Oldham: Well, what happened is when I went to Intel and I saw once again this model of cooperative research where you have a lot of smart people in a single place and they all talk about all their problems and they solve them together. I mean I had this decision, I had to leave Intel and come back to Berkeley, and that was a financial decision because it was big bucks to stay at Intel, I mean serious big bucks, and I decided that wasn't for me.

03-01:35:08
Burnett: Oh, this is '74–'75 period?

03-01:35:11
Oldham: That was '74–'75, and it wasn't till then that I said, "You know when I go back to Berkeley, I am not going to do research in my own lab with my own students. I'm only going to do collaborative research. I'm never going to write a research grant for which I'm the sole, principal investigator," and I did that. And when I came back to Berkeley, that was now '75, I was still working at Intel, but I was back at Berkeley, and I tried a couple of people in our department, no names mentioned, they either had no interest or no concept. And so then Andy had come back, and Andy knew about photolithography because of Rick Dill and was interested in that, and I said, "Andy, let's write a proposal" and so we wrote this NSF proposal and got funded. It got funded in—doing this NSF work on photolithography modeling. And we got some

equipment, and we had multiyear proposal, and I said, "Why don't we jointly supervise a bunch of students? So we can supervise some ourselves, but why don't we joint—?" and we did. We had several students like the key guy who wrote SAMPLE, the guy who wrote all the code, Sharad Nandgaonkar, he was a joint student, you know, jointly supervised, so he had to put up with both Andy and myself, and several of the students were like that. It was simply a wonderful thing and makes your life more enjoyable again.

03-01:36:59
Burnett: Did this project take care of or focus on the different aspects of the manufacturing process, the problems of different aspects?

03-01:37:15
Oldham: Yes.

03-01:37:15
Burnett: So how did the graduate students fit in? Did one graduate student take one process and another take another, how did it work?

03-01:37:23
Oldham: That's a good, a very perceptive question. Yes, the way it started out is let's do this photolithography research, which Rick Dill had already started at IBM, but Andy and I had a vision of writing some software that made this possible to do this by design, so you don't have to do the experiments, right? And so we hired two—the first two or three guys like Sharad to write this code, which does the photoresist part of it. We had visions, okay, then the photoresist is there and then the next step is you etch something. Typically, you etch something or you implant through that, where did these end up and what does that look like. And then we said, "Well, we've got plasma etching, we've got wet etching, we've got—and then we have CVD, chemical vapor deposition, and evaporation. When you do that with these structures, what does the result look like? And it used to be that you do it and then you go look at them, but now we can do it and look at them on the computer and so we would get students. So we got a student in plasma etching, a student to do this, a student, to do that, we—and so we just started hiring a lot of students.

03-01:38:55
Burnett: So in the coding of this software, and I guess it depends on the process, right, but what are you coding for? You're coding for the electronic properties of a material or the—obviously, you're coding the math of these relationships.

03-01:39:21
Oldham: Yeah, but mostly, it was the physical, we're coding for the physical evolution of the structure. Suppose you have a step, a cliff, and you're evaporating something on it, well depending on the angle that the stuff is coming in, it builds up in some sort of a structure, right?

03-01:39:46
Burnett: Right.

03-01:39:48
Oldham: We're watching that evolve, or if you're etching something, you watch the evolution of a contour of an interface and so that's what we're doing. We're mostly doing that kind of thing, mostly a physical structure.

03-01:40:09
Burnett: And you need a function or some kind of equation that describes that process?

03-01:40:19
Oldham: It depends, different things, you can actually use equations sometimes, sometimes you just—so there's a lot of ways to do it, but you can almost do it like you do an experiment. You say, "Okay, let's throw a hundred balls at this thing and see where they land," and you could do that physically, right? But then if you can do it physically, you can do it on the computer, so you do it like that. You're trying to mimic what's evolving in the simplest possible way, and there's a lot of ways to do it.

03-01:41:05
Burnett: Right, so you might include probabilistic—?

Oldham: Oh, yeah.

03-01:41:09
Burnett: Yeah, okay.

03-01:41:10
Oldham: But sometimes electromagnetics because when you're exposing photoresist, the light goes in, and it's more intense in some places and less in others and there, you may be able to do that with an equation or—you know? So it's this combination of things, but that's why it takes some time and a lot of students to figure out what's the best way to do that.

03-01:41:37
Burnett: Yeah.

03-01:41:39
Oldham: And we did all that initially in FORTRAN. SAMPLE was written in FORTRAN, that's right, it was not written in Unix, although they dragged us into Unix at that time—

03-01:41:50
Burnett: The students did.

03-01:41:51
Oldham: But the code, you know, high—powerful numerical analysis, a lot of it to this day is still done in FORTRAN. There's still FORTRAN stuff done.

03-01:42:03
Burnett: Really?

03-01:42:03
Oldham: Some of our most prominent colleagues in computer science, but I mean it's very, very sophisticated, but, yeah, because FORTRAN let's say what we used to call subroutines exist to do certain things in math, and they're the fastest way. They've optimized those to run fast on the computer, so you make use of that, you know?

03-01:42:31
Burnett: Right.

03-01:42:32
Oldham: That kind of thing.

03-01:42:33
Burnett: Interesting.

03-01:42:33
Oldham: You don't want to recode it.

03-01:42:34
Burnett: Right, right, that's really, really interesting. So SAMPLE is an acronym, and this is what you and Andy Neureuther do, Simulation and Modeling of Lithography and Etching, I'm missing the *p*, is there a *p* in there?

03-01:42:54
Oldham: Yeah, I don't know. I should—

03-01:42:55
Burnett: Simulation—

03-01:42:56
Oldham: —know, I should know—

03-01:42:57
Burnett: —so Simulation and Modeling Program for Lithography and Etching.

03-01:43:01
Oldham: Could be, I don't know, I'm not good at that.

03-01:43:04
Burnett: Okay. [laughter] All right. It's really interesting, and we were talking about teaching and students, and I imagine this being this fantastic career-launching opportunity. Each of these students is now an expert in the modeling of a step in the process of integrated circuit manufacture. So do they go on to work for these Intel and these companies after they work with you?

03-01:43:37
Oldham: They either did that; some of them started their own companies. One of Andy's students started a company. He's a Canadian guy, and he got some kind of a green card here and started his own company. It's been in Berkeley ever since, a simulation program that's an amazing, wonderful program to do

certain kinds of electromagnetic simulations for this technology. But mostly, they went to work for the companies in the business. Asian students went back to a university in Japan, but, yeah, I think most go to a company. And they didn't only learn about their—I mean if the student who does plasma etching didn't learn about plasma etching, he knows the whole program, he knows every other student, he knows what every other student is doing, he knows how it's done, yeah.

03-01:44:46
Burnett: It's just—

03-01:44:46
Oldham: No, they get a broader education than their thesis.

03-01:44:50
Burnett: Yeah, absolutely. So this is just amazing ground-floor education. Sharad Nandgaonkar, and he built the parser in FORTRAN?

03-01:45:03
Oldham: He and I think Mike O'Toole was—

03-01:45:06
Burnett: Mike O'Toole—

03-01:45:06
Oldham: —another key guy in that. In our first paper you find their names but—

03-01:45:10
Burnett: Yeah, according to Andy, he built the lithography modules and then John Reynolds did work on the etching, does that sound—

03-01:45:18
Oldham: John Reynolds—

03-01:45:19
Burnett: —right?

03-01:45:19
Oldham: —did the first plasma work I think, yeah. And Sharad was one of the—my two students in my career who wrote bugless programs. If he released a program, it didn't have any bugs. He was a very methodical guy. He'd drive you crazy because say, "Well, okay, we've got to have that by Tuesday," and Tuesday comes and there's no program. He says, "Well, it's not fully debugged." "Well, does it work?" "Well, yeah, but it's not fully debugged." He would never—he was a—

03-01:45:57
Burnett: Meticulous?

03-01:45:58
Oldham: —meticulous. He's exactly the right guy. I mean that's who you want for your master programmer. He won't release a program, and really his stuff didn't have bugs. Whereas almost all programs—every program I ever wrote had a bug in it; I never successfully wrote a significant program without a bug. And I had only two students, one in—that could write with—code without bugs, yeah.

03-01:46:28
Burnett: There's a Stanford story in there too, and I'm wondering if you tell me a little bit about, is it Bob Dutton?

03-01:46:37
Oldham: Bob Dutton, yeah.

03-01:46:37
Burnett: He was a student at Berkeley.

03-01:46:41
Oldham: He was a Dick Muller student. And he went to Stanford, and he's the father of their program, of SUPREM.

03-01:46:49
Burnett: SUPREM, okay, so there's another program that was working, and I understand that there—they were kind of complementary, or that you were working on different regions of the problem.

03-01:47:03
Oldham: Yeah, well, we talked about this in the beginning. They were doing the oxide growth and impurities and diffusion, that part of the program. Initially one dimensional and eventually SUPREM 3D came along where did the—our program was 3D from the beginning because the structures are fundamentally 3D. Yeah.

03-01:47:31
Burnett: So this is—yeah, okay.

03-01:47:33
Oldham: And actually one of my students later, Pantas Sutardja, he did a program, which eventually got incorporated into SUPREM, which was oxide flow program, a very complex, horrible problem that you think of glass as a rigid [taps] subject or material, but you know glass can flow when you get it hot, right?

03-01:47:59
Burnett: Yeah.

03-01:47:59
Oldham: But it can actually flow at any temperature, and it does under the enormous forces and so that problem was—is a very difficult problem, and I had Pantas—when you do anything but one-dimensional oxidation, then you come

into enormous stresses and then oxide flow, and the effect of those stresses on other properties, diffusion, and it's very complex, and I had one of my students do that. But it doesn't go into SAMPLE, it goes into SUPREM because they were doing the oxide part of the structure.

03-01:48:40
Burnett: Right, and so SAMPLE is operating in the region above the silicon surface?

03-01:48:46
Oldham: Not above, it's just that we did—yeah, it would be below. If we etch, we can etch right down through the silicon, you know, we can etch. And SAMPLE could attack the problem of etching, what they call through vias. You know, nowadays, you etch a hole clear through the wafer, so you can get together a side and put one chip on another and connect them. That kind of thing were so-called through vias. SAMPLE can do that problem, I don't know if they've—I mean I'm not in touch with what SAMPLE does today, but I don't know if they've done that problem but whereas—but we didn't do oxidation and we didn't do impurity diffusion.

03-01:49:26
Burnett: Okay. So this work, was that all part of this NSF?

03-01:49:32
Oldham: Oh, it started out with NSF and then we got other support. We only had NSF for probably two rounds, so probably for six years, something like that. I don't know if they were two-, three-year grants from NSF but something on that order. I remember that we had—SAMPLE was very successful, and our review for NSF was—I mean—we tried to get it extended another three years, and we had the highest reviews we ever got for that because the first one was so successful. But then NSF says, "Okay, that's it, you guys, we do fundamental work, go to industry" or something like that, "and continue to fund it," which we did.

03-01:50:22
Burnett: There is some different information I was getting. Just to be very, very clear, your time at Intel is '74–'75—

03-01:50:38
Oldham: Yes, and then '75—

03-01:50:40
Burnett: —seventy-five–'76

03-01:50:41
Oldham: —seventy-six, part time.

03-01:50:42
Burnett: Part time, but you're already working, you had already gotten the NSF grant for SAMPLE?

03-01:50:47
Oldham: About that time, I don't know exactly when we got that.

03-01:50:50
Burnett: Okay, coterminous.

03-01:50:52
Oldham: I don't know when now, but about that time.

03-01:50:53
Burnett: According to Andy, your first paper on SAMPLE was at Kodak conference in '75, does that sound about right?

03-01:51:03
Oldham: Sounds about right.

03-01:51:03
Burnett: So kind of coterminous, but you're learning something. In '74, you're already bombarded by the what's going on at Intel in the sense of what the problems are and what you can turn around and do with your students. Immediately when you come back in '70—for the '75–'76 year, you're doing that work, or was it even before you went to Intel?

03-01:51:33
Oldham: You know this is a long time ago.

03-01:51:36
Burnett: I know. I mean the—

03-01:51:38
Oldham: I would have to look. I can look tonight but—

03-01:51:43
Burnett: But I would say—

03-01:51:44
Oldham: —I would have to look at my—see when my master's. The first year the student come in, you had to do a master's degree, and I have a marker when they got their master's degree to tell when they did their first work, and I could tell from that. But my guess is I wasn't doing very much before '76.

03-01:52:02
Burnett: Well, I think the Nandgaonkar, the—I mean the papers with Andy Neureuther are—the first one I'm seeing here is like '78.

03-01:52:14
Oldham: Yeah.

03-01:52:16
Burnett: And you're not—

03-01:52:17
Oldham: But we had a working program then, so there's a lot of work done.

03-01:52:21
Burnett: Oh yeah, yeah, yeah, absolutely. Okay, so '78, yeah, and that's—yes. So O'Toole and Nandgaonkar.

03-01:52:35
Oldham: Nandgaonkar, yeah.

03-01:52:37
Burnett: Oh yeah, there isn't a *d,* okay. And so that's with the Electrochemical Society in '78. But as Andy was saying that you were already publishing on—or presenting on SAMPLE in '75.

03-01:52:53
Oldham: Now, the Kodak paper, I have to go back and look what that was, but I don't know what the title of that was if that was SAMPLE or if that was a subset, a lithography—

03-01:53:02
Burnett: Or—

03-01:53:02
Oldham: —subset.

03-01:53:03
Burnett: —right, a precursor maybe of that work.

03-01:53:07
Oldham: Because the lithography work—that might have just been a lithography, but I don't know, I have to look.

03-01:53:12
Burnett: But anyway, it's transformative on so many levels. You're transformed by going to Intel, by being exposed to some of those problems, then you turn around and create with the students and with Andy these tools, right? Do those tools then feed back out into industry? Is SAMPLE something that industry can pick up on?

03-01:53:39
Oldham: Oh yeah, we started distributing as soon as that first paper came, which we gave at some conference around '79 or so and was published in two different IEEE journals, then we were distributing SAMPLE. We give these codes away, and people can start to play with them and say, "Ah, this, you know, this is—it doesn't do this, I am not interested," or "Yeah, this is good. Let me—" you know.

03-01:54:10
Burnett: Right.

03-01:54:12
Oldham: It just depends and then we keep improving it. But, yeah, that was distributed starting then, and every year, we send out lots and lots of copies.

03-01:54:21
Burnett: Can we dive a bit more into the time at Intel? You said you were in charge of a project; is this the 16K RAM?

03-01:54:28
Oldham: Yeah the 16-kilobit DRAM, it sounds like. [laughter] You've got to remember, Intel started making 1-kilobit DRAMs in about '72, and that was their first big product really. I mean they tried to do a lot of things. They tried to make bipolar memory, then they tried to MOS memory, and that was their first product that—and it became a landslide seller, 1-kilobit DRAM, okay. So then they immediately started a 4-kilobit DRAM project, which was done in '74 and then it was ramping up in manufacturing, and that's when I went there, and they said, "Okay, we got to do 16-kilobit." So they gave me charge of the 16-kilobit DRAM project, which was both the new technology required for it and the design, the chip design, layout and design. And today, if you did a memory project, of course today it would be—I don't know how many megabit, but some huge number of megabits. I don't know how big the memories are today because the chips, they aggregate them and then you buy a thing, but it's not a single chip in it. But it's not a terabit, but it's lot, it might be a gigabit or something.

03-01:56:06
Burnett: Oh yeah, the RAM for my Mac is 64, and I think they have 128 now.

03-01:56:13
Oldham: Oh, gig?

03-01:56:14
Burnett: Gigs, yeah.

03-01:56:14
Oldham: And I don't know if it's all on one chip or not.

03-01:56:16
Burnett: No, it isn't. It's—

03-01:56:17
Oldham: Yeah, several.

03-01:56:17
Burnett: —yeah.

03-01:56:18
Oldham: But anyway, so 16-kilobit, you say why did you only make 16 kilobits? Well, you remember the technology then was the smallest lines, feature size was seven microns I think when I went to Intel, seven microns. Today you talk about seven nanometers, so that's like a big difference and so on. So today,

you would have a hundred people doing that project; you'd have a hundred people to do a project like that. We had—I was there, there was a circuit designer, a guy who knew how to make the circuits, lay them out, and then simulate them on their simulator. And then we had one guy who was not even a degreed engineer, but he had a lot of experience in both circuits and technology, so he was very useful guy, maybe he had five years' experience. And then two college graduates right out of college who were technologists and that was—oh, and I had a lab technician too, so there's probably five or six people.

03-01:57:35

And then the day I got there, Intel, there was a big problem in the industry. Industry had one of these periodic, *phoo* [gestures indicating a rapid economic decline], and so they had to shrink, Intel to shrink, and so my first job was to lay somebody off. I said, "I didn't come here to lay somebody off," but I had a group of six guys, and I had to lay somebody off, so I laid off the lab tech but anyway. So with that crew, we did the technology, and we did the circuit design. And we did that in a year, and we had a working chip in about a year and then it took us about a year to make it manufacturable. I mean I'll be honest with you, we had a gangbusters technology, we had the best technology, we had a really good—it was a two-level polysilicon technology. It was the first time with oxide isolation. We led with shallow junctions, which means arsenic instead of phosphorous, so we had a lot of innovation in there. And it was the technology, which was used for that and several more generations of products at Intel for probably five or seven years, but the design was inferior to the competition. Other people were making DRAMS, and we could manufacture that, and we were first out with it, and they could've ramped it up. But Gordon Moore and Bob Noyce see that the price of RAMS are dropping like this, and they didn't see profit in this, so they were very slow and cautious about committing. In those days, a hundred million dollars is a lot of money then; today, it's nothing. They didn't want to do that so they were slow in ramping.

03-01:59:32

And in the meantime, this company called Mostek, they had two experienced designers who were terrific. They were the world's best circuit designers, and they came up with an architecture, a better architecture, which was the most fundamental thing. So instead of like we had to have—I think we went into a two—twenty-two pin package. It's like those little funny-looking things like—okay, theirs would go into a sixteen-pin package. For people designing a computer, that is like day and night in terms of the area taken out of circuit board, it was brilliant. So they multiplexed their address space. So you need addresses—a RAM consists of a bunch of lines like this and a bunch of lines like this, and at the cross point, there's a memory. To get one of sixteen kilobits, you look at this line and that line, or you look at this line and that line, right?

03-02:00:42
Burnett: Mm-hmm.

03-02:00:42
Oldham: So you have to address this—

03-02:00:43
Burnett: Coordinates basically.

03-02:00:43
Oldham: —and you have to address this. Well, we used a pin for each address here and one for each here, sort of, decoded. And they said, "Why don't we do them in the same pins because we don't need them at the same time?" very clever. So you send in, they're called row address select and column address select. So they use the same pins, so they reduced the number of pins. Moreover, their circuits were clever than ours, okay, it was just a superior design, and as soon as I saw that design which was after—long after ours was being manufactured, I said, "You—we got—there's no chance, that this is a better architecture. We could redesign ours so that—it's not a patented architecture and—" which is what, of course, happened eventually and then all future designs followed that Mostek invention. They had an inferior technology, but they had a superior circuit design, so it was very good. Intel was a memory company up through four kilobits, and they never was a memory company after that, I mean DRAM. They did nonvolatile memories, FAMOS based, Dov Frohman's base—technology based, and they've done that all along. Then they were the only game in town, they had the only nonvolatile memories around, and they made a lot of money on that. Then microprocessors came along, and they became a microprocessor company in the eighties.

03-02:02:28
Burnett: Yeah, right. So looking back as a researcher, as a scholar, and as a teacher, what were some of the things you took away from that experience at Intel? And including being kind of scooped by that other company?

03-02:02:46
Oldham: We weren't totally scooped, but we were scooped in the market. Well no, look, any real engineer wants to see the results of their work somehow become used, right? It's great to invent a new engine and it's very—if you're an engineer doing engines, very wonderful, and you've got this superior thing, but if nobody ever makes it, it's not the same thing. So that part is really rewarding, and working at Intel, it's very exciting, right, to do that, and you don't see that at Berkeley. Your results are these students you turn out, right, and, yeah, some research. Some people, they get down and they publish a thousand papers, and after a thousand, they still—it's a thrill for them to publish the thousands and one. That didn't do it for me.

03-02:03:47
Burnett: Yeah.

03-02:03:47
Oldham: So it was very exciting. I loved that part of it, working on something that's real and even though our product, our particular product eventually, we—it went down. There was other products out there, and Intel wasn't going to spend to make a commodity product. Memories have always been a commodity product, always. But the technology we did, that was used, I mean Intel did so many products on that technology, so it was not at all like a waste or anything.

03-02:04:27
Burnett: Right.

03-02:04:28
Oldham: At Intel, I stayed on as a consultant for many years, and like Intel ran a program in—I was trying to—there's many aspects. The reason I got interested in lithography was because to make that chip, you're trying to print this big chip, which had, at that point, the state-of-the-art number of devices on them right. Sixteen thousand transistors and capacitors all on one chip sound like a lot, okay. It was a chance of making them defect free and so in those days, they used to do contact printing. So they used to make a plate with the pattern on it, and you press that plate against the wafer and shine a light through that plate. That's the technology when I got there, and that's how they made their 1-kilobit DRAMs. And you could use that plate only maybe a dozen times, by then it was destroyed by grinding into things, and, oh, every chip would be defective.

03-02:05:35
Perkin-Elmer had invented this scanner, which was a photolithography tool for doing noncontact printing, and I really pushed hard to get that technology on my chip. I've forgotten now, I think we succeeded—well, I know initially because we had to do contact printing, but I think that technology was there and so I got very interested in projection. It was called projection printing then as opposed to contact printing. And that's what's stimulated my interest in projection lithography because you both got the optics and then you have to capture the photons and do something with them. That's the photolitho—you know—

03-02:06:26
Burnett: Photolithographic aspect?

03-02:06:28
Oldham: Yeah, the photo materials that are sensitive and still have the resolution and all that. And it was used negative—this old-fashioned negative photoresist, which was developed for the printing industry to make or print for offset lithography where they etched patterns in aluminum and then use the aluminum to print papers with. That was a technology we were using. It was not developed for our business, but some people had come up with the positive photoresist, which became the industry standard in the seventies. And so I pushed the project and ran that project at Intel for a while to introduce positive photoresist. That's just as a consultant and with another guy and working on

that, and the tools for that were just coming into the business, the—which will be a later part of the story in the Berkeley lab, the tools. How do you deal with these—what became very expensive tools. Contact printer used to cost $10,000 or something like that, and very quicky the projection printers were 100,000 and then $150,000 for the tool, this kind of thing. Anyway, but that whole area became very interesting, and especially Andy here, we have this E&M guy, so it was just a great fit.

03-02:08:00
Burnett: Right, and so you're kind of launched on your true career destiny at this point, right, and then take about ten years to get it settled on it. But also speaking of opportunity, right, you had to meet the moment, and the moment wasn't there until you got invited to this situation, and you spotted a partner and had the right students and had the right computing power. All these things come together to make it possible.

03-02:08:33
Oldham: Yeah.

03-02:08:35
Burnett: And we'll talk more about—and the Perkin-Elmer?

03-02:08:38
Oldham: Perkin-Elmer was a company that was a spectroscopy company. It was a spectroscopy company, but they had—they may have had some military products, I don't know, but they made spectrometers, and spectrometers have very sophisticated optics. People don't appreciate what a spectrometer is, it's very sophisticated optics and so somebody there—oh, in fact, there was another guy, Dave Markle I think was the guys who also became a good friend of ours. I think he's the guy who developed that Perkin-Elmer scanner tool. I mean I loved sophisticated, mechanical optical tools, and that was just a gem of a concept.

03-02:09:25
Burnett: Yeah, the elegance.

03-02:09:26
Oldham: And it worked, and it worked. Yeah.

03-02:09:31
Burnett: Yeah, so there's the elegance of tools, there's the elegance of design, like you appreciated this other competitor because they had this—there was an elegance, a simplicity, and efficiency to it. And then another recurring frame is material science. You like the actual substances of which these—the properties they have, discovering how they might be used or optimized. That's another key ingredient to what makes you interested in something?

03-02:10:04
Oldham: Yeah, I don't know why, but, yes, it's true. The photoresist and, they had these things to coat on your photoresist, antireflection kind of things, and the materials are very interesting in that field.

03-02:10:20
Burnett: Well, maybe we should pause for today, and we can take up tomorrow.

03-02:10:26
Oldham: Good.

Interview 4: September 16, 2021

04-00:00:16
Burnett: This is Paul Burnett interviewing Bill Oldham for the University History Series, and this is our fourth session, and it's September 16, 2021, and we're here in Oakland, California. So yesterday, we were talking about your coming back from your experience at Intel, and you're beginning to team up with Andy Neureuther and getting a crack group of graduates students together to work on different aspects of semiconductor manufacturing processes and figuring out ways of modeling them. So can you tell us a little bit more about how you got that group together, how you got it funded, how you were thinking about it as a research program?

04-00:01:17
Oldham: Okay. Well, I think you stated better than I could what happened right then summarizing what we did yesterday. As I think I said, Andy Neureuther had come back from a year at IBM and he—where he worked a lot on photoresist modeling and so he was much more into processes for integrated circuits than he was before he left. And he was, thanks to this work on trying to quantify how photoresist worked with Rick Dill, into modeling of a process. So he was really up on that, and of course he's a crack electromagnetic guy, so that means optics are like easy, I mean it's just part of electromagnetics for him. I was not an optics guy, but I had just returned from Intel and so I was very up on what the state-of-the art in processing was. In fact, I developed the processes for Intel they were going to use the next couple of years, so I was pretty much up on, not so much what their processes were, but what you had to do to make progress, what were the interesting research problems.

04-00:02:53

And I was looking for somebody to get together with, and we hit it right off. Well, we were already friends, but technically, technically it made sense and so we—somehow, we agreed to work on this together. Actually, I look back and at the time, I actually started a joint project with a couple of other people too. I was really serious about this collaboration. One of them, I never remember what became of. I did a project with Bob Brodersen at the time, and I did another project with a fellow from chemistry, chem engineering named Green, no, Dennis Hess—no, no, Green, anyway another one and so I was really into that. But Andy was the one, and Andy is right there in Cory Hall, and we had access to very good graduate students.

04-00:03:56

That's an interesting thing to point out, that at that time, semiconductors were recognized pretty much as an important future for people to work on for engineers and especially in China and Japan, and so there were still a few Japanese people coming. Japanese had come more in the sixties than they did in the seventies, but there were still a few Japanese coming over, but the flood from Taiwan, all the best students from Taiwan. And if happen to get one of those good students, then he tells his buddy in Taiwan, "To come here, this guy is okay" or "This is good" or "That's good." And so I, in particular, was very fortunate in getting a series of top students from Taiwan, their very best students, and they're extremely competitive there. These kids are just smart, they have spent their life competing to try and be the top student and so we had these people applying to Berkeley. And so we'd go through there and say, "This guy looks like he has some interest, let's—" and so we would go through and then we'd get some money together and offer them fellowship support or a research assistantship support if we had. We didn't have as many fellowships then as now, so fellowships were rare. So we're able to put together—get some good students and start the program.

04-00:05:42

I think we mentioned already yesterday, I can't remember, in our discussion about we put together an NSF [National Science Foundation] proposal in this period. That was funded a little bit later; that was funded in '77. I think we probably started working on that in '75. I was away at Intel through '74, '75 and sort of part time, '75, '76, so we were getting this going, and I was still dividing my time a bit at Intel. But anyway, by '78, '79, it was going strong, and we had then recruited a bunch of students. They were doing, at that point, mostly master's degrees because you usually do a master's degree and then you get them through their qualifying exam and then you do the PhD research.

04-00:06:43

And right in the midst of that, I had a sabbatical and I decided I had an—I decided the place I wanted to go was back to Germany. I had been to Germany two years already, this was my—going to be my third year. But Siemens was very interested in getting this. Siemens at that point started a big research program—I think they called it Micro—where they wanted to build the next microprocessor, and so my background at Intel and so on made me a good, useful property for them. So I just wrote a proposal to Intel and said—or to Siemens and said, "Look, I just want to be a guest in your laboratory. All I want is just to keep your laboratory and an office, and I'll work there and I'll work with your people, but I don't—and not be an employee," and they granted that, so this is like ideal. And they were working really hard then, they were halfway to the American workstyle, they were unfortunately compromising their life standards.

04-00:07:57
Burnett: No longer closing the lab at 5:00?

04-00:08:00
Oldham: Yeah, they didn't lock you out. [laughter] They didn't lock you out, but nobody stayed late though. I mean we didn't stay late, but there was a lot of pressure. Every project they did had unrealistic deadlines, that kind of thing that was typical of any American company. If it's a two-year project, you have a one-year deadline to finish it, and of course everybody said, "Sure" but then they know they can't—it's something—some things take time.

04-00:08:30
Burnett: [laughter] Is that kind of baked into particular tech because there are—it's a fast-moving business?

04-00:08:39
Oldham: Yeah, competitive, it's very competitive especially in the early days. I don't know today how it is because later on I did a lot of expert witness having to do with trade secrets and patents, but at that point, patents and trade secrets were not playing a big role. It was really how fast could you get your product out. It wasn't can I get this patented and then I have it for—? That wasn't the game; the game was to get it out there and sell it, and the other guy will be two years behind you, and you've already designed the next product, so.

04-00:09:18
Burnett: Yeah, yeah. Both—sorry.

04-00:09:21
Oldham: Yeah, that was the period in which HP, for instance, half of their sales from products designed in the last two years at HP for a number of years like that. I mean it's just staggeringly difficult to—you just have to compete and so you can imagine the deadlines.

04-00:09:39
Burnett: Yeah, yeah.

04-00:09:40
Oldham: Siemens had gone to—a little bit more in that direction, but it was still a very fun place to work and great people. And there were two guys there who were really good lithographers, Dieter Witman in particular. He was a wonderful man, he's unfortunately since passed, and so he was interested in almost the same things I was, in lithography. We were then getting these very new machines, which were just coming out with state-of-the art optics and doing—printing finer and finer lines. And we were printing submicron features, and everybody said, "You can't go below one micron with optics." That was the myth of the industry.

04-00:10:27
Burnett: So one micron you said?

04-00:10:29
Oldham: One micron, that was the barrier then, and there were all these people then talking about x-rays and had to do x-rays: I mean Hank Smith at MIT and so on, a guy at Bell Labs x-rays, he had this huge x-ray program. IBM had a big x-ray program. And x-rays then meant—it meant a route for shadow casting with a heavy metal mask that you shine x-rays through and where it goes through, it hits a resist and where it doesn't, it doesn't hit the resist. So it was really primitive, and that was going to be the answer to one micron and below. Well, it was clear that wasn't going to be the answer, but it wasn't clear to them. [door creaking] Oh, you have a front door that's creaking open.

04-00:11:24
Burnett: Oh.

[break in audio]

04-00:11:28
Oldham: Okay, so before the door creaked, [laughter] we're mentioning x-ray lithography and optical lithography. I was one of many people that believed in optical lithography and working on that and Andy. And as I said, so I was at Siemens working with these guys and doing—they had a tool there, which was a great tool to do experiments on, and actually one of those people came over to Berkeley and did some experiments on two tools I had so we—that was a productive collaboration. Anyway, I—

04-00:12:09
Burnett: Could I ask about that?

04-00:12:10
Oldham: Yeah.

04-00:12:10
Burnett: Because when you went to Intel, it was clear in that conversation with Andy Grove, that you should invest time and come and work for us, actually work and be part of the organization. Because you were fresh from that experience, what was the motivation behind going to Siemens for that sabbatical? It seems more altruistic, like you were helping them more than you were learning.

04-00:12:43
Oldham: Some people trust consultants and some don't. It's a tricky thing being a consultant because, to be an effective consultant, you have to know the company secrets and then are you going to spread them around? And there are those, I've run into such people—for instance later on when I was working, not as a paid consultant but a free consultant to SEMATECH, I had people in the room say, "Oh, get that guy out of here because he's from university, and he'll just spread all of our secrets around the world." I mean, we had people thought like that. Whereas you have other people like I know Andy Grove, all the people at Intel, and it's very clear, I'm not going tell anybody any Intel secrets technology or whatever. I'm not going to do that, but there's no way to legally enforce that, right?

04-00:13:50
Oldham: You just have to choose your people well and so yeah. And Intel had no problems with me going there. Certainly, I wasn't there to provide Siemens with any technology. One of the things I worked on at Intel for instance in technology is something called design rules. So design rules are the rules by which you lay out a pattern. So if you're going to make a circuit, you have to run wires. How wide can the wires be, how far do they have to be from other wires is a simple part of a design rule. Everybody has their own design rules

because they know what causes problems in the fab and they learn. So design rules are interesting to me.

04-00:14:48

So while at Siemens, I said, "Look, let me work with one of your guys on what I call scalable design rules." Nobody to my knowledge at that point had ever done scalable design rules, I mean realistically scalable design rules. There were some very simple ones for university designs done by foundries, but if you're going to do a technology, we'd like to say, "Look if we make an advance in lithography, how will this impact our design rules?" and that would be how do they scale, and can you set up some rules and some equations to do that? And so for instance, that's the kind of thing I worked with the Siemens guys on because not to make them—they like that, it helps them, but not to make them more competitive, but just to explore, is this fruitful, does it even make sense, and so on? And so that kind of thing is what you work on.

04-00:15:50
Burnett: You're trying to enrich your research knowledge so that you can be a better professor of engineering because that's ultimately your role, I suppose?

04-00:15:59
Oldham: Yeah.

04-00:16:01
Burnett: But you're also interested in making better things, and in a fast-moving technology space, you almost have to think about scalable rules, right? Because you were just laughing about the one-micron barrier, right?

04-00:16:20
Oldham: Yeah.

04-00:16:21
Burnett: As if it was this frontier that was just physically impossible to cross. Whatever space it is now is orders of magnitude smaller. And we've learned other ways, work-arounds when we hit a technological barrier. So you're asking the question, if we have rules and rules imply inflexibility, imply a set way of doing things, how can you build your rules so that when things change, it can be easier to move to the next thing? Is that a fair assessment of it?

04-00:16:57
Oldham: Yeah, that's one of the things and for—my interest at Berkeley is then is this an area where we can have a student do some modeling and make some—? We never did publish or model anything on design rules. Now we, of course, brought up—maybe I'll talk about that little bit later but maybe—we brought up a process in the new laboratory, and it had design rules, and we had to design, but those were rigid design rules for the technology we had. So we never did publish anything on scalable design rules. That's all just stayed at Siemens; to whatever extent they ever made use of that, I don't know.

04-00:17:40
Burnett: Well, when I was asking about the motive for going to Siemens, it's—I think what you're suggesting is you're going around—you're not giving things to other people. You're going around and you are by, right, just by dint of being there, but you are gathering questions. You're gathering questions at Intel, and you're gathering questions at Siemens—

04-00:18:02
Oldham: That's quite correct.

04-00:18:02
Burnett: —and you're bringing them back to Berkeley—

04-00:18:05
Oldham: Yeah, good problems to work on.

04-00:18:06
Burnett: Good problems to work on, exactly.

04-00:18:08
Oldham: Yeah, and, *and* good collaborators to know around the world that you work with. And as I say, Binder was one of those two guys I mentioned, he came to Berkeley and spent three months with us and did experiments on our—two of the machines we had to see what—we were trying to characterize what could we learn about the optics in a machine by studying the patterns it did, and the photoresist was kind of the theme of our research. And he did that with us so that was cool that we had that little collaboration. And then when he comes there, then guess what, a bunch of students get to know him and then if they're in Germany, they go see him, and it's the kind of thing you like to see happen.

04-00:18:57
Burnett: Yeah.

04-00:18:57
Oldham: And Nancy and I liked Germany a lot so that's why I chose Germany, and here was Siemens just beginning to get into electronics, which, by the way, they later abandoned. They got in it and made some—they tried to make memories and then they started a company, Infineon, and spun their work out to this company. They decided they couldn't do it, they spun it out into Infineon and then Infineon eventually spun out into something else. So Siemens, like a lot of big companies, couldn't manage, the General Electrics of the world, couldn't manage to compete in chip manufacturer, it's interesting.

04-00:19:40
Burnett: And is it—

04-00:19:40
Oldham: They tried.

04-00:19:41
Burnett: It's a different culture, isn't it? Didn't a company acquire Fairchild in '79, right around that time, and it was an old-school industrial, and they tried to run Fairchild as if it were an old blue-chip company, and that was—there's—only one of the factors, but that exacerbated, I think, the problems at Fairchild.

04-00:20:05
Oldham: Well, if you think of all the—it's interesting, of all the companies that were in electronics in the forties and fifties, they made all the tubes and then the circuits, and those were very clever circuits. Those tube circuits were very clever circuits; I'm amazed. And they all tried to get into the transistors and then there were some early start-ups Transitron, I don't know them all, but if you think of Sylvania, General Electric, RCA, they were all making tubes. None of them were successful at getting into transistors so then the question is will the first generation of semiconductor people make it in the long run? Fairchild didn't; Fairchild was like the star, right?

04-00:20:55
Oldham: Fairchild and TI, Texas Instruments were the two companies. TI managed to stay in, but even now, you see, they had to give up manufacturing chips. They now use foundries, and they just designed, and they're in a niche area. They're not in memories, they were in memories once, they're not in microprocessors, they're in their own niche areas. So it's very hard for companies to make those big transitions, and I don't pretend to understand that, because if I understood it, then I'd be a billionaire.

04-00:21:31
Burnett: There's a couple of issues in there: One is the sclerosis of the old industrial model and on being unable to make a stepwise leap into this next generation of electronics. But there's also this question of the separation of design from manufacturing, and that's something that—the manufacturing of the chips is so expensive and requires so much in sunk costs just to get it going and up and running. And the margins are small if you're talking about the—having to build it all and actually make the physical chips and get them out, but designing them is the profit area.

04-00:22:20
Oldham: See, it's only in the US where the big companies can't make the transition. China is so different that you can't compare it, but in Japan and Korea, which are capitalist countries, the big companies there go into it and are successful. I mean the big companies made it, and Samsung is very close to the number one producer of chips. They and Intel are battling every year who makes more chips, right?

04-00:23:00
Oldham: And then TSMC, this foundry in Taiwan is very close, so there's—but big companies, Samsung. So it's only in America that the start-ups beat the big companies, but tell me about a South Korean start-up.

04-00:23:26
Burnett: Well, this is very interesting. I'm glad you're talking about this because it's at this time, late seventies and into the early eighties, where you have a concerted, coordinated, national, state-led effort to get into these high technology areas on the part of Japan, the Ministry of International Trade and Industry, right?

04-00:23:54
Oldham: Yes.

04-00:23:55
Burnett: MITI. And, because they controlled the currency, they could demand that each of these tech companies have their own CMOS program for example. And by the early eighties, Americans are complaining about being—there are all these congressional reports about being routed by the Japanese and this unfair competition and price cutting and so on. So those are different ways of doing tech innovation, but to do that, it requires an end goal. There had to be an American semiconductor industry towards which a nation could gear its entire electronics industry, right? The United States is out in front, and California is out in front, and my next question after this long-winded digression is about state support of industrial innovation and university innovation in support of industrial innovation. Does that figure in this time period in how Berkeley EECS is operating and how you are operating? And if we don't want to talk about this now, I just want to put a hand up and say that I'd like to ask you about that, if not now, at some point maybe.

04-00:25:34
Oldham: Yeah, we could talk about that as—maybe in the next session or so.

04-00:25:38
Burnett: Sure. Yeah, absolutely. You had these fruitful encounters and—

04-00:25:46
Oldham: Yeah, so that has all started because, right in the midst of this start-up with Andy Neureuther, I took a year off and went to Siemens. But they had a computer, and I could do a lot of the stuff we were jointly doing there that I was going to do or ran a lot. They had an old-fashioned system, I had to use punch cards I think, something really—was really primitive but anyway. And so I spent the year there, it was good, did everything I wanted to, and I got to live in Germany, which we like a lot, and my kids learned German, it was altogether good.

04-00:26:34

So I came back to Berkeley in—then in '81, and we were going full bore on this program with Andy. What happened right then was I had—I think, I don't know exactly the history, but Hodges was the leader of the lab I think. We never had an official title of that, and it wasn't any job you got credit for as administrative, but somebody always had to be in charge of the lab, right? I don't know who it was in those period of the earliest seventies, but I know in

'77, I took the job on. I'm speculating because I don't remember, but I think probably [David] Hodges was prodding me to getting me to work on modernizing the lab. He was the guy that had brought in the ion implanter, which was a very big piece of equipment, a very big expense, but a really good move. Somewhat earlier in the early seventies, he executed that and somehow, I don't know, anyway. So I took on that job in—around '77, then I took off this year. I came back and Hodges was working on a new lab. He had this vision of getting another room aside from the one room we had and was working with the university people probably, mostly the dean at that point to raise money to do this. We were not full bore yet with getting industry to fund these things. This was something that developed in the next round when we built the Pederson Center, on the fifth floor, we built another, but that was about five years later. But Dave was really instrumental, and I don't think he mentioned that much in his own oral history, at least I don't remember it but—

04-00:28:53

So I came back, and so the outcome of that was why don't I be vice chair of space, a vice chair of space for Cory Hall? That's an actual job because that's trying to get everybody—keep everybody happy in a building that's too small. And so I took that on, and that gave me the opportunity to look around a little bit and find the space for this new lab. I give myself some credit here for moving a bunch of faculty out of their offices. We all had the best offices, we're on the fourth floor, on the top floor, we're on the north side, we never had sun in our windows. We had double windows, so it was quiet, it wasn't street noise, so we had the best offices, and that whole row of offices is what I—I said, "Look that whole row of offices, we got to have that for our lab." And there was this electronics research lab administrative office up there, and my friend Diogenes Angelakos was running there, and that was there and so I convinced all those people to move. I said, "Look, I'm moving my office, I've got this place in the third floor, we're going to renovate this little space, and we're putting in these offices, we'll move you there." And Pederson agreed, and everybody agreed. That's an amazing thing from a college faculty who are used to being prima donnas. It's an amazing thing, so I give myself some credit for that. There were no battles. We didn't have to condemn anybody and have the sheriff move them out. [laughter]

04-00:30:50
Oldham: So we created that space, the potential space, and Hodges had got the ball rolling on the funding. And I have some good memories of driving up to Sacramento—the chairman then was George Turin, and Turin and I drove up to Sacramento with—and [UC Berkeley Chancellor Mike] Heyman went probably—or Heyman—wait, wait, wait, Heyman became chancellor around '84, so I remember—

04-00:31:23
Burnett: Oh, eighty I think.

04-00:31:24
Oldham: Eighty?

04-00:31:24
Burnett: Yeah, yeah.

04-00:31:24
Oldham: Yeah, okay, so I think Heyman, I remember being grilled by this—who's—his name, Vasconcellos, famous, hard guy on money. He's a very hard guy and so I remembered some tough questions from that guy.

04-00:31:38
Burnett: From state assemblymen or—yeah?

04-00:31:40
Oldham: Yeah, yeah. Vasconcellos is from San Jose or somewhere like that, and we're saying we want a million dollars. We wanted, I don't know, $2 million, and I mean it's just nothing by the kind of monies you spend today on some facility like that, but that's what we wanted. And so we had a year or two of that and then planning, hired architect, got the plans done. Through, uh—the connection was—I'm forgetting the connection to a Bell Labs guy who had built a lab at Bell Labs.

04-00:32:28
Oldham: I'm trying to think, it was Bruce Wooley who was a professor at Stanford. I don't know if he was a professor there then, I think he was, but he had a friend, and he had worked at Bell Labs, and Alex Voshchenkov was a guy who built a small lab at Bell Labs in Holmdel, New Jersey, and had a lot of experience in how to make a small lab work, and he introduced me. Somehow, I got introduced to Alex, and Alex is very strong-minded, just a character, very strong-minded guy, but he had some great ideas, and he played a big role in our—defining our lab in a way which I think it made it very successful in its flexibility. We were trying to build something that we didn't know how we were going to use it exactly, so we it had to be clean and we had to put equipment in it and need lots of services. It needed electricity, it needed hot water, it needed nitrogen, it needed oxygen, it needed this and that, and so you have all these services you have to bring in, and the most important service being ultraclean water, and he had some experience on how you keep ultraclean water clean different from how fabs do it. Because fabs spend millions and millions on this, it's very expensive, and so how could we do this and so on? So I used Voshchenkov a lot and we—the whole thing came together.

04-00:34:00
Burnett: So the idea, like your interest in scalable rules, is not just to build a lab but to build a lab that will last, and to build a lab that will last in a fast-changing world, you have to have a modular lab?

04-00:34:17
Oldham: Yes.

04-00:34:18
Burnett: Is that what—?

04-00:34:18
Oldham: Yes.

04-00:34:19
Burnett: That's what they were doing in those days, but is that what you had planned or—?

04-00:34:23
Oldham: A lab usually consisted of—a fab itself consisted of a large clean room with a floor below it full of the all the auxiliary equipment, all the vacuum pumps and all the plumbing and all the electric and then they would just poke a hole up and bring it in, okay, and so they had access. But we didn't have that luxury. The floor below was some other kind of room, and in fact, we didn't—we couldn't even run the drains down there very well and so on and so we had some constraints. And so we had this idea, which he had some experience with of building individual rooms so that you—somebody could do something quite different here, maybe on III-V compounds, and somebody doing silicon here, and they're separate rooms for good reasons. They're both clean rooms, and then there's—in between there's this what you call a service chase, which has all the equipment in it and so this module.

04-00:35:24
The other thing is you don't want to spend a fortune. A factory, they spend a fortune on the plumbing. They'd spend $50 million putting the plumbing in of a fab, and we didn't what want to do then because most of that plumbing, you're not going to use. Do you want to plumb nitrogen into every room or whatever gases, there's three or four gases you need? Do you need 50 amps, 220 service in every room? No, you needed in some and not the others. So we had this idea of running things in a way that you—and then being able to hook up to them. And so we did some cool things that I think worked out very well, and I give Alex Voshchenkov just enormous credit for—he had the experience of doing it once, you know?

04-00:36:17
Burnett: Yeah.

04-00:36:18
Oldham: And then you find out what worked and what didn't work, and I had the benefit of that experience. I had my own strong opinions about maybe what we needed in the next few years, so yeah. So I think that was a good experiment, and it went together very fast, we opened in '83.

04-00:36:39
Now another thing there, which probably interests you a bit because it deals with the industrial-university cooperation, is the equipment. The equipment was starting to get expensive. It used to be a piece of equipment for an IC fab was $10,000—$10,000 in 1970 was a reasonable amount of money—but

suddenly in 1980, it's $100,000 a piece of equipment. I mean it did not go linearly. And the most expensive piece of equipment is a wafer stepper. We were in the age where the contact printer method of making—of doing photolithography was ended; you didn't want to do that. You want to do it by projecting an image through optics, and those tools were state of the art coming in. There were half a dozen companies making wafer steppers then, and I had some connections to two of them through my work at Intel and at Siemens—well actually three of them and so I said, "Well, how are we going to do this?"

04-00:38:01

So I just went to the one company that Intel had to put a big factory order in for was a little company called Ultratech, no longer exists. It may exist in some form, but it no longer exists as making lithography tools for making chips. It's lithography for other things now if it exists. But that was pretty much a state-of-the-art tool. It was interesting, and Intel had bought—recently bought thirty or forty—made a big order for them. The guy who was a—who started the company was a guy named Leo de Bos, and I called him up and said, "Look, we really need one of these at Berkeley, why don't you guys think about giving us one? Look at all the publicity you'll get and all the students will love them and then they'll go and buy them from you?" Baloney, but anyway. He said, "Well, I think we should look into that."

04-00:39:06

Well, interestingly enough, about the time that we were just finishing the lab, I get a visit from a very well-known guy in the business called Bill Tobey, Aubrey Tobey, but he went by Bill Tobey, and Bill Tobey was the inventor of the wafer stepper. He was not an engineer; he was a salesman, and they had a product that you made masks with, which was called a step-and-repeat camera. In those days if you use a mask to print a wafer, you don't want to print one chip, you want to print a hundred or a thousand at a time. So you need the image on whatever mask you are, a hundred times all placed exactly correctly so that when the next mask came along, they all matched up, right? Maybe you use six or ten masks, they all matched up. So they had invented a camera called the Mann step-and-repeat camera, and it just made these masks this way. And Bill Tobey had the idea that said, "Well, why don't we make some modifications to that, and instead of making a mask, we'll just print that image on the wafer instead of printing it out on a mask? That way, we won't introduce defects. You print it on a mask, then you've got to crunch the mask against the wafer, or you put it in a Perkin-Elmer scanner and you scan it and then it doesn't crunch the wafer. But anyway, it was brilliant, and they made this GCA stepper, and that was the industry standard for about four years, *the industry standard*.

04-00:40:46

So Bill Tobey was—happened to be in my office one day, sitting in my office, and he's in my office, and Leo de Bos calls me from Ultratech, and I'm sitting there. And I don't know why nobody answered the phone because at that point

I was—I think I was ERL director, and there's somebody answering for me. But anyway, I answered the phone, and it says, "Bill, this is Leo de Bos, and I just talked to the board of directors, and we're going to give you a stepper." I said, "Well, that's great, Leo, thank you, I'm kind of busy now, I'll call you right back," I hang up. I said, "Bill, you know, that was Leo de Bos, and he's going to give us a wafer stepper," and that was the cheap product compared to the GCA. That was like, I don't know, a $30,000 or $40,000, a $50,000 product and GCA was $100,000 or something like that, I don't know. Anyway, I'm making those numbers up, I don't know what they were, but they're—and Bill says, "Well, I think I could arrange that we could give you a wafer stepper," [laughs] and this was the one we really wanted, the GCA. And that's how we got the GCA wafer stepper, [laughs] which became the workhorse for—that was the workhorse for like five or six years, then we upgraded to the next lens and used it another seven or eight years, so.

04-00:42:22

But we were just getting into getting industry to give us the tools we needed. And a lot of faculty had relationships with companies and so that helped. And then the Micro program, which you referred to, that came along, and we would use that in a way; you could make a micro proposal to get equipment and so on, and so. But I would say of the equipment that went in that lab, we probably—of the dollars, we probably bought half and probably got half donated probably, you know?

04-00:43:05
Burnett: Mm-hmm.

04-00:43:06
Oldham: When somebody gives you something, people are so foolish, people feel guilty when somebody gives them something, it's really not like that. It cements a relationship, which the person who gives it to you now is interested in your success. It's way more than the gift, the value of that.

04-00:43:32
Burnett: Correct.

04-00:43:35
Oldham: So if you can talk somebody into giving you something, you really got more than the gift.

04-00:43:45
Burnett: Yeah, and without meaning to, it's pure chance, but this is a development strategy where people go out and say, "You know, I talked to So-and-So, and they're thinking of giving us x million dollars," and they're like, "What? I'll give you twice that," you know?

04-00:44:02
Oldham: Yeah, I can't do that. [laughter]

04-00:44:02
Burnett: No.

04-00:44:03
Oldham: I can't do that.

04-00:44:04
Burnett: But it just happened; it just worked out.

04-00:44:06
Oldham: This was Leo du Bos, I was on the phone and Bill Tobey was in [laughter] my office. I would never scam somebody like that. I wouldn't do it, but anyway. [laughter]

04-00:44:17
Burnett: But it did happen to work out, and that's great. So the whole lab initial costs were around $4.5 million.

04-00:44:27
Oldham: Something like that. It was very cheap per square foot by any—even the standards of that day. And something which I forgot to mention there had happened, which was relevant and improved our lab, and that was, as I think I said, I was made—when Hodges wanted me to work on this thing, somehow, the chair made me vice-chair of space and all that. Well, I was the vice chairman, and there was a guy in the dean's office, Dave Brown. Dave Brown was this wonderful guy who had worked for all of the deans of engineering for twenty-five, thirty years, and he was in charge of the money in the dean's office, okay. And he's a terrific guy, one of these guys who understood the mission, the mission is to help students. And so one day, in the middle of June, I get a call from Dave Brown, and he says, "Bill, I've got $40,000 that if I spend it in the next month, then you get the 40,000, but I lose the money if it's not spent by then," so they had something like that, and I said, "I think I can take care of that, Dave." I said, "I have an idea that we should improve our undergraduate teaching lab in microelectronics." We had a very primitive lab that we had set up, and again, I was not the leader in that. I think that was Dave Hodges and originally Bill Howard who was an assistant professor for a few years and then went to Motorola, became a prominent guy at Motorola, but one of Don Pederson's students. But anyway, they had set up a lab, and it was pretty primitive. I mean it was just like an ordinary, dirty, old room that they had some equipment in, and they tried to make chips in there. So I had this idea let's see what we could get for $40,000, and I got Herman Miller, the furniture company in Michigan, a very famous company, a very high quality company, quality stuff. They were doing stuff for hospitals, and they had a line of furniture, which had really nice modular drawers and things, so you know, how hospitals like a certain look and cleanliness and—?

04-00:47:10
Burnett: Mm-hmm.

04-00:47:11
Oldham: Somehow, I talked to the guy at Herman Miller and said, "I got a project for you. You might be interested in the semiconductor lab business. If you are, here's a chance to do a little research project in how your equipment could be used, and how about looking and seeing what you could do for a lab of such and such a size and so on?" And so they put together a system of walls and tables and drawers and just make a laboratory. And what we did then is we—and so we learned not to do this again—we hung laminar flow, air flow HEPA filters on those walls just right down over the space. So every bench which had the microscopes and mask aligner and all these things, and it had a laminar flow, it was a clean room, a real clean room, and it was all modular, it was just like—it's like snap it together, all their—Herman Miller stuff did that. And so they built this, and we did the whole thing for $40,000, and we installed it. We interrupted the lab in the fall of like '80 or whenever it was, I don't know fall of '79 or '80 or '81. We stopped the lab for a week and installed this thing. Everything snapped together, put it together, plugged it in, turned it on, and we had a laboratory, very interesting.

04-00:48:47
Well, we learned that you can't put a fan hanging on a wall because then the wall vibrates and then the table is moving, and you're trying to do something precision and like look in the microscope and everything's—so we learned some things. I mean you can fix all that, that's all easily fixable, but we learned some things, but—and Herman Miller learned they didn't want to get in the business. They went ahead and helped us with the Microlab, but that was their last time doing microelectronics labs. So that was a great experiment pre-experiment into how—what kind of a room, modular room we could build. And then we built a whole series of those rooms upstairs, and we can unbolt them. Like when I move the GCA stepper in, I just unbolt six feet of the wall, remove it, roll the stepper in, build the wall back together, that kind of stuff upstairs. That came out of this experiment we did downstairs.

04-00:49:54
Burnett: And having modular walls was—

04-00:49:57
Oldham: Oh yeah—

04-00:49:57
Burnett: —crucial?

04-00:49:58
Oldham: —really good. And since we had all the utilities overhead and we just brought them in where we needed them, we didn't have all the walls covered with utilities. If you look at 90 percent of labs that have like a service—so-called service chase, the walls are all full of pipes and drains and everything, and you can't do anything with those walls. So it was very cool, it was a lot of fun, I mean it's just fun to do this. I'm an engineer, right, so it was fun to do these things.

04-00:50:32
Burnett: Oh, wow, yeah, because I was reading about that, and I don't think I quite understood it. So the advantage of having the overhead utilities and the modular walls are connected in that you need to have the utilities above in order to have modular walls.

04-00:50:49
Oldham: Of course in the real lab upstairs, we didn't hang the fans on the walls. The fans were hung from this concrete ceiling, but we're in the same space as if they were hung on the walls—

04-00:51:04
Burnett: Yeah, and—

04-00:51:05
Oldham: —so we didn't have the vibration.

04-00:51:07
Burnett: —they're decoupled.

04-00:51:08
Oldham: They're decoupled, yeah, but similar, so. The other thing we did in there, and we had done this to the biggest extent downstairs as we could but then we really did it upstairs, was to make everything transparent. So when you went into that lab, there were no hard walls, it was all plastic. So you could see a couple of rooms down through a bunch of reflective things, so you can't see high quality, but you can see if somebody is in there, and I always said that transparency leads to good behaviors, you know what I mean?

04-00:51:49
Burnett: Mm-hmm.

04-00:51:50
Oldham: So if people are going to do something that they maybe think is a bad idea, they're less likely to do if they're being observed. It's just a funny thing that way. And this is an educational lab, so it's good of anybody can see what everybody else is doing, right? So we really took that to the limit, including making all of the utilities visible. We put all plastic up there, so anybody coming in, the student can see what it takes to run that piece of equipment because they can see all the utilities, and why shouldn't they know that, isn't that part of—?

04-00:52:34
Burnett: Right.

04-00:52:35
Oldham: So we executed a number of cool things in that lab.

04-00:52:38
Burnett: Yeah, and they were color-coded, weren't they, the—?

04-00:52:40
Oldham: Well, yeah, everything had a color and all that, a lot of plexiglass in there. Now I don't even know if you could do it today because of the fire hazard, the plexiglass. I don't know if that's allowed today, I don't know, but anyway, I really don't know.

04-00:52:56
Burnett: I'm wondering about the—you know, we're talking about Bell Labs and the design. I think you said the designer wasn't a good designer at Bell Labs, but there was this happy accident of the hallways and the little kind of cubbies where there'd be these experts, and it lent itself to collaboration. It lent itself to just being able to—the world expert in this—

04-00:53:23
Oldham: It was the hallways, which connected everybody, yeah. You had to go down this corridor which had twenty, thirty offices off it.

04-00:53:31
Burnett: So as an engineer, a builder, a designer, you're thinking about designing space for research and teaching and how to facilitate student learning. So that was part of what you were doing.

04-00:53:49
Oldham: Yeah, and we had a good architect too. I don't remember the architecture firm's name or the individuals, but they were cooperative.

04-00:53:58
Burnett: So these student lab was an opportunity for a dry run?

04-00:54:01
Oldham: It was sort of a dry run, it was an experiment—yeah.

04-00:54:07
Burnett: Yeah, and that's great because you were able to fix some of the problems and—that you hadn't foreseen. And you're able to get this lab built, and there's some industry money, there's some state money, and there's some university money, is that right?

04-00:54:22
Oldham: Yes.

04-00:54:22
Burnett: I think it all comes from—cobbled from different sources, and it comes together and then donations on top.

04-00:54:30
Oldham: And then donations, donations of equipment, yes, and wafers. Just about that time, industry changes wafer sizes every few years, so they have this stock of wafers that now they can't use because they just move to this size wafer and all their equipment takes this size wafer, and they got still a thousand of these. We said, "Give them to us," so we were four-inch wafer fab, we were four-

inch wafers. Industry and moved from three to four in the early seventies. And so at that time in the late seventies, four was the standard, and they were moving to six and so we had a lot of four-inch wafer equipment and wafers until all the old ones were used up, then it became hard to get four-inch wafers. [laughs]

04-00:55:22
Burnett: But also older equipment and they—you know? Wasn't there something that you repurposed something? There was something about the 256-nanometer device and—was it a laser? I'm trying to remember. And you fixed it so that way you got a different lens on it, and you were able to use that.

04-00:55:45
Oldham: Well, I don't know. We did upgrade the wafer stepper once from one wavelength to the next, to a shorter wavelength.

04-00:55:54
Burnett: Okay. Oh, so there's a company called Cymer?

04-00:55:57
Oldham: Yeah, Cymer, I'm trying to think when Cymer came in. In around '86 or '87, Cymer was the first company to build laser specifically for lithography because up to that point, you used a mercury line. You had a mercury bulb, and a mercury bulb has a bunch of wavelengths, you can pick one of them and make a lens for that wavelength. I think by 1980, it became impractical to use more than one wavelength. In the old days, you color corrected lenses and you used. But the resolution requirements of the optics for lithography became so stringent, you had to get so close to the diffraction limit that there's no way to make a lens work at more than one wavelength. You had to, in fact, use a very narrow part of the spectrum, very narrow in order not to have color dispersion of the glass. Light doesn't pass through glass at the same speed for all colors, some go slower and so that makes a mess.

04-00:57:29

So by then, we were using so-called g-line and i-line lenses, and i-line was sort of the really very difficult because glass became absorbing with i-line, so most of the optics then were g-line and h-line of mercury. And Cymer came along—I don't know when Cymer started, about early 1980s, and they decided to make lasers for lithography, and we saw that as a way—I mean I saw that clearly, that's the way the industry is going to go, you're going to use a laser light source. I mean it's so much brighter if you got to cram it into a narrow space, and you really want to use a laser. Lambda Physik was the company, which made power—and Spectra-Physics were the two laser companies that made gas lasers, which would operate in those wavelength ranges. But they were lasers for research, and they would produce a reasonable amount of power for a few thousand hours and then you have to rebuild the laser. The life of those was quite short, like an incandescent bulb, sort of that kind of a life.

04-00:58:51

And for the industry, that just didn't cut it, and Cymer says, "Okay, we're going to build" and so—how did that go about? I wanted a laser to start working in the laser wavelengths and so I guess I contacted various companies, probably Lambda Physik was the competitor and Cymer, and said, "Look, we want to get a laser for our light source to do experiments, and we also want to possibly line narrow it." There was something called line narrowing, and that gives you a different kind of performance. And so Cymer bid, I mean they were just starting, and they bid on the laser and sold us a laser, which was the same price as the Lambda Physik's laser, the big company but had a line narrowing option. I think I paid $10,000 that I could send the laser back and get it line narrowed, something like that. And they put this in there and so I said, "Okay, so we're going to buy this laser," and I was their first customer, I was really sticking my neck out, this was a start-up, but they were good people.

04-01:00:18

And I bought their first laser, and I was so impressed. I mean it was one of the best. I was so impressed with those guys, their quality of—they understood quality of manufacturing, which most start-ups don't get. For instance, the classic thing, which convinced me I did the right thing is right away, there was some problem, a hundred hours and the thing starts degrading. And we'd call them up, a service guy comes out, and he says, "Well, I think this behavior is like there's a seal missing on this front optic. I wonder if that's the case?" So he calls the people back at Cymer, the only—the factory, the whole company in San Diego and says, "Well, get out the build manual for this laser," and they had that detail in there that as each part was installed, it was detailed what the part was, everything, I mean everything about it. And so he said, "Yeah, that—that's missing." So he takes it apart, put that in it, and so on. Well, I don't know of any start-up in the world at that time that didn't just throw the first one together and say, "Get it out. We're not going to detail what kind of O-ring and is it actually installed and all that in the build," they don't. So I said, "We chose the right company."

04-01:01:55

And of course Cymer then became the—as you probably know, it became the dominant supplier of lasers in the business and was eventually bought out by ASML about—now, I have to disclose the fact that I was on the Cymer board of directors at the end, at the end. Later on, I was asked to consult for Cymer and then they asked me to be on the board of directors many, many years later. So my opinion of the company is quite high, but actually at that time, I had this opinion from the quality. So we had that laser, and we had other lasers later on.

04-01:02:42

Burnett: And you had done work in lasers before, and it was a dead end for you, but did having that exploratory experience in the early seventies help you in this?

04-01:02:54
Oldham: Not especially. That was in semiconductor lasers, which are a different kind of creature. They're lower power, relatively low power. I mean they can be high power, but they were semiconductor lasers and infrared lasers so I was—so it was kind of in my turf of processing semiconductors to make cool things but—yeah.

04-01:03:21
Burnett: Did you modify this? This was like a 248-nanometer laser, this is like a commercial light source that Cymer built.

04-01:03:31
Oldham: Yeah.

04-01:03:33
Burnett: And you've modified it somehow.

04-01:03:34
Oldham: Well no, I eventually sent it back and got the line narrowing package because I had it on the end in that line narrowing package, it's like a $50,000 cost. But I had that in the contract to get that for, I don't know, $5000 or $10,000. It would be very interesting to look at it, but it was a hell of a deal. And we did that because then we got—because what we were using it for initially was we were studying the materials. We were exposing resist, and we were studying the materials, the glasses, and something called the pellicle, which is a membrane you use to protect the lens. We were studying the properties of those with the laser. I don't know what the laser did to those things.

04-01:04:29
So that's what we used it for initially but then we—I forget, we got an optic from somebody, and we said, "Well, let's put together an imaging system with this." My friend John Bruning at—which what became Corning, he offered us an optic at this wavelength, but we had to have the line narrowing. So we sent it back, got the line narrowing and then he gave us another laser at a shorter wavelength where we could explore yet another wavelength, and he gave us that laser. That was a solid-state laser, and that was fun, and then I had a student building lasers again, and—because I had to build the—no, he didn't give us the laser, he gave us an optic at the fifth harmonic of YAG. So if you take the YAG, which is like 260 or something and you divide it by 5, you get a wavelength, which is a little bit shorter than the industry standard 193 and so John said, "Well, why don't we look at that wavelength for—we'll make an optic for you?" Okay, he was one of these friends in the industry that you know, and he's a cool guy. He's another ex-Bell Labs guy, an optical expert from Illinois like Andy. He was an E and M guy at Illinois and then he became CEO of this optics company, and in fact they—yeah, he and a couple of other guys bought it and ran that company. And so he made that optic for us at the fifth harmonic of YAG and so then I need to make a YAG laser. You can buy the YAG laser, but then you have to build this fifth harmonic generator, which is a bit of a thing. You need a crystal that is nonlinear and so,

yeah, we got into that. I had a couple of students do that kind of thing, and it was a dead end, but it was fun.

04-01:06:44
Burnett: You had the new lab, and you had this collaboration with Dr. Neureuther, and can you talk a little bit about—? I think in the last session, we were talking about how you set up this kind of research program to have students work on particular parts of the process of manufacturing integrated circuits. I think you did something analogous with the new lab; you set up a research program. Can you talk a little bit about how you were able to—or how the students were able to take advantage of the new lab once it was up and running?

04-01:07:36
Oldham: Yes, some of them did a lot of their work in the old lab of course because we didn't have a new lab till '83, but I don't know. I don't know the student perspective very well on this like I probably was a little blind to it, but we'd get a bunch in every year and then we'd say, "Look, would you work on—?" Think about one guy, Sanjay Mehrotra; he's the CEO of Micron now, which is the fourth biggest manufacturer of chips in the world. So Sanjay came in really nice, these are great, nice kids, I mean you'll love these kids. You say, "Look, we've got these five problems, would you be willing to work on characterization of a certain photoresist for a master's project?" This is for a master's project and so a master's project is supposed to take the equivalent of about one class for a year, which is that kind of time. Some people run it into several years and so on and so on, but that's what it supposed to do. It's a project, not a thesis, but it's supposed to be a research problem that they make some—and they don't have to be successful, they do a research problem.

04-01:09:10
So Sanjay agreed and he—because I've forgotten what he had worked on, and I went back and got out his master's report and then called him up and apologized for giving such a crappy project. Because other guys were working on like a new method of oxidation or a new method of annealing or something. If it was successful really went right into manufacturing, you're a hero and everything. And this is in—not in actually processing, it's in photoresist, and it's like imaging on photoresist. It's like afar from electronics if you think about it; it's just a subset of a subset, right?

04-01:10:02
Burnett: Right.

04-01:10:03
Oldham: But it's necessary, and he agreed and he worked on this and did his project and got his master's and then he didn't stay on. Well, I said, "Sanjay," later, thirty years later. At that point he was CEO of a different company, of the company that makes all the flash memories, the biggest company SanDisk. He was CEO of SanDisk. I said, "Sanjay, how could I have given you such—how come you even talk to me, I gave you such a shitty master's?" Then he

reminded me, he says, "Look, when I finished and I decided to go out, I asked you were to work, and I wanted to work in design." He wanted to design chips, and I said, "Well, I know who—three guys who I think are the best designers in the world" because I was just finished with the DRAM design, and I said, "I'll introduce you to these three guys, and see if any of them—" And he got job offers, and he went to work for a really good friend of mine, George Perlegos who was the—he had started a company called Atmel, he and his brother started Atmel, very successful, they made lots of money and then Atmel is still around I guess.

04-01:11:20
Burnett: How did you know him, George?

04-01:11:23
Oldham: He was a young guy at Intel working for another guy right close by. They were developing a non-volatile—state-of-the-art, non-volatile ROM, and he was one of the engineers and you just became friends over the years. But George was a designer, and he was this quiet—nobody would think of him as anybody. He just was invisible, quiet guy, but his designs worked, his designs worked. And I could see, you get to know who are the guys that actually produce something, other guys talk a lot and stuff, and so he was great. And actually, Sanjay went to work for George. There were other more famous guys, the guys who did *the* successful DRAM design that put the Intel DRAM's a generation off, Probstein and, uh, I forget the other guy. So he interviewed them, and there was a third one, I forget who it was at the time, but anyway. Yeah, so Sanjay was happy, but he got one of those bad projects, whereas other students came in, maybe they work on plasma etching, maybe they work on something on epi, maybe work on this, work on that. And they all knew each other and see each other all the time and stuff, so they all mostly became friends and went to different companies, still friends, you know?

04-01:13:18
Burnett: At the beginning of our interviews, we talked about engineers being interested in stuff and things—it's not so much about people. [laughter] But it is, it is, you're telling me about people making contacts, you introducing students to people, helping them, you learning from people in industry, and so much of it being about trust, right? There's a strong social element to this stuff, right, that it's—

04-01:13:59
Oldham: Well, to the successful guys—

04-01:14:01
Burnett: Sure.

04-01:14:01
Oldham: —that has to be there. You know how you tell an extroverted engineer?

04-01:14:06
Burnett: No.

04-01:14:07
Oldham: He stares at *your* shoes. [laughter]

04-01:14:13
Burnett: That's great.

04-01:14:17
Oldham: Yeah. So, yeah, so there were this cadre of students Andy and I had, and we used to do things. We'd go up to Tahoe and take them skiing. I remember Sharad of the whole people, this Indian guy who had never seen snow almost. He's from Bombay or somewhere, I don't know, and Sharad up there on skis, we had a lot of fun.

04-01:14:46
Burnett: So that's awesome that you brought that the social life is important for the success of students. Of course, they socialize well each—with each other.

04-01:15:00
Oldham: Yeah, they do.

04-01:15:01
Burnett: I want to ask if there was something more deliberate about students and the lab? Because to get it going, you just figure out what—how people are going to use the lab, how you're going to keep track of things. So wasn't there something about the first semester that you were in there with the students, and the students would take on different roles?

04-01:15:38
Oldham: Well, I don't know. Andy and I decided that we—you know. First of all, there's another topic we should talk about, which is the use of the lab by non-semiconductor EE [electrical engineering] students. That's another subject, but for the integrated circuits-oriented people, not just the circuit designers but people who are interested in processes and—or even in photonics and stuff but need silicon chips, those—or need to be makers of silicon chips, we thought, okay, there should be a standard process, there should be a CMOS [complementary metal-oxide semiconductor] process. CMOS was the state of the art then. It had been NMOS up through the mid-seventies, and suddenly, power was just getting out of hand. And so even at Intel, I started some projects on CMOS, CMOS DRAMs. I realized that there's only going to be another generation maybe one more generation of NMOS DRAMs and then they're just going to be running red hot, you're going to go to CMOS.

04-01:16:57
Burnett: Because they run cooler, that was the—?

04-01:17:00
Oldham: Yeah, they don't run a current all the time. NMOS basically if you think about it, you turn this transistor off, then this one's on and so there's always current running in NMOS. Whereas in CMOS, you turn everything off, so the only time there's anything is when there's a switch. So it uses less power, still uses way, way too much power today, because you've got billions in transistors instead of thousands but—or millions. So we switched to CMOS. So then we said, "Okay, so let's do a standard CMOS process." So Andy and I just created a course, a 290—290 is a course you can do anything in, and 290 is a universal number and then you put after it what it's about. And so we did a 290 on the standard CMOS process, and we got a bunch of students to enroll, and we say, "Okay, what this course is, is develop our standard CMOS process. We're going to break up the job into the different jobs. You're going to do the lithography, you're going to do the oxidation, you're going to do this, you're going to do that. You guys all have to work together, and at the end of the year, we want working CMOS chips, that's what we want. And so you're going to work the bugs out of this lab" because we bought new furnaces, we had a lithography tool. We didn't have an ion implanter. We decided—again Hodges is very strong force here. He figured out, and he was right, that we really don't want this big implanter in there. We can take the wafer in a day and take it someplace, get it implanted, bring it back. That's a better way to do it and then we don't have this overhead of this monster tool, which we're not running 24/7.

04-01:18:48
Burnett: Yeah, is it physically big?

04-01:18:52
Oldham: Oh yeah, because it's sending ions of boron and arsenic and so on at like hundreds of kilovolts, maybe 200 kilovolts at silicon in order to bury it in the silicon, right, so it's a big accelerator. It's really the kind of thing that used to be—

04-01:19:14
Burnett: Up the hill.

04-01:19:14
Oldham: —thirty years before was a physics tool.

04-01:19:18
Burnett: Right, right, so that it's a light source.

04-01:19:19
Oldham: But now, it's a tool for making chips. So anyway, so those things are pretty expensive, they take a lot of maintenance, and they only make sense if you're running them 24/7. So Hodges again, I think Dave again was the brains, behind get that thing out of here, we'll—we can do that one. But anyway, everything else we did and then the students put together a process. I don't remember when we had our first working chips or something, but we did. And

Katalin probably knows more about that than I do because she was a student then.

04-01:20:03
Burnett: This is Katalin Voros?

04-01:20:05
Oldham: Voros, yeah. She was a student then, but later on of course, she ran the labs, so—

04-01:20:12
Burnett: Yeah, from '87 on I think.

04-01:20:14
Oldham: Yeah from '87, yeah. I don't remember when she came as a student but right around in the time when that lab was starting. Yeah.

04-01:20:22
Burnett: So it also worked out spatially too in that—and this is what I read or heard. First semester, you build out the processes for using the lab, the workflows, quality assurance, that kind of stuff. The second semester, the students went into the lab to work on and build circuits, that's what you're talking about. But you worked out the baseline processes in one section of the lab, and in another section, you could run a new experimental process and you could compare the two. Does that sound familiar to you?

04-01:21:05
Oldham: No.

04-01:21:07
Burnett: Okay.

04-01:21:06
Oldham: But it may be to Andy or somebody who did more of that than me.

04-01:21:11
Burnett: Okay, okay, so that was something else and it was part of the new lab?

04-01:21:16
Oldham: It was interesting that we had this lab, which had like—we call these rooms GL1, GL2, I don't know what it meant; GL stood for something lab. Anyway, the rooms were GL1, 2, 3, 4, 5. What goes into what room? Well, we figured out where the wafer stepper should go and made that room to accommodate it because GCA [stepper] actually had its own environmental chamber that goes around this thing, and that's for temperature control. You've got to control the temperature of that lens to a fraction of a degree, right?

04-01:21:16
Burnett: Oh my God.

04-01:21:54
Oldham: So this one was special, so that one went in, and then everything else we assigned some tools to, then we had some empty. Well, Andy and I just took one of them, and we put our laser, our laser from Cymer in one of those rooms—I think it was GL4—and I don't know how the other ones got assigned. I was only in charge of that lab through I think '84. I mean we put that thing together. I got out of there, and we have this amazing, distinguished set of faculty who would step in and run that thing. I mean guys like Ping Ko who's been long, long gone from Berkeley, he was a strong collaborator with Chenming Hu on development of the BSIM process. He was a device guy, a SUPREM device guy and circuit too. So I think Ping Ko probably was their first director then, and we have all this series of people that come in. And probably Andy had to do it a couple of years, and I never was—I never had to do that again. And I don't know exactly—

04-01:23:25
Oh, another brilliant thing that happened was that at that time, Dave Hodges got interested in manufacturing, and he was starting this research on manufacturing. I never understood what manufacturing was because I'm not a data guy. But now that data is what runs the world, and we're starting whole colleges of data right? Berkeley just introduced a new dean of data, and all these people say, "I'm a data engineer" and all this stuff. Well, what Hodges was doing was—I mean, the way I see it today—he's never told me this—but I think what he was doing was saying the data can drive the improvements in manufacturing. If you really look at what you get carefully and understand what you get, guess what, you'll be able to go back and do what you did better, and that's what manufacturing was about. So Dave started this program manufacturing. My field was a little bit invention, a lot of making stuff work, and figuring out what process is good for what use and then trying it out. I was definitely not a guy—except for six months in Intel when I had to bring a process from a yield of 1 percent to—up to something where you could manufacture it, but I was not a manufacturing guy, and I never quite understood that.

04-01:25:16
Dave did, and then he and Costas Spanos made that hire happen, and he was the young guy in manufacturing there with Dave. Spanos probably wasn't even there then we started the lab, but he was probably at CMU. But Dave had a student, I think he was a student, do a program that talked to all the equipment. I forget what we called that program; it was very clever. What was the name of that program? [BLIMP, Berkeley Laboratory Infrastructure Monitoring Program]

04-01:26:20
Burnett: It would be in Katalin Voros's history.

04-01:26:24
Oldham: Oh, yeah. Anyway, they wrote a program because we had a VAX, so they had a VAX in every machine, and I was very enthusiastic about this, but I had nothing to do with either the idea or its development, I just wanted to see that happen. And so by the time that lab was running, every piece of equipment in there at least the power plug went through a box controlled by this computer. So if you wanted to use that piece of equipment, you had to log in, so you had to be—go in the lab, you had to log in, and then if you want to use that piece of equipment, you had to log into that piece of equipment, so we know who used that piece of equipment. And if there was a problem with that piece of equipment, you can't go and say to the technician, "Hey, this is broken" or something, no, you go into the computer, you report it. So we have a total log from the beginning of all the equipment, how it behaved, who used it, how many hours it's been used, how many times it's been used and so on and so forth. So he started that, which was an amazing thing in the university. I remember having a visit from the CEO of a company that made one of our pieces of equipment that was not very reliable. And I remember walking him over to the—because we had these terminals everywhere. I say, "Well let's look in, let's look and see how your equipment is doing." This is the CEO of this company, go in there and say, "Fail this, oh, we reported this," and said, "Oh, this is how it's doing." [laughter] It's was just a terrific thing.

04-01:28:11
Burnett: Well, it also, I imagine, ends up being handy for reporting when you've got grants and you're talking about the share of the cost of the tools for a particular grant. Does it help in that sense as well?

04-01:28:26
Oldham: Oh yeah.

04-01:28:27
Burnett: It's like—?

04-01:28:27
Oldham: Well, the way the accounting very quickly evolved too is, it was run like a country club. I called it a country club because—and I don't know how quickly it evolved to this, but the idea was if you wanted to be in the lab, you had to pay so much a month, that was it. There was a fixed fee to be a member of the lab to get a key. And then you were charged by the hour you were in there up to some maximum amount, so there's a maximum amount of like $1000 or $2000. So if you had a student in the lab at the maximum rate, it's going to cost you $15,000, $20,000 a year, which seems like a lot of money, but they're getting a lot of value out of that, and not everybody is in there all the time. Those rates were all adjusted every year by a process designed so the bills could get paid, right?

04-01:29:27
Burnett: Right.

04-01:29:28
Oldham: Now Katalin could tell you that she was mad at me for years because when she became lab director, she inherited a $900,000 debt, something like that because we had built this thing on credit. We didn't have enough money to finish it, so we built on credit and we said, "Well, we'll pay this thing off with a loan," and the university let us do that, and we just built it into our rates every year. And so she had a mortgage burning after about four or five years as lab director and then she quit complaining to me about it. [laughter]

04-01:30:04
Burnett: Yeah, she notes the year that the debt is retired.

04-01:30:08
Oldham: Yeah. [laughs]

04-01:30:09
Burnett: Yeah, it's a milestone.

04-01:30:10
Oldham: I heard about it a lot though before that, trust me. [laughter] But that's why you want a Hungarian management because they care about it and they make it disappear, you know?

04-01:30:22
Burnett: So it sounds like it was a great kind of classic experimental lab not classic, but if one section of the lab is—has baseline processes for manufacturing and another section is a lab where the students could swap out a new process or a modification, you could use the first section as the control, and you can see what a difference a modification made. That's what I heard or read about.

04-01:30:56
Oldham: I see, that's somebody's perspective. Yeah—

04-01:30:58
Burnett: Yeah—

04-01:30:59
Oldham: —that—

04-01:30:59
Burnett: —on a particular phase of the history of the lab.

04-01:31:03
Oldham: So, yeah, that's somebody's perspective. If I walk through the lab, I mean—I built it, I was still in there a lot in those days, I would never say this part of the lab is dedicated to such and such a process because, for instance, we had a room which had all the furnaces in it. Well, some of them were used for the standard CMOS process, three or four of them; others were used for others. I had a student doing a special kind of epitaxy in one of those furnace tubes and then when he was done, Tsu-Jae King, who's our dean now, she came in and was interested in growing epitaxial germanium or something, and that tube

went to her and stuff like that, and that had nothing to do with that base process. So it wasn't like it was actually physically oriented different things, but some rooms were dedicated to specific things, and other rooms were for doing more flexible experiments.

04-01:32:08
Burnett: So this is a group of pretty outstanding students. I mean you've had outstanding students throughout, but in the period before the lab was built with Andy Neureuther and the period after it was built, you're doing the signal work in modeling processes, really working closely, watching what's happening in the industry, bringing those questions back into the lab to work on. Are there other sources? I mean, of course, I guess journals would be another source of inspiration for experimental work. The field itself is generating questions, so it's not purely like an industry lab at all.

04-01:32:59
Oldham: Yeah, not at all. Yeah, originally when I got going, I was very much—I was thinking about this in connection with preparing for this oral history, and I was thinking about my own—let's say how I identified problems to work on and so on. And originally, it was from reading literature and then occasionally meeting those—when I was young, those famous guys, people. There were a few women, not too many in the field then, but anyway, those famous people. But reading the literature and then that became less and less true. As you got more and more into it, you were more working with your students, and they're talking about things, and you're working with other colleagues and you go to conferences. Conferences are really good for if you really sit down and really make careful note of them and think of all the questions that the person is giving a talk and they've raised more questions usually than they answer, if you really listen.

04-01:34:18

And that changed for me over the years, and I got less and less somehow reading literature critically I think as I got more into administration doing various things. So my productivity, I was trying to struggle with why did my productivity, it did this [indicating going up] and then it just tapered off. Now, that's a characteristic of probably most people but certainly a lot of people, your productivity changes, and it's interesting to speculate why that is. I had two years where I graduated four PhDs each year, only two years where I did that, and before that, it was a few per year, something, and then after that, it tapered off to one per year, and I say, "Well why is that?" Because I had a lot of money later, I had—but I thought—so it's very interesting to think about things like that.

04-01:35:25
Burnett: Well, you're taking on more administrative responsibility. Isn't that what they say about Bell Labs is like you'd get bumped up and then you're—at the very senior levels you're—? Well, I actually know that that's the opposite with Bell Labs is that the senior people were real research scientists who were—sort of

maintained that passion, but in universities, it's often that you get bumped up to these administrative tasks.

04-01:35:58
Oldham: Yes, you don't see too many deans doing the kind of work they did before they became dean. A few do, I mean a few maintain it. One of the things I was thinking about is that we—I was in the lab until about 1980, I was in the lab myself physically, and in the seventies, I was in there all time, and I was doing the experiments, and my students were doing experiments and so on. And then gradually by end of the eighties, I was never in the lab. I would go in there, I have to do some single thing, but I was rarely in the lab. I was always talking to a student what they did, right?

04-01:36:49
Burnett: Right.

04-01:36:50
Oldham: Or a postdoc, we had postdocs. And whereas in biology, all the—my friends in biology, all of them, even the senior professors, they were in the lab, and I think you've got to be in the lab if you're an experimentalist, I don't think you can—if you're a real experimentalist. I mean there are some people, there are some very famous people, like Einstein didn't have to be in the lab but he—I mean he defined some experiments, which are pretty amazing, and he was not in the lab. He was doing it with a pencil and paper, but most of us are not like that.

04-01:37:35
Burnett: Well, there's experimental, yeah. I mean experimental physics is a lab-dependent thing, and there's the theoretical folks too, but—

04-01:37:47
Oldham: What I think is to stay at the state of the art in experimental work, you actually have to physically do a certain amount of experimental work. And as we got more administrative and this and that, we did less, I did less and so I think I—anyway, I was just kind of speculating a little bit.

04-01:38:10

While we're still on the talk about this Microlab, the other thing that happened in this period was that once we got this thing rolling, and it was rolling a couple of years, we always encouraged by the way the physicist who had interesting devices to build to come on over and use our facilities. Well, this is kind of strange for other people because in other departments, they didn't share and they didn't share the equipment amongst the whole group. Maybe one or two faculty members would buy something and then—well so we got like John Clarke and these guys who were very experimental, they were always using our stuff. After the lab was running, like by the time Katalin became director, we were—half the people using the lab weren't EE at all. They were from civil engineering, from mechanical engineering, from biology, from physics, from chemistry, ChemE. We had them from all over because we had this micro capability of making stuff small, and it turns out there's a lot of cool things you can do when you can make stuff small.

04-01:39:29

So Katalin, I mean she's a businesswoman, and she made that work. I give the credit to her because Don Rogers who ran it before her, he was like an experimentalist himself and he was not a—Katalin hired this accountant Spivey, Roseann Spivey? Man, it's terrible that I can't remember these people I knew well, but anyway, Spivey and she was the accountant for—oh man, for like twenty years for that lab. And so they figured out what works, and they adjust the rates, and they figured out, it's an interesting thing, it's a market. What can people afford to spend to send a student in to do an experiment and so on and so on, and how do you pay for all this stuff and then when—if you can pay for it. So then this whole thing becomes a different kind of model where maybe you can even buy some better equipment with the money, and the whole thing becomes a sustaining thing, and so I think in Katalin's years, that's what happened. That's what she turned it into because she had a good, what, twenty years almost as director or something like that?

04-01:40:51
Burnett: Yes, makes sense. Twenty-two years I think. So, yeah, at the very least, you don't want to be losing money, and that you've invested and created this space, and it cost money to operate and if only half of the students are EE, you're—

04-01:41:13
Oldham: Yes, you can't subsidize the department.

04-01:41:14
Burnett: You can't subsidize it, right. So just costing it out so that—and there's a small revenue stream for the actual improvement in the lab because the lab does need to be updated and upgraded, and we'll talk about that in another session, what happens to the lab later.

04-01:41:33
Oldham: Yeah.

04-01:41:36
Burnett: One of the things I noticed when I read Katalin Voros's history of that lab was that there were a number of women who were really crucial in the functioning of it, not just Katalin but there were others as well.

04-01:41:53
Oldham: Spivey, the accountant, Roseann or—

04-01:41:56
Burnett: Yeah, I'm not sure of her name, but there were a number of administrators and—

04-01:42:03
Oldham: Well, the technician Andy and I had for years, this Kim, Kim [Chan]—she was terrific. And we always hired her about half time just to do certain processes which are standard, you just like [the same] technician to do [them] so they are always done the same way, and she would do that.

04-01:42:29
Burnett: But engineering has long been a very male field, and it still is today, it's changing.

04-01:42:37
Oldham: It's finally changing.

04-01:42:38
Burnett: It's finally changing.

04-01:42:40
Oldham: You look at our department now, it's really—there are some awesome people in there now that are women. I mean just in our field in lithography, I mean there are just amazing people, so yeah, so finally. It took a long time.

04-01:42:59
Burnett: There was some scandal at MIT in the—was it 2000, around that time frame with the—with women just being sidelined or—I mean they would get into the assistant professor level, and they just wouldn't get any further and that kind of thing. Were there efforts to recruit? What was the state of things? Now this is like the eighties, right, so there's not necessarily a lot happening in that area until much later.

04-01:43:46
Oldham: You know, it's not only women. If you're at Berkeley, you get a false impression of what academia was like if you're at Berkeley engineering because we had Asian faculty members. We had a black faculty member in the fifties. So in engineering there was never a—I don't think there was ever a problem in Berkeley engineering with discrimination. I'm sure there were some racists. There are racists everywhere if you dig a little bit. But in the operation of engineering at Berkeley, we have like the most distinguished Ernie Kuh who just recently died. Whereas, *whereas*, the first Asian faculty member in electrical engineering at Stanford I believe was my student Simon Wong.

04-01:45:00
Burnett: Wow.

04-01:45:02
Oldham: I think he was the first Asian. Now if you think about in the seventies, the number of qualified Asians that were just superb, that they didn't have an Asian, it's amazing, let alone women. Now, the second I think or third at Stanford was also a Berkeley grad, Teresa Meng, so they had a woman. So we had a big role in pulling Stanford into the twentieth century. [laughter]

04-01:45:32
Burnett: You know, there's always work to be done and there is—there's diversity and inclusion along certain axes, right, and so there's—sort of the Asian numbers increase earlier, right? And Asian and South Asian, there's fairly strong representation earlier on, and now it's quite significant. But I think that the gender thing was a bit trickier for a number of cultural reasons not necessarily to do with discrimination—not with someone consciously saying, "I'm not going to admit this person," but about a pipeline, about who gets to the point where they apply to the engineering school. I think that's something that people didn't really begin to confront until after this period. But it just noted that there were a number of women in key positions operating the laboratory, making it function, and being a part of that community.

04-01:46:45
Oldham: See, MIT had Millie Dresselhaus, and she was—and Millie is dead now. So she was from the Ernie Kuh generation, so she was very prominent. She was I think in materials science, physics, and EE. So they did have a very prominent woman faculty member at MIT a long time ago, a long time ago before we did. Hmm, we had Sue Graham in computer science.

04-01:47:19
Burnett: Oh, she was the first I think—

04-01:47:22
Oldham: Yeah, she—yeah—

04-01:47:22
Burnett: —yeah, '69 or—

04-01:47:24
Oldham: —I'm trying to think of—

04-01:47:23
Burnett: —something like that.

04-01:47:24
Oldham: —someone before that. In my era, I don't think we had any other women, and after that, we started one by one hiring women, uh—I'm trying to think. But now since I had retired in 2003, just spectacular results in hiring women. So I don't know, we're still probably only 10 percent women or something in EE, I don't know what it is. But in the new hires, I think it's pretty good, I think it's maybe 20 or 30 percent or something, I don't know, I don't know the numbers, but it's impressive, and the things they do are just like mind-boggling, so.

04-01:48:10
Burnett: I didn't mean to go off the plan here, but I think that there's one question I did have to return—I'm just going to return us a bit to the seventies. There's this paper about VLSI [very large-scale integration] that was I curious about. There's a couple of papers from the seventies I'd like to ask about, and this is part of that modeling project. First of all, just to briefly explain VLSI and

then—and talk about what that paper did, and this is again those key students that you were working with in the beginning and Andy Neureuther as well if can explain that, the importance of that paper it seems?

04-01:49:09
Oldham: Well, we had two papers, the two papers about two years apart on SAMPLE, that were based around SAMPLE, this program which would—you could in principle design your process with this program, and you could figure out what you're going to get. And you use SUPREM to get the junction depth and all that kind of stuff, and you use our program to get the structures, the physical structures and what the cross-sections look like. The first one was that—was given at a conference and then published in—it was—actually, it's funny the IEEE published it in two different journals the same paper. I don't understand that, but that whole conference is published in the journal in integrated circuits and the journal in electronic devices, their journals, so it was in two journals.

04-01:50:23
The VLSI, SAMPLE something VLSI, the first one's on lithography basically on modeling lithography, and that was Sharad and Mike O'Toole and Andy and myself and there may have been one other person in that paper. And the second paper, we—by then, we had the etching working, and what else do we have in the second paper? I forgot.

04-01:50:56
Burnett: I just wanted to check that that was part of that, that whole group and that whole research endeavor and it's one of the big ones was that—

04-01:51:05
Oldham: That was the central thing that binds it all together, but there were two papers on the—sort of on, here's the program, here are some examples of what it does, and then there's a slough of other papers on the details like how do you model plasma etching, how do you—? So the student and their advisor or advisors would publish that and then they publish another one on the different aspect of the processing, yeah.

04-01:51:39
Burnett: And I just had one question about back in the seventies, a paper you wrote for *Scientific American* after your time at Intel. How did that come about, and that was kind of foray into a larger public [venue]?

04-01:51:55
Oldham: Well, it was fun because *Scientific American* was then quite a different thing than it is today. It was sort of the—I wouldn't call it popular science but a high-quality introduction to science for the layman, and they picked prominent people to do it. So, in those days, it's an honor to be an author in *Scientific American* in the seventies. So yeah, so how that happened, why me? Well, I'm pretty sure that the editors approached Gordon and said, "Okay—" Because Intel was like the star company then and approached Gordon, "Oh,

okay, who's the right person to do this or that?" Dave Hodges did the article on memories in that same issue; I believe Dave Hodges did the article on memories. By the way, I did some of the pictures for his article.

04-01:52:59
Burnett: Oh, did you?

04-01:53:00
Oldham: Yeah. Because I just took some chips we did and made some cool stuff for him, but anyway. And then so I think Gordon said, "Oh, well your guy is Oldham for [explaining] about how you make chips." That's what my thing was, how do you explain to a kindergarten class how you make chips. And so that was fun, and they gave me a thousand dollars. I never was paid a thousand dollars before. Of course, it's twenty cents an hour, but it doesn't matter.

04-01:53:34
Burnett: Yeah, of course. [laughter]

04-01:53:37
Oldham: And I submitted. I had a beautiful picture of a plasma etcher. In a plasma etcher, you have this plasma and you have these wafers, and I had a really good picture. I was kind of amateur photographer too, one of my things then. I had this great picture, and I submitted that hoping to get the cover. What I really wanted was the cover of *Scientific American*, but I didn't get it, [laughs] I didn't get it. They didn't use the picture but I—

04-01:54:08
Burnett: Semiconductor manufacturing is—it's very complex, but it's really interesting and it is—it can be visualized, and it's beautiful. And this was the interesting thing about that article is that you do peel the curtain back, and you're introduced to this world that becomes a real world-changer, but something that's in the background. We have devices running in this camera right now, on our phones, in our watch, or whatever. It was a really interesting contribution to the public understanding of science, and that's an interesting marker for you that you're at Intel, you're absorbing and bringing these questions back to Berkeley, but you are also now an established authority on semiconductor manufacturing and all of the engineering that goes on and around that. I think that's an interesting milestone in your career, in addition to the other awards that you're given later.

04-01:55:33
Oldham: Yeah, no, I agree, I was very pleased to do that even though it's some work to do it.

04-01:55:39
Burnett: Yeah, I bet.

04-01:55:39
Oldham: You get a thousand bucks but no, no doubt, it's great. I think I had a greater challenge a few years later when I was asked to be the speaker at—there's an—every summer, maybe you know about it, you're a Cal guy. You know about Cal Camp at—up in the Sierra? There's a summer camp that you can take your kids to, you know, about Cal Camp?

04-01:56:14
Burnett: No, but I know about that there's other things aside from that but, yeah, no.

04-01:56:19
Oldham: Well, Cal Camp is a bunch of cabins out in the woods and so all Cal alum are eligible to come, and so every summer these people come and every summer, they come back because you get to know the people in this tent, and you say, "I'm coming back week six, you make sure you come back." And you get together, and you drink every night and then the kids go down to the pool and play or go over to the lake. Anyway, so one year somehow or other, I got asked to be the speaker and they have—they invite you to come, and they're going to give you a tent free. It's 600-bucks-worth of free or something, whatever, it is. And you come and you can stay in the dirt with everybody else and then you—one night over a fire, over a fire side, they have a fire there, and there's these bleachers, and people sit around, a few people, maybe a hundred people will come into that, the chat.

04-01:57:15
So I was invited to give a talk about your research and so my idea was to explain to people over a fire side how—what's an integrated circuit. That was the bigger challenge.

04-01:57:29
Burnett: That's great.

04-01:57:29
Oldham: That's very interesting.

04-01:57:30
Burnett: It's a very vivid image, actually.

04-01:57:33
Oldham: And it was fun because you think about it, and the analog I used, of course, was if you're going to—if you had a chance to build a new city, not how cities are actually built, but you say, "Okay, I'm going to build a city for a hundred thousand people, how do you do it? Well, you come in and you dig it up, and you put a bunch of pipes down, and then you cover them, and then you put some more pipes and some electricity down and then you do this. And then you bring those up where you need them and then you have sewers and all that and then you build this infrastructure up, right, and then you connect this to all these buildings." I said, "Well that's what we do in an integrated circuit" and so I used that analog to try and get people to visualize what a chip really is. It's just a bunch if interconnected devices, right? So that was—

04-01:58:24
Burnett: Built in layers.

04-01:58:24
Oldham: In layers, and it's built in layers. And in a chip, you don't go back and dig it up and ruin the other layers. In a city, that's what you'd do, [laughter] anyway,

04-01:58:38
Burnett: That's very true.

04-01:58:38
Oldham: That was a more challenging way to do it. In *Scientific American,* you can have diagrams.

04-01:58:45
Burnett: Right, right, right.

04-01:58:47
Oldham: You don't have a projector in the—at the campfire.

04-01:58:51
Burnett: Right. Well, maybe we should pause for now, and we'll come back next time and—

04-01:58:55
Oldham: Oh, it's three o'clock? Good. Okay.

Interview 5: September 17, 2021

05-00:00:24
Burnett: This is Paul Burnett interviewing Bill Oldham for the University History series, and this is session number five, and it's the 17 of September, 2021, and we're in here in Oakland, California. Welcome back, and the last time, we were talking about the two major topics: The development of a research program with Andy Neureuther and a number of graduate students around the computer modeling of fabrication processes of microchips. And the other piece of that was your supervision of the design and construction of the new Microlab at EECS, the electrical engineering department at Berkeley, that came online in early '84 and the administration of that and what it became down the road.

05-00:01:41
Before we go further though, I think it might be interesting to talk about some of the range of problems that you were working on with your students with respect to modeling. I think last time we talked about there were different things that you can account for when you're developing a model for processes. Are there particular projects that we haven't talked about that stand out in your mind as interesting problems to do with modeling microchip fabrication?

05-00:02:20
Oldham: I don't know where to go with that question except to add perhaps a little bit that—and I think we said this a little bit before, in that the kinds of things we were doing was not just modeling what is done in industry, not just trying to get equations for the things that they were doing without equations, but we were, yes, inventing at the same time. Let me contrast this to make it clearer with the manufacturing people. As I've said, Dave Hodges had started this manufacturing program and continued with Costas Spanos. Well, Spanos, in particular, did some invention there, but in general, they were trying to—trying—I would say it was a big data program before big data was identified in that they were trying to say, "Okay, here's what's going on, let's see what's going on, look at it from the actual facts, and maybe then there's ways to improve it." And, of course, it was very productive as big data programs are today. Whereas we were tending to try to—especially to modify process, invent them, not so much—*invent* is too strong a word but to—

05-00:04:04
Burnett: Innovate.

05-00:04:06
Oldham: Yeah, innovate and then at the same time, do this in a way that it was modellable, and you could simulate it on a computer, so you could do the full design on the computer before you had to run it in the lab. And an example of that, the best example of that I think is in our work was this. We got involved in this modeling and simulation of a very simple process, oxidation. Oxidation of silicon was the key. That's why silicon is still this—the semiconductor

today because it has this—you can put in oxygen or steam and grow an oxide on it, and it has a very electronically quality interface between these two materials.

05-00:05:03

And otherwise the interface, if you just take raw silicon and like cleave it, it's hopeless electronically. It ruins the properties of the material, just the fact that there's a naked interface, whereas the alternative is so-called passivated by the oxide. So it seemed like a simple thing, and from the beginning, silicon oxides were used and then MOS transistors were possible because of this fine interface and so on. But it turns out there's a lot of ways to do this, and they all had different properties and in particular when you considered their third dimension. When you grow silicon, there's a stress because the—if you think about it, you've got two solids: you've got a silicon solid and you've got an oxide solid, and you're growing this oxide solid, but the volume at the interface is expanding. Maybe oxygen comes down to the interface, oxidizes a piece of silicon, and that has to move out, and there's stresses involved, and it creates and actually can damage the silicon when you consider the third dimension. And so we got into that much later this later student about, oh, I don't know, five years into this period, Pantas Sutardja, and his thesis was really that, modeling that very thing. We did that with finite-element methods, to predict what the geometries were and what the stresses were, which determines electronic properties.

05-00:06:54

But at that time, we were interested in the geometries and how do you do it. There's a lot of ways to do it, and in particular, you can mask oxidation with silicon nitride, and this chap, Else Kooi had invented this, and I think they probably had patents on it at Philips. And Kooi came to California and worked in the Valley for Philips Semiconductor and so we got to know him, and he was a great friend later on, and so on, very interesting, a very nice chap and we got into that. And then I had a student, well, T.Y. Chiu who said, "Oh, I'm going to make silicon nitride by implanting—" This was his idea, and he was going to make this happen, it was a wonderful thing. And so he's going to implant nitrogen into silicon and going to make nitride that way, and that way, it's not like depositing on the surface. There's nothing in between them; it's a really intimate connection when you do this. And so that had a whole bunch of interesting proprieties and that got us looking in too and then other students came along, this chap John Hui and a couple of others looking at different ways to make what you call local oxidation of silicon by masking the oxidation process. And that became a whole theme and that—we had a process, which was invented in there in the midst of that which actually became—I forget which companies used that process. We called it SILO.

05-00:09:01
Burnett: Oh, is this silation?

05-00:09:03
Oldham: No.

05-00:09:03
Burnett: Okay, it's a different thing.

05-00:09:05
Oldham: No, we called the process SILO, and SILO, of course one of these acronyms, I don't know. I is for interface, and I don't know, I don't remember. But it was one of the processes for doing local oxidation and getting the profiles you want. So in the process of modeling, you sometimes improve processes or invent new ones. As I say, *invent* is maybe the word or maybe it's just improve, but we came up with this process, which was used. And that work on local oxidation brought us a lot of attention around the community of Japan, the US. The action was pretty much in Japan and the US in new processes in the eighties. And so the group was well known, and we used to get—the way to tell is how many times you get invited to do this or that, that kind of thing.

05-00:10:26
So yeah. So the modeling work is this interesting mix. Once you dig into something, I don't care if you're building an engine, to use an engine analog. If you're building an engine, you really get into trying to understand it. Guess what, you invent new ways to improve that engine in trying to understand the old one and say, "Wait a minute, I never knew this was doing—I don't want that to happen" and then you find a way to make that not happen and then you've got a better engine. So the process is like that and very fun for nerds, rewarding for nerds—[laughter] to find a problem and solve it and improve it.

05-00:11:15
Burnett: I was thinking yesterday about how to talk about your passion for cars, and to ask you what really gets you going with respect to cars, is it the admiration for the original design. Do you want to opt to respect the elegance of the original design, or is it, as you say, going in, realizing as you get into the details, that it could be better and further optimizing it? Is that the passion for you whether it's cars or engineering?

05-00:12:00
Oldham: I don't know. I'll say this, if you think of somebody who's a model railroad hobbyist—and there's a lot of people who do that, and some of them in a very big way—it's the building of the model railroad and putting those buildings up that looked proper, and maybe it's a building of that steam engine that you do to make a miniature of a train engine. That's where the fun is. It's not once you got it running. For me, I've never been to a racetrack, I mean I've been on a race track with Porsche at an event where we were allowed to make a few laps, but I've never been to a car race, and it's very funny. So the running of the car is—well, we do that, we take tours, but that's not the fun. The fun is making it work, understanding how it works, and making a little bit better. And that's where the fun is for us, speaking for nerds in general. [laughter]

05-00:13:14
Burnett: Well, I mean *tinkering* is a word that gets bandied about, but it's almost a pejorative term, I'm a tinkerer. But it is this incremental innovation that ends up being really crucial, right? Here you are at the beginning of your career; you are involved in this stepwise innovation. When I say that, I mean it's going from vacuum tubes to solid-state electronics. It's a categorical shift in devices that has all kinds of implications that we don't need to elaborate on. But often what you're passionate about, it seems, is this interest in the choice of materials, the experimentation to see what might work a little bit better and this kind of optimization work that is—is that a fair characterization or is it—you're interested in a whole bunch of different aspects of engineering?

05-00:14:27
Oldham: I think it's a fair characterization. I would say that if you do look at a very—what appears to be a very simple process and then you challenge yourself to understand it so well that you can do it on a computer and get the same result, you discover things about it. What was a very simple process, you discover a bunch of things that you never knew what's going on and then that leads to obvious ways to improve the process. And it's really that going in one step deeper, and again for people who are not electronics or aren't materials people, again, you think of the engine. It's obvious how car engines work, you put some gas and some—and there's an explosion, and it pushes the piston and all of that. Well, when you go in and then you start to look at how that flame front propagates, and you try and model that and you say, "Wait a minute, why is this shape like that?" Suddenly, you get a different shape and then you get the Honda CVCC engine because they went in and really tried to figure out what was actually happening in there. And so this is the process.

05-00:16:01
Now, we didn't think of that as a model for research and then say, "Let's go do that to semiconductors." We just said, "Let's just go play with semiconductors and have some fun," but it's—in retrospect that's what we were doing. We were taking apart the details of the process, understanding them, and in the process, you find out things, which—you just find things which surprise you, and therefore, you are able to make innovations.

05-00:16:33
Burnett: Modeling is often characterized as an oversimplification in order to visualize better and to see better what's going on, so. But the irony is that the simplification reveals complexity.

05-00:16:51
Oldham: That's right.

05-00:16:54
Burnett: And you see, oh, no, I did not include this in the model, this is actually—and it—by accounting for the visible things, you reveal the invisible, the unintended, the unanticipated, and it becomes legible, and then you can zero in on it and work on that.

05-00:17:16
Oldham: Yeah, and often improve it.

05-00:17:17
Burnett: And often improve it, yeah, and incorporate it into the model. Now, you've got a bigger model and a better model.

05-00:17:22
Oldham: Yeah.

05-00:17:23
Burnett: Well, I started to talk a little bit about engineers as people and what makes them tick by talking about you as an example, but that's just—that's one perspective. But you observed dozens of engineers up close, each one of them different, each one of them with different backgrounds, different personalities. Can you talk a little bit about some of the other qualities of the accomplished engineers that you appreciated that were different from you obviously but that had particular personality traits or qualities that made them really uniquely adapted to the work that they were doing? And you mentioned someone last session who was so meticulous for example, and you said, you need that for someone who is doing I guess modeling, I can't remember what it was specifically, but you need someone who is meticulous to do that type of work well and they need to be on your team, right? Can you talk a little bit about the range of skill sets that engineers need to have to do this kind of work that you were doing in the eighties and students whose names pop up that make you think, oh yeah, that person was really good at this and that's—that complemented the work well?

05-00:18:51
Oldham: I haven't thought about this deeply enough to say anything very coherent about it except to agree with you that different folks have different skill sets, and having a variety of skill sets is really, really good. You can solve a problem in many different ways, but if you have a whole bunch of different people working on it on different ways, you can probably solve it better and faster. But all this is observed in retrospect. I wish I had been so smart as to figure these things out and say, "I need this type of person and that type of person and I'll throw those three together in a group." I mean whether I was at Intel trying to get a group together to do something or at Berkeley, we weren't doing that. We were just taking what comes along and say, "Hey, why don't you work on this?" and then sometimes they worked.

05-00:20:00
We were talking about yesterday about diversity, and I was thinking, why didn't I have more women for instance? I had Americans and Asians and so on but I never—and I did have a large number of women master's students, and I failed in getting them to stay on and do a PhD. So, actually, I failed there. I think one of the things we found out is that you really should figure out what makes women comfortable or uncomfortable and pay attention to that and then you might get them to do these technical things. Women avoid technical

things in America, let's say very broad and general thing. Far less true today than twenty-five years ago.

05-00:21:11

I remember talking with—what's her name from MIT we've talked about yesterday—Millie Dresselhaus, who was this super prominent, brilliant faculty member. I think she was the thesis advisor of Bob Broderson, one of our prominent faculty members. Talking to her about that when she has a woman working for her, her goal is to get that woman—well almost on a guilt trip that she owes it to become a teacher to get more women involved.

05-00:21:51

I had one or two women working for me at the time, but as a man, I was never able to get myself in that position where I could get these brilliant women on a guilt trip that, yes, you need to get your PhD and you need to become a teacher. That's how we get women into this field where they can contribute so much, and it's good for womankind that that's available to them, right? And so I was unsuccessful at that. Just thinking back, I had half a dozen women, master's degrees, only one went on to her PhD, and I deliberately moved that person to another faculty member, a close colleague who then supervised her PhD. This idea of recognizing different skills and personalities and what drives people and then using that information to make them more effective. Only when you get very old and you're not doing this anymore that you understand that you should've done that. [laughs] It's the rare faculty member who optimizes the problem to the student.

05-00:23:15
Burnett: Right, or there were—it was later than this period in the eighties when institutions began to face the problem of actually gathering information about and figuring out what the pipeline was. NSF [The National Science Foundation], with its ADVANCE program, funding research into why are women somehow shepherded out of STEM fields [and to develop and test strategies to increase participation and retention of women in STEM]. They drop out at these rates, and is it the larger society, is it the deeper, cultural thing, or are there specific things that are happening in the schools at every level that weed women out because they don't feel comfortable, they don't feel like there's a place for them, or their needs aren't recognized and accommodated? That's begun to change, happily.

05-00:24:14
Oldham: Oh, yes.

05-00:24:15
Burnett: It hadn't really reached that point. It was such a male field. I mean I remember when I was in college in the—at the end of the eighties, engineering was—people shied away from it because it had this gender—bad gender reputation that it was this uncomfortable place for women to be, kind of almost like a macho—I mean this is not at Cal, this was in other schools, in Canada, in fact.

But that was the reputation, and it's taken a long time in the broader culture to recognize that there's a cultural problem with making space that is welcoming for women in STEM, but it's beginning to happen now.

05-00:25:13

The other problem is that it's difficult to have a taxonomy of the talented x, those—all those self-help books for this is how Steve Jobs did it, and it's not necessarily the—what you realize is that extraordinary achievements are often the result of this happenstance. And I think that's what you said effectively is that these great people came together at this time when this money was available, and this set of decisions was made by the administration and by the department, and it took off. I think what you have said though in your statements in the last sessions is that you have these contacts, you have sought out work in other—in industry, at other universities, at Bell Labs, and you knew people from these different domains, and you were able to plug students in, is that fair thing to say?

05-00:26:24
Oldham: Oh, yes.

05-00:26:24
Burnett: It's a network, it's a network of people?

05-00:26:28
Oldham: Yes.

05-00:26:34
Burnett: It's clearly an extraordinary time. You graduated a number of PhDs, sometimes multiple PhDs in a single year, and it was an enormously productive. Were there other fellows or professors from other universities, other faculty, and other universities who were coming to visit and working on this? As you said, you became known, this program became known as a place where this work on oxidation, for example, was happening. Were there partner programs in other universities that you deve—? You said the Japanese were working on this as well.

05-00:27:23
Oldham: Yes, so the answer is, of course, yes. It's interesting, we—unlike our colleagues in, say, chemistry, we never used postdocs in the period prior to, say, 1980 in electrical engineering. Maybe there were a couple around, but it's very, very rare. In engineering, you went through school, you got your master's or your PhD, you went out, and you had a job. You weren't an intern or some low-level flunkie. You had a job even as a BS. My daughter got her bachelor's degree in engineering and then she went out and took a job and was working in a factory as an engineer. Whereas, if you do that in biology, a bachelor's degree, you're going to be a lab technician, and you get a PhD, you're not going to go get a job, you're going to do a postdoc for five years or ten years.

05-00:28:38
Burnett: You still might be a lab technician.

05-00:28:41
Oldham: We never used postdocs and then, in this period, we started getting requests. We got a request from a prominent professor at—in Israel to send this fellow, Yosi Shacham-Diamand, and that's how this—I think I wrote in my notes here, he came here in this period around '84 or '83, '84. He came to Berkeley as a—well, he was a professor there, so we made him some kind of acting assistant professor, we found some title. I don't think we called him postdoc, but he was—essentially came as a postdoc and working with our group. So the way you use a postdoc is you bring in, and you fill a hole, and sometimes the hole is in managing a few students, and sometimes a hole is doing some piece of research you don't have the student to do right now, that's how. And so we brought Yosi in, and he was a man of many skills. And he stayed here, I don't know, I was trying to figure out, I can't figure out. I go through the papers I have, I can't figure out. He must have stayed here four, five years and did any number of joint papers with myself and Andy Neureuther and our students on this research.

05-00:30:12

And on one sabbatical, he covered for me, and that was our first experience, and that was so good that we got—somehow, I don't remember if we recruited or if we were recruited. We brought another postdoc in named Chris Spence who again was just this terrific person who was from England and—where they didn't have the kind of operation going we did where you have a facility and a bunch of people, I mean hundreds of people working in the facility doing interesting things, and you can go into this milieu and find stuff to do. And Chris came here, and of course, he prospered well and then eventually, he never went back to England. He stayed on and has—today works for this company ASML but went—worked for a couple of different companies after he left Berkeley.

05-00:31:17

Yes, so you get these people coming in. So these programs, once they get going and it's successful attract the people you want to work with and stuff and the students too. Like I think I said once before, if you get the best student in from National Taiwan, he writes to his buddies back there and then you get the next year's best student. And so we were fortunate to do that for several years, so several of these students whose names are on here were the best student in National Taiwan University. So that means they worked very hard to do that; it was very competitive. Japan ceased about that time to send people. I don't know what happened, I never quite understood it, but somehow, it was no longer that great on your resume in Japan to have done your work in the US, I mean because they had great universities there too, and their universities gradually moved into this field. They were not so much in microelectronics in engineering until this period when electronics boomed in

Japan. I mean it was a very short burst where Japan, sort of, took over the microelectronics area and then lost it.

05-00:32:57

In 19—say—75, Intel was the only one doing much in memories. They dominated that, and there was a couple of other companies. There's like three or four other companies in the US trying to do memories, and Japan made the big effort. Well, I remember, I don't know which year it was, but sometime in the eighties DRAM became a very big thing because the IBM PC had come out and so every PC needed memory, and then all the big computers needed memory and so there was a huge market for what we called DRAM, dynamic memory, and so that was a big business. It had already become a commodity business, but there were thirteen major manufacturers of DRAM at that point. This is probably 1988 or something like that. Thirteen major manufacturers of DRAM in the world: ten of them were in Japan, only three were left in the US.

05-00:34:13
Burnett: By which date, I'm sorry?

05-00:34:14
Oldham: In the late eighties.

05-00:34:15
Burnett: Late eighties.

05-00:34:15
Oldham: I don't know when that was. Okay, then you fast-forward to year 2005, there's no DRAM manufacturer anymore in Japan. There's still a couple of DRAM manufacturers in the US, but it's run mostly in Taiwan and then Samsung came long in Korea, and Hynix, these two big companies, so it's very interesting. So by then, there were very prominent researchers in Japan in semiconductors. We had close contact with over the years of the eighties with these guys, they're fun guys, and we used to have this conference in Hawaii every one or two years, and that was sort of halfway.

05-00:35:11
Burnett: Right.

05-00:35:11
Oldham: It was very cold and so we would meet in Hawaii and—

05-00:35:15
Burnett: Is that your introduction to Hawaii as a place?

05-00:35:19
Oldham: It is absolutely, I never had any interest in Hawaii. I said, "Why would anybody to go to Hawaii?"

05-00:35:24
Burnett: And then you learned.

05-00:35:25
Oldham: When I was a graduate student, I got a letter from the University of Hawaii, "Well, we're trying to get into electronics, would you come and talk to us about this?" And I said, why, what the hell, that's—I'm not going to go lie on the beach, and I threw the letter away, I never even considered it. [laughs] And then in 1980, I was at a conference there, and this fellow, Walt Kosonocky from RCA, organized this as a subcommittee of IEEE, ordered this conference half-Japanese, half-Americans, and I went there, and I said—you get up in the morning, at 6:00 in the morning, you go out in the surf, and you swim and you—then you come in, and you go to the conference all day, and then in the afternoon, you go out, and it's gorgeous, and there was wind surfing, and I said, "What was I thinking?" [laughter] And ever since then, I never missed a year in Hawaii, going there.

05-00:36:32
But anyway, so the industry—part of that was very interesting how fast the industry came up and died in Japan as a commodity business, the commodity business and the way they support that. We talked a little bit already, the way they support their industries with the government, the large industries in Japan, the way they have these subsidiaries that they support, and so on. And then it was perfected in Korea.

05-00:37:12
Burnett: I was going to say, because MITI, the Ministry of International Trade and Industry in Japan, begins to lose its control inside Japan in the late seventies or right around the time that you're saying this shift happens. The second thing that happens is the United States imposes a lot of trade punishments on Japan for its perceived sneaky dominance of this, seizing control of this market. And they have to agree to have 20 percent of their domestic market made up of foreign chip manufacturers, and that breaks the control of MITI. And at that same moment, export-led growth becomes this model for the other Asian countries, especially Taiwan and especially South Korea. And they become that model that everyone talks about later where there is this concerted, coordinated approach to target specific industries supported by this government, supported by major industry and over the long term. I don't know if you have any answer to this, but I wonder if the students coming from Taiwan was not just word of mouth, but it was part of a program in Taiwan to develop talent that would then be used to produce a domestic semiconductor industry in Taiwan.

05-00:38:59
Oldham: What makes me think it's not so directed is the fact that almost every one of them stayed here. Very few went back until the nineties, when the company started there. And like T.Y. Chiu and Mark Liu, they both worked for—well T.Y. worked for Bell Labs, IBM initially then Bell Labs and then Mark Liu worked for Intel. And today, Mark Liu is the chairman of the board of a company, which is competitive with Intel in the number of chips they make and totally dominates the market, Intel claims they want to get into, which is

the foundry work, so it's' very interesting, and he was an employee at Intel. A little oversimplification, the way I see it, the way these students saw this is there's no glass ceiling in Taiwan for Chinese. There's no glass ceiling there, and there certainly was in the US, at certain places, not so much in California. In California, you saw the Asians being very successful of going up through management, maybe not as easy as a non-Asian, but in the East Coast and the Bell Labs of the world, there was nobody above a department head that was an Asian. It's very interesting. So they all eventually went back, and that really made a lot of people mad. I know people at Bell who felt that they were robbed by these people. They came in, and they learned the technology, and then they left, but guess what, they left to be CEOs and so on, you know?

05-00:41:03
Oldham: You can't fault that.

05-00:41:03
Burnett: No.

05-00:41:05
Oldham: But another interesting thing about the growth of the Asian industry, which while we're talking about that, it's a little off the topic, but what I saw is that the universities and the companies there have an infinite supply of very eager, hardworking students. Whereas in the US, we have to import half of the people who were doing this work, which made the US business were first-generation Americans. They came from all over the world, I mean eastern Europe, Iran, a lot of great students like Reza Kazerounian. Our department head when I came to Berkeley, Lotfi Zadeh, these people were Iranian. So we imported these people because we didn't have enough here that had this set of characteristics that make you want to work that hard as a student and then go in to do this stuff, right?

05-00:42:25
Burnett: Yeah.

05-00:42:25
Oldham: And there's infinite supply in the east—you know?

05-00:42:30
Burnett: It is this globalization of the education market, which happens earlier on in engineering than in other places, right? And you see that, that pattern, and, yes, we do have a pipeline problem of getting people from the K–12 space in the United States to go to college in the STEM fields.

05-00:42:52
Oldham: Yes, and no problem bringing in people from outside, no problem. There are lots of people eager, especially India, and India never still to this date has developed an industry of its own. My analysis of that is they unfortunately learned to do well—too well from the British how to make bureaucracies that

don't focus on what they're supposed to do. They focus on the procedures rather than—

05-00:43:26
Burnett: And the turf.

05-00:43:29
Oldham: —because they are the masters of bureaucracy, and they have the world's largest well-educated set of people that they could use and, to be successful, they have to come to the United States. Anyway, of course, we benefit.

05-00:43:51
Burnett: Yes.

05-00:43:54
Oldham: Sanjay Mehrotra, okay. I don't know if he was first generation or not, I don't remember where. My guess is his parents came to the US, but I don't know, I have to ask Sanjay.

05-00:44:07
Burnett: Right. The semiconductor industry is becoming a global industry. There's this circulation of knowledge, technology, but most of all, people, and that begins to shape the semiconductor industry as it begins to move offshore. And it's in the late eighties, early nineties where you see the offshoring really starting to take place. And Taiwan is the first major foundry outside of the US, would you say, Taiwan Semiconductor?

05-00:44:46
Oldham: Yes, the first foundries were I think probably TSMC [Taiwan Semiconductor Manufacturing Company, founded 1987] and UMC [United Microelectronics Corporation, founded 1980] in Taiwan. I don't know if there were any big foundries before. What's his name, the fellow from TI [who started TSMC]—[Morris] Chang? I'm thinking Chang. The founder of TSMC was probably Taiwanese [Chinese American] working at TI, was a big executive at TI, and then he saw this opportunity, but he started in Taiwan this foundry. Certainly, he was one of the first, if not the first foundry, and then UMC followed and then a whole bunch. Yeah, and—

05-00:45:44
Burnett: There's a couple of strings that I'd like to pick up on at this point, and one is this collaboration with Chris Spence, who I understand was a postdoc. He came around in the 1990 period.

05-00:46:01
Oldham: Yes, around 1990, so it's a little bit later but we were still very—we had the lab then that we were very heavily involved in, Andy and me. And we had our first crop of students already out, and we were going on with other subtopics in this field.

05-00:46:22
Burnett: And did you work with him to develop a new process for silicon?

05-00:46:30
Oldham: I don't know—I would have to—

05-00:46:31
Burnett: Or maybe I'm misinterpreting it, that this cooking process where you expose a resist to a monomer—

05-00:46:40
Oldham: Oh, we did some resist work with Chris. Chris was a very well—he must have been a Cambridge guy—he was very well broadly educated guy and so he could jump in and do optics, and he could do photoresist work and so on, and he did them all. I had a collaboration with John Bruning who was the CEO of an optics company, and he gave us—I think I mentioned before. First of all, he gave us a lens for 193 lithography and then—no, he—I purchased that because we had the laser, and that's the laser we lined out. He suggested this fifth-harmonic work and gave us a lens for the fifth-harmonic work. So when Chris came in, he got involved in trying to put together that tool, which was kind of difficult, and it was very difficult to do this. We didn't have the kind of resources to build a—it's like a mechanical—mostly mechanical and detector resources to put together essentially a stepper. And a stepper is a several-hundred-thousand-dollar gadget because of the complexity, you have to do all these motions with precision. So we were doing this sort of on the cheap, and that was difficult, and Chris worked on that a lot, and then he was involved in a lot of the resist work. We're doing a lot of different kind of resist work. I don't know some with—he probably worked with Andy on some things and me with some things. I would have to look back to the publications and see which ones he was on, but he was a very flexible guy, and he could do anything and worked very well with the students, just such a good—effective with that. So, again, he would cover for Andy or I if you needed some coverage on something, and I don't think he taught a class here. He certainly could've, but I don't think we ever had him propose and have him teach a class.

05-00:49:27
Burnett: So you had a visiting professor in the mid-eighties, Yosi Shacham-Diamand, and Chris Spence who was a postdoc, and the first postdoc effectively as part of that team. And as you mentioned, postdoc-ing was not a thing much until that time, and it marks a kind of transition point in the history of engineering. And I wanted to ask about that actually because in talking to a number of engineers in different universities, one of the things that comes up in recent decades is this dissolving boundary between engineering and the natural sciences, right? That the stereotype of engineering in the—say the fifties, maybe even earlier was that it's the applications people. They take the physical—the innovation of research and the physical sciences, and they take those principles and apply them to make things that are needed in the world.

And I'm wondering if you could talk a little bit about your experience with the image of the engineer and what's actually happening in EECS in the decades that you were there that respond to that notion of dissolving boundaries between engineering and science?

05-00:51:04
Oldham: I don't have, well, anything very profound to say about that. It certainly happened, and probably the best examples were not in my field, they were in bio, what we called bioengineering, which came about in this very same period, bioengineering. I think the leadership in that was probably—at Berkeley was in mechanical engineering, and several of those people took on projects because things like bones, okay, so breaking bones. Well, mechanical engineers know a lot about the forces and all that stuff, and the material scientists know a lot about the materials, and the doctors who were involved in that kind of stuff, they just fixed it. They had procedures, which there was no science based in their procedures; they had mechanical procedures that seem to work. And so then, they eventually called themselves bioengineers and got involved.

05-00:52:22
A classic case in again, I believe, it was mechanical engineering [chemical engineering as well] was that—with the optometrist—an optometrist was kind of a low-class ophthalmologist, and that was a full MD, optometrists had a degree. They called themselves doctors, but they were only working on the eyes, and so they got involved in this. When contact lenses came along, it was just because of a wonderful set of problems, and the mechanical engineers here got into that in oxygen transpiration through the lens and all that stuff. That was done jointly. So that work led to—and some others led to this idea of we've got to have bioengineering, and eventually, we did get a department here. That took a long, long, long time to get a department of bioengineering, and we had—several of our faculty were involved with that, Tom Budinger and so on. And, yeah, so that was the best case where you had this kind of continuum between science and engineering, and you could work anywhere on that continuum. I forget how we got on to this discussion—

05-00:54:05
Burnett: Well, so we've talked about your interest in materials, right, and materials science effectively. So that's chemistry and physics and all of—it's—so you're not just necessarily reading—this is a question, but you're not just necessarily reading engineering journals only, like you might venture into chemistry or physics journals to do research? How would it work for you?

05-00:54:40
Oldham: Well, the problem, as I mentioned perhaps yesterday, I—as time went on, I found myself reading journals less and relying on my students more and relying on conferences, and so on. I was not taking half a day and going in the library and going in depth like I used to and so that was—that had some impact on my skill set in doing research and in choice of problems. But, yes, I

did have some students who did. One of my students, late students not mentioned anywhere in here, Carl Galewski, he probably didn't graduate until like the nineties. Carl and I got deeper and deeper into this epitaxy and—which has to do with how do you prepare a surface, a naked surface of silicon, what's a clean surface, how do you make it clean, how do you keep it clean? Because anytime you're in an environment, it's being bombarded with—in a vacuum, high vacuum, the surface is bombarded—every square centimeter is bombarded with like 10^{15} atoms every second. I mean you don't appreciate what—how dirty the world is if you're a clean surface, right?

05-00:56:11
Burnett: Right.

05-00:56:13
Oldham: And so I got soon into that, and that plays a role in—when you're trying to grow one material on another. So I got Galewski very interested in that, a very good student. The previous one who was way back was the first one Bob Holmstrom. I got him into doing that kind of thermodynamics, which governs what goes on on a surface and—yeah. So every now and then, we got back to that level of things, but normally, we were a couple of levels up from the fundamental science, yeah. But in the materials world, yeah, every now and then, you have to go back and that came up a lot in later—in—but more in consulting on EUV lithography with this big company, Cymer where the materials were everything, and they had no knowledge of materials in the company. So I was counseling, weighing in, and trying to get them to hire materials guys, and telling them that you got this and that.

05-00:57:25
Burnett: Right, right. Well, so let's talk about that kind of shift in the mid-eighties, a number of things are going on for you especially right in the mid-eighties. You take another fellowship year, it's a Guggenheim.

05-00:57:46
Oldham: Yes.

05-00:57:47
Burnett: Can you talk about how that came about, and what you did, where you went, and how that influenced you?

05-00:57:53
Oldham: It was funny, Andy and I were just getting this program going, and we had just finished the lab. So we had six or eight years under our belt as having a joint program and then we just had the lab and we had just run our first students through the lab and had a process and all that and so suddenly, I take off again.

05-00:58:21
Burnett: (laughs) Why—?

05-00:58:23
Oldham: But it turns out Andy took off the year before me. I believe he was in Cambridge the year before, and I was due for a sabbatical. I hadn't had a sabbatical in a long time, in fact, because when I was Intel, I didn't take a sabbatical, I took an industrial leave. So you accumulate these sabbatical years and so I said, "You know, we—" It was work very intense then and so I just said, "I'm out of here, let's take a sabbatical," and I was looking for a place and I won't go into how—anyway, but I ended up in London. I had already started, and we can talk about that, this consulting work at Chrysler but—so I was needing to come to the States pretty regularly for that. That was like four times a year, and I needed to come to Berkeley because we had this program running. Even though by then we had—I think we had Yosi there, so Yosi was covering for Andy when he was away and me when I was away, but you need to—if you got six or eight students or ten students—I don't remember you had then—you've got to be a bit here, so I would come back once a month, so I chose London. I said, "Okay, they got an airport, I can fly from London to Berkeley, bingo," and I did that, I came back ten times that year.

05-00:59:47
Burnett: Wow.

05-00:59:50
Oldham: So that actually probably was the biggest factor in the choice because I looked at South Hampton and Cambridge and this and that, and there was some wonderful places to go. Because in England, they were—they all those people wanted to have a state-of-the-art research program in semiconductors and so I was welcome anywhere but—

05-01:00:11
Burnett: So Berkeley was it? I mean I've heard that when that micro lab was built, you said that the industry pooh-poohed your lab when you were done, that it was already behind or something like that.

05-01:00:22
Oldham: Not industry, certain people. Other people appreciated it very much, some people said, "What are you guys doing? We do that, you guys teach those students and send them to us."

05-01:00:37
Burnett: In the sense that it was duplicative, it was not innovative or—?

05-01:00:41
Oldham: Well, in the sense that we couldn't possibly afford to do the kinds of things that they do, which is true, and we didn't do the kinds of things they do. But the things that we did we—I think we did better, and you needed that lab to do that. It's not fair to say that industry pooh-poohed it, certain people. You know, there are those kind of people around that are negative, basically the glass-half-empty people, they pooh-poohed it.

05-01:01:19
Burnett: Okay, so we've corrected the records, so certain people, but I've also read and heard that that was the most advanced microelectronics lab in the world at that time, at that moment.

05-01:01:33
Oldham: At a university.

05-01:01:34
Burnett: At a university.

05-01:01:37
Oldham: Possibly it was. Yeah, if you've read that, I'll accept it, but I don't know, I wouldn't say that.

05-01:01:43
Burnett: Okay.

05-01:01:44
Oldham: I mean because—

05-01:01:44
Burnett: Well, because Stanford had one or—

05-01:01:47
Oldham: Well, Stanford—

05-01:01:47
Burnett: —in MIT?

05-01:01:47
Oldham: —came later, Stanford built their—they had the individual labs at that point and they built this wonderful—what do they call it—CIS or something at Stanford. Anyway, they built a bigger and better one than ours.

05-01:02:02
Burnett: And MIT had a—?

05-01:02:03
Oldham: MIT did the same thing afterwards. They built some more common facilities, yes, later.

05-01:02:10
Burnett: So was there another university that had a—?

05-01:02:13
Oldham: You know, I don't know all universities. When I was a student at Carnegie, we had one lab that my faculty member, Milnes, Don Foyt, Angel Jordan, they all—Dick Longini, they all used that, so we had sort of a common facility, but it was like the Berkeley original one, it was just a big old room. It wasn't a so-called clean room.

05-01:02:38
Burnett: Right, purpose built.

05-01:02:40
Oldham: Yeah, so—

05-01:02:41
Burnett: And—

05-01:02:41
Oldham: —I don't know, maybe, maybe it was, but that's not important. [laughter]

05-01:02:45
Burnett: Well, it might be. Berkeley is one of the top engineering schools, electrical engineering and engineering in general in the United States, and Stanford and MIT come up as the other top ones that might be better. And they built Microlabs after Berkeley did, and they did it after in the early sixties when you built the Microlab—when Don Pederson built it, and they built [their new ones] after you and others built the Microlab in the early eighties. And you're in Silicon Valley, right, not in but—

05-01:03:28
Oldham: Well, yeah, we were close enough—

05-01:03:28
Burnett: —in close prox—

05-01:03:29
Oldham: —we were close enough.

05-01:03:29
Burnett: —yeah, close enough, exactly.

05-01:03:31
Oldham: Yeah, we were close enough.

05-01:03:31
Burnett: I think that's a plausible supposition.

05-01:03:37
Oldham: Yeah.

05-01:03:39
Burnett: Okay, but this is relevant in the sense that you're—you need to take a sabbatical, but it explains why Bill Oldham would be a good person to know if you're interested in electrical engineering and semiconductor properties, research in other universities. So wherever you landed, you would be a good person to know?

05-01:04:03
Oldham: Yes.

05-01:04:03
Burnett: Okay. So that was that fellowship year and so you were working with people. Did you have space or were you—?

05-01:04:13
Oldham: Oh, actually at University College London, that was probably, by far, my least successful sabbatical in interacting with other people. The reason I looked at UC London is because we had people that had sabbatical there before. I think Dick White had taken a sabbatical there, but—so we knew who the department head was and this and that. I didn't know anybody there myself, so when I write to them, I say, "Okay—" In those days, you used to write letters and stuff, the internet wasn't there and so you used to write a letter to people and say, "You know, I'm kind of—"

05-01:05:10
Anyway, they give you a space. I had a Guggenheim fellowship, so I didn't need any support or anything. Although the Guggenheim didn't pay very much. Guggenheim was for $5000 or $10,000, so it's really funny, not much money, but you have your sabbatical pay, and you have the Guggenheim, but they give you a space. But I never interacted and did joint research with anybody at University College London. I never found somebody who was interested in the kind of stuff I was interested in, and I hadn't paid attention to that in advance which was really stupid. But it was really handy, and life in London, I learned about life in London, I realized I don't like big cities. I knew I didn't like New York; I would never go to New York, right? I detest the big city like that and life in the big city. It's a great place to visit for the weekend, but life there is, well, a continuous hassle, and that's what it was in London. London is like living in New York. And the people, I didn't succeed in getting a going interaction with the people. So I was there and I did various things around England and the UK, and I traveled back to Berkeley every month.

05-01:06:34
Burnett: Right.

05-01:06:34
Oldham: So—

05-01:06:34
Burnett: Well that was part of it I think.

05-01:06:38
Oldham: And so, but you have a chance, you're sitting there. I believe that was the year Andy was the previous year in Cambridge and so he left. We had bought one of these luggable computers. I forget who made those.

05-01:06:52
Burnett: Oh, Osborne?

05-01:06:53
Oldham: No, Osborne was the first, but there was a later one, which ran standard IBM. It was an IBM PC clone.

05-01:07:01
Burnett: Okay, like a Compaq or something?

05-01:07:03
Oldham: I think it was Compaq. Anyway, their first one was a luggable, I mean it's about thirty pounds, you know?

05-01:07:09
Burnett: You can't call it a laptop.

05-01:07:10
Oldham: And so he left that there and he had a printer. He bought one of these little—I think HP had brought out this dot matrix printer, a little—a cute, little thing, and so I had a printer and a computer. So I just sat there most of the time doing sample stuff because I had a computer, that's all you need. And interesting year but no interaction like every other sabbatical, major interaction with the local people writing papers, interacting with the students. That didn't happen there.

05-01:07:46
Burnett: Well, you're also taking over as director of the Electronics Research Laboratory, which is the larger kind of—

05-01:07:53
Oldham: I just had done that for about a year or two and then I would do this sabbatical so that's when I got Paul Gray I believe. That was the year I got Paul Gray to substitute for me. I mean I searched around trying to find somebody who would take over that ERL directorship for a year, and Paul Gray agreed. I mean this is a—the dream to have colleagues like I had colleagues at Berkeley. So he gladly stepped in there and took that job for a year and then went out.

05-01:08:27
Burnett: There's a real sense of service at Berkley in general but in engineering especially, the sense of service to the greater good of the engineering community. That's the word I hear from multiple—not just in EECS but in other engineering science and other fields at Berkeley engineering and the college.

05-01:08:54
Oldham: Of course, that has its own rewards. I mean service has its rewards and if you—in Berkeley, the reward is, to my mind and I appreciated it already maybe not in '84 but certainly by 1990 or so when I was getting into further reaches. The rewards are you've got this incredible university full of incredible people and you—maybe in the faculty clubs for lunch, you'd bump into somebody with your tray, but you don't have any real interaction with

them. And when you do things like even as ERL director, you suddenly had contact with a bunch of people in administration, too much contact with the dean. I used to fight with Karl Pister, terrible, terrible. But you interact in a way you never did before and the—you have this rich set of people. So that was probably jumping ahead into when I got more into the senate service but—

05-01:10:05
Burnett: Well I—

05-01:10:06
Oldham: —but even then, it was—that was the advantage of being ERL director, not having money. You had to do the JSEP management, so you had to manage this big contract, which you may have one student on it or something like that, but it's for a bunch of other faculty. And that means you interact suddenly with the air force and the army because those guys—and I knew those guys because I had previous contracts with them myself when I was doing radiation effects work. But with those guys, those are interesting guys, these are the scientists at army and at air force research labs.

05-01:10:52
Burnett: This is the Joint Services—

05-01:10:54
Oldham: The Joint Services—

05-01:10:54
Burnett: —Electronics Program.

05-01:10:55
Oldham: —so that's interesting. In my mind, that was the benefit. I only understood that gradually as you get into it. You don't take the job saying, you're going to want to do that. So anyway, I had started that. I started ERL directorship, and before I took that sabbatical, that was this other factor, I had started this consulting job with Chrysler, and that was not many days, but it was intense. Maybe I should give a little background here if—because what happened is prior to that, I believe it was prior to that I was approached by Jim Meindl. Well he was the guy who built the Stanford lab.

05-01:11:57
Burnett: Okay, the other one that you—

05-01:11:59
Oldham: Yeah, the big—

05-01:12:00
Burnett: —the successor to yours.

05-01:12:01
Oldham: —CS lab. And Jim was, again, another guy you want to know, a great guy, a very knowledgeable guy, had some very famous students. He approached me and said, "Well, I've got this connection with Monsanto, that Monsanto wants to have a scientific advisory board." I had never been on a scientific advisory board. He says, "And I think you'd be a good fit." And Jim approached and asked me, and I didn't know Jim that well, so this was—the great thing about that was getting to know Jim Meindl frankly. So we started this—and the whole concept—I got the concept that these companies need outside review, they really—otherwise companies get all ingrown and make all the same mistakes. Detroit, think of Detroit, they get all ingrown and don't talk outside and so I said, "Sure." So they're going to pay you money, and you go there and listen to what they're doing and then you react to it," right?

05-01:13:20
Oldham: That's really the job. We did some of that too, reviewing other universities, and we'd have people come and review us. I had done that a couple of Cal campuses, but anyway, that got me into that concept and then I did that with a number of other companies. That was a great job, by the way, the Monsanto one because it turns out it involved two things. Monsanto is a very high-class chemical company at the time. I didn't know when I took the job that they were going to go into GMOs, I didn't know that. They made silicon, they made silicon wafers, strangely enough, they had that business, and they made photoresist. They had two businesses, which were important to us and so probably more than half the time we did our reviews, we talked about those things, and it was very good. They were good people, and they needed our guidance so that was good, and I learned a lot. You learned a lot about the realities of like this thing about making silicon ingots, and I was just a user, so I learned about how you make them and what the trade-offs are, and it turned out to be a commodity business. Eventually they got out of it of course; it's a commodity business. Now they are in some commodity businesses but they—they're—like all successful companies, they don't want to be a commodity business because that's competitive, anyway.

05-01:15:22
Burnett: It's competitive and costly, right?

05-01:15:25
Oldham: Yes.

05-01:15:24
Burnett: And the margins are tiny, right?

05-01:15:26
Oldham: Yes, so it's easier to lose money than make money, yeah. So I had gotten into that there, and then as soon as I became ERL director, I remember sitting in this office in ERL, and the secretary says, "Bill," says, "there's a phone call for you, it's Lee Iacocca." I says, "Yeah, it's Lee Iacocca, give me a break." So I go over and say, "Yeah?" and so this deep voice on the phone [mimics voice],

"Hello, this is Lee Iacocca," and I said, "Whoa." I didn't say, "Who the hell are you really?" I didn't say that. [laughter]

05-01:16:13
Burnett: But you wanted to see.

05-01:16:14
Oldham: Anyway, it was Lee Iacocca, and he says, "Well, we're forming this scientific advisory board, uh, and we wanted to know if you want to be part of it?" I said, "Oh, really?" I said, "Well, yeah, tell me a little about it," and he says, "Well," he says, "what do you want to know? How much we're going to give you or something or what?" [laughter] He's very gruff; he's very funny. And Lee Iacocca, of course, was the famous salesman. He had just the years before that gone on TV and saved Chrysler by selling these horrible K-cars to the world, and he wasn't—

05-01:16:54
Burnett: I remember those.

05-01:16:54
Oldham: —doing a good job of selling to me. [laughter] Anyway, after a while, I said, "Yeah, I'm interested, yeah, I am" because, yeah, I loved cars, right?

05-01:17:07
Burnett: Sure.

05-01:17:07
Oldham: I was from Detroit. I hadn't been to Detroit in twenty-five years.

05-01:17:10
Burnett: That's right.

05-01:17:12
Oldham: This was from Detroit. I said, "Yeah, I'm interested."

05-01:17:14
Burnett: Did you tell them you were from Detroit and—?

05-01:17:15
Oldham: No. Anyway, so yeah, so somebody and I—to this day, I don't know who suggested me for the job. I have no idea why Lee Iacocca called me, I have no idea. I mean I know a couple of people that may have done it, and I didn't ask them, people like Gordon or Bob Noyce or these guys or it could've been somebody at Berkeley, Tom Everhart or somebody, but anyway, I never—somebody recommended me.

05-01:17:43
So I took that job, and that job involved that trip to Detroit four times a year and a lot of preparation for that. We had to give them some presentations, and we wanted to do a good job on feeding back on their presentation and as—with very high-level guys, it was very cool guys, the chief technical officer of

Boeing. Boeing was at the peak of its prominence then as a US manufacturer. Maybe it was the biggest US exporter, I don't know, then; it certainly is today or was until recently. So we had their chief technical officer, we had a guy from—a very interesting guy from MIT, from Princeton, we had the guru of combustion, and it was a very cool cast of characters. So this was a very fun thing to be on. And then this was a consulting committee to Lee Iacocca who was the chairman of the board and to—I forget. Bob Lutz was the—I don't know if he was CEO or something like that and then the chief designer was Hal Sperlich was—all these were former Ford guys like Sperlich. Sperlich was the guy who created the K-car, you know, he created the K-car and then he went and invented the minivan. This is really what—really what put Chrysler back into—and they were making money by then. They were making money, so it was a good time, and they give you cars and everything. So I want to do that and so I was coming back, so I'm in London coming back for all these things and so I didn't—if I had gone to London and stayed a year and not come back, it probably would've been different, I probably would've gotten more involved with them. Although they had no processing capability whatsoever at University College London, so.

05-01:20:00
Burnett: So it's largely a kind of theoretical or pedagogical proposition?

05-01:20:03
Oldham: Well, it was a department, which was pretty broad, but it didn't have actual fabrication facilities. So if there's people who were interested in that, they went to somewhere. They could go to Imperial College or somewhere on the other colleges of the University of London and do work. Yeah, so there I was '85–'86.

05-01:20:30
Burnett: Were the questions relevant to your expertise in materials like what—how did they best make use of you—

05-01:20:39
Oldham: Oh, you mean—

05-01:20:39
Burnett: —at Chrysler?

05-01:20:40
Oldham: Chrysler?

05-01:20:42
Burnett: Yeah.

05-01:20:43
Oldham: I was viewed by them as the electronics guy, and I did have an impact because Lee Iacocca was minting money right then. He had turned out these cars that Hal Sperlich had designed that were high-margin cars. And they were simple to make as Detroit goes, simpler to make and so they were making profits and

so he was in a buying spree. He bought Gulfstream at that point. He went out and just bought Gulfstream because he thought that was cool. And so then one day, he says, "Well, we're using increasing number of chips in cars." They were just designing the first electronic transmission, so there's a chip. I mean, of course, they had engine controllers, which were chips, but they were like going to do—the transmission was it now going to be electronically controlled, and it all pneumatic up to then and so on. And so he says, "We're—we need to be in the—making those chips." So the next time it was my turn to give a lecture, I gave a lecture on why they shouldn't make chips. And so I remember giving this lecture, and I started saying, "Well, let's talk about—" Because I knew about the cost of making silicon then because here I was a consultant in Monsanto, and they made the silicon. I said, "Okay, so let's think about this business. If you make the wafer that all these chips are going to be on and you do all this incredible work, the most purist material ever made almost and then you slice it with a saw into little, thin platters and then you polish those to perfection, and then you clean that surface, so it could be used directly in a factory, you'd get about 100 bucks for that wafer, and that's going to be made into a thousand chips, so you're getting the—your profits, if you make any profits, only a couple of pennies for the chip," I said "so that's that business."

05-01:23:06

I said, " So let's look at the next level, if you process the wafer and you go through all this," which is what he wanted to do, he wanted to buy a company that made that. I said, "You take this thing and then you spend eight weeks and do all this processing to it at the state of the art with them." It wasn't a billion-dollar factory then. The factories then were half a billion or two hundred million or something, so a small factory. I said, "So you have this big capital investment, and what do you get? You produce these chips, which sell for, if you're lucky, ten bucks, so you get ten bucks a chip." I said, "Now if you take those chips and you build a radio, what you get for the radio, you get a hundred bucks. So where in the business do you want to be?" I didn't say it exactly like that, but that was the theme of the lecture, and Lee Iacocca at the end says, "Oh, very interesting, Professor," and then he left. [laughter] And they never did buy a chip company because then there was twenty chip companies in the valley, you could've bought one. For a million bucks, you could—five million bucks you could buy a chip company because there it's almost to the point where they've got to get out of it because they can't afford the next generation. You spend a hundred billion—maybe they had spent thirty million putting a factory in, and now that, that's obsolete, and you've got to spend three hundred million putting the next factory in. I said—

05-01:24:49
Burnett: And you're just chasing your tail.

05-01:24:51
Oldham: —"We don't want to be in that business." So gradually one by one, all those chip companies either folded or were sold to another company. And then

eventually the foundries came along, and they just said, "Oh, we won't make it ourselves, we'll just have it made by a foundry." What TI did for instance, and that was a big company that did that. So that was all going on. So that was the Chrysler consulting.

05-01:25:17
Burnett: I mean that's fascinating because it's as if vertically integrated manufacturing with all of its assumptions, right, went to have a conversation with Silicon Valley, and Silicon Valley talked back and said, "Vertically integrated isn't all it's cracked up to be." And that was what was happening at that moment. You had—

05-01:25:43
Oldham: It was coming apart rather than going together.

05-01:25:45
Burnett: It was coming apart, exactly, and the separation of design from manufacturing, which becomes the key feature of the profitability of Silicon Valley, right? That's where all the profit is, is in design. And TSMC made it work because they had—they've reached the right level of scale with lower labor costs? Is that where it comes in to—? I mean I'm—

05-01:26:15
Oldham: I think it's scale more than labor cost. You know, there's a misconception in a lot of markets at labor cost. Like in cars, labor costs are not the cost of cars. That's why—

05-01:26:26
Burnett: It's capital.

05-01:26:27
Oldham: —manufacturers come to the States, it's cheaper than in Japan to assemble in the States. Not labor costs because labor costs are like 10 or 20 percent of the cost, right? I don't know in 1984 if it was 10 percent or 40 percent of the cost of the chip was labor cost, I really don't know the answer to that, but it was not—it's not dominated by labor cost. It may be dominated by availability of reliable, trainable labor. For instance, in the US in the valley [Silicon Valley], you get somebody trained, and somebody across the street offers them ten bucks more, they cross the street. Well, it's really hard to build the kind of workforce you need if you—if that's the case, right?

05-01:27:26
Burnett: Mm-hmm.

05-01:27:26
Oldham: So you can't invest in your employees, and you really need to invest in your employees, so, and that's not the case. They didn't cross the street. Japan, you never change companies in Japan, you never. If you did that, you're done. In China, I don't know, but I don't think it's so common as it is here to just jump across the street.

05-01:27:51
Burnett: So it's not supply, it's mobility, it's—

05-01:27:55
Oldham: The place—

05-01:27:54
Burnett: —labor mobility. So low labor mobility and—

05-01:27:58
Oldham: Is helpful.

05-01:27:58
Burnett: Is helpful with a good supply as well.

05-01:28:02
Oldham: Well, look at the only company from that era that survived to this day is Micron. They manufactured, they're the fourth-biggest in terms of acres of silicon. Acres of silicon, that's how they measure it, how many acres of silicon do you produce a year. They are the world's fourth biggest I understand. I mean they're in Idaho. Guess what, there's no labor mobility in Idaho. They're the only one there. They have factories now in China and elsewhere, but their basic design, process design and development is in Idaho and big factories there, Idaho and neighboring—

05-01:28:49
Burnett: Yeah, Utah, is a big place, not necessarily for circuit-building but in electronics.

05-01:28:57
Oldham: So mobility, I think mobility is the only reason Micron probably stayed because what did they have? I mean I don't want to pooh-pooh the leadership. They had great leadership, but it was just this American company making DRAMs, and it's the only one that survived. Nobody else makes DRAMS here or any kind of RAM here except Intel.

05-01:29:21
Burnett: I imagine there are strategic considerations when you're thinking about chip making and the need to have something on shore and you also then wonder about the tension around the security of Taiwan if—

05-01:29:38
Oldham: Can you imagine?

05-01:29:39
Burnett: Can you imagine?

05-01:29:40
Oldham: And South Korea.

05-01:29:41
Burnett: And South Korea.

05-01:29:43
Oldham: Whoo.

05-01:29:45
Burnett: Right, so, yeah, so these are—and we began, I think, our conversation—at one point, we were talking about what's handy about the integrated circuit and the miniaturization has all kinds of electrochemical and thermodynamic features to it, but it's also handy. You can put it at the tip of the missile and so there's the obvious multidecade military patronage of IC research and manufacturing. It's there in the background, isn't it? Even though it's this highly diversified, highly globalized space, I don't know, that's a question I guess, do you think about it?

05-01:30:33
Oldham: Well, yeah, but I don't pretend to know any of the real boundary conditions on the problem of strategy because that's those people who are—who dedicate their lives to understanding these kinds of things. And it's ridiculous because the unknowns are Trump becomes president, and his last days, he presses the button. These are the unknowns that the strategist really can't predict. So they do all the strategy but based on some assumptions which are questionable. The leader of North Korea, are you going to predict his behaviors? I mean, holy smokes!

05-01:31:19
Burnett: Right.

05-01:31:22
Oldham: And that's everything in those strategies. But I know that US manufacturers, because I was intensely involved with Intel, in the years, they were deliberately putting up factories around the country. In those years, they put up the factory in Oregon. I can't remember when they moved also to—they put up the factory, in the years I was intensely consulting there, in Albuquerque and then—and the one in Israel. That was really interesting the one in Israel. Yeah, so they talked about the need because of California earthquakes. They didn't know that Mount St. Helens was going to blow in Oregon when—they didn't regard that as a possible—

05-01:32:23
Burnett: Or in Washington, yeah.

05-01:32:23
Oldham: —problem, and their factory was right there, and it filled the air with this stuff for a month right when Mount St. Helens blew, and they had a big factory there in Portland. But they were more worried about earthquakes and not having all their factories upset by earthquakes.

05-01:32:45
Burnett: The capital costs are one thing, but we just finished talking about labor mobility and that is the problem and the salvation of Silicon Valley, this incredible labor market where there's this churn. If you need someone in this esoteric area, you can have them in the office tomorrow morning or that afternoon. There's something so incredible about this boiling labor market. But for these certain things, and never—this is such a revelation, it never occurred to me before that what you want is low labor mobility. You want stability, you want—and it's like the analogy insurance companies took advantage of farm wives. So you had this supply of educated women who are on the farm and did the books for the farm and had this kind of accounting skill and had gone to the local community college. And so you have Mutual of Omaha, you have insurance companies moving to the Midwest because there's this untapped labor supply of a talent that's not going anywhere.

physically.

05-01:34:09
Oldham: Yeah, I didn't know that.

05-01:34:11
Burnett: And so this low labor mobility becomes this key ingredient, and I wonder if that was happening in the decision making for Intel around moving. Neither of us knows necessarily the answer to this, but you hinted at it, in that there's something to moving to Idaho and to Albuquerque. The people that are there, they have family, and they're not interested in going to the coasts for example, and that's a key advantage for that type of manufacturing.

05-01:34:46
Oldham: Yeah, I don't know if it played a role, and I have no idea because I wasn't part of the decision. I was very good friends with Dov Frohman at—in those days, and he was the reason Intel went to Israel. He says, "You've got a—" and he talked them into it. First of all, it was the design. There was so much talent. There's a lot of smarts in universities in Israel, a lot of smarts—

05-01:35:17
Burnett: Yeah, Technion, yeah.

05-01:35:20
Oldham: So he talked him into putting a design center there. Dov wanted to go back to Israel himself, so he wanted to see it there for his own reasons, but he also, out of his loyalty to Israel, wanted to see Israel have this capability, so it's kind of a dual thing with Dov. I talked to him, he says, "Well, I was talking with Gordon and all the executive staff about trying to convince them to do a plant in Israel." I said, "Dov, you're crazy, why would anybody put a plant in Israel? That's nuts, I mean it's in the middle of a warzone, you don't want to put a plant there." And, of course, Dov didn't like me saying that, but I was only saying it to him. I never said that to—and I wouldn't—[laughter] Intel didn't

consult with me on that, and I wouldn't pooh-pooh Dov's dream, but he pulled it off, I mean it's interesting.

05-01:36:22

That has to do with the fact of key individuals influence history, key individuals influence history. There's no question about that, and Dov was a superhero at Intel who rightly deserved and so he influenced that, and they went to Israel. Israel benefitted enormously because then the other little companies sprung up around it, and now, they have that mobility right there in Israel between companies. You could change companies in Israel.

05-01:36:54
Burnett: Wow, the same advantage and burden, right?

05-01:36:58
Oldham: Yeah.

05-01:37:00
Burnett: Yeah, oh, that's really interesting. In the late eighties, you're doing consulting for a number of companies, and we'll talk about more different consulting in our next session as well. But you're the director of the Electronics Research Laboratory and PI for the Joint Services Electronics Program; in '84 you take that on. Can you talk about that part because we just finished talking about the military's interest in semiconductor manufacturing and innovation. Can you talk a little bit about that program? And it goes always, right, at a certain point. Can you talk about the nature of that—of the management of that research program?

05-01:37:55
Oldham: I haven't thought about this in preparation for this discussion, but it's interesting both on its own right and this was interesting for me to learn a little about that kind of management, which I had never done. I was, of course, manager at Intel, but it's a different thing. There, you have a product to get out, and you hire some people, and my boss said to me the first day, Ron Whittier, he says, "My job—I want to tell you my job is not to tell you what to do. My job is to provide the resources you need to do your job, that's my job, so remember that." And that was really a brilliant thing, which I took to heart and thinking about my job as a research advisor and how much I appreciated those students who self-directed themselves; I didn't have to say, "Oh, this week, go do that experiment."

05-01:39:10

I remember, okay, anecdote, I'm off the subject here you're on, we're talking about—

05-01:39:15
Burnett: No, it's okay.

05-01:39:16
Oldham: —ERL, but we'll come back to ERL. One of my students, Edita Tejnil, and she was one of these really smart women who was from Eastern Europe. She had spent part of her life in Eastern Europe, and there, women are not taught that women don't do STEM, they're rather the opposite. Eastern Europe and actually from Asia, the women, they're like men, they—math, yeah, it's great, physics, great. So she was one of those, so she knew all that stuff; she was extremely competent. And so I had the style of usually once a week, the student comes in—she was just a master's. The student comes in and you say, "Okay, so what'd you do this week and how you doing?" and they tell you this and that, and they'd show you some results, right? Maybe previous week, we talked about an experiment be an interesting thing, and they've gone and done that. And Edith was unique in that she comes in and she's—I say, "Well, how did you do that?" "Yeah, well, this happened and that happened," and I said, "Oh, that's kind of interesting." I said, "Hmm, you know, if—I wonder what would happen if you tried to correlate this with this other variable?" And she reaches into her file like this and says, "Oh, you mean this graph?" She had figured me out and knew my response was going to be to what she told me and then she had prepared the answer. This would be the next week's work. In other words I would—normally, they come in, they tell you something, I say, "Well, this really is cool, but how about looking at this?" And then the next week, they come in with that. Edita—

05-01:41:27
Burnett: Anticipated it?

05-01:41:28
Oldham: —she would do that, and she'd bring out the damn graph, so she wouldn't lead with that. She would lead with the usual stuff and then she'd—so she was really—anyway. So the role of the leadership in not telling people what to do but providing the resources for them to do that, I wish all managers of the world understood that that's their job. That you hire people who are competent at their jobs, so they—and you've made it clear what the goal is, and you don't over constrain the problem about how to tell to get to the goal, which route to take. You let them do that and you—and they say, "But I need—" and you say, "You got it," that's the role of the manager. It never had been crystallized to me until Ron Whittier had made it explicit and so you're blessed with that.

05-01:42:34
So there I was suddenly the director of ERL and it's this—the ERL was created because—to do research at a scale which was becoming important post-World War II. You had to have a fair bit of money, you had to travel to conferences, you had to do all these things that took bookkeeping, that took expertise in things that not everybody needs to have. Remember, there used to be travel agents before where they had the internet? You had travel agents, so if you're going to take a trip, you just said, "Hey, I'm going to Chicago next week, what's the best flight?" and then bingo, you got the tickets. So all of those things were—what—the kind of support faculty needed to do their

research, and the university wasn't giving it to them. So somehow, somebody in electrical engineering said, "We really need an organization that's—to support research," and that's what ERL was. It was simply to support research, and they had to have a few employees.

05-01:43:42

And originally, university since there was this thing called overhead, they take a certain fraction of your grant, where does that money go, where does that go? Well, part of it is to turn the lights on, right, and part of it is you might say to pay for the building, but the building's already paid for or maybe to have the custodian clean the building. But they were taking a lot of money, and they're not delivering any. So somebody convinced them to give us so many bodies, which we could have secretaries, the machine shop, various support services. And ERL came with that, okay, but it also had with that a set of rules. These are rules and the obvious rules about travel. You don't travel first class. There are certain rules about doing things, and it suddenly was the enforcer of rules because if you are the organization that when somebody travels and they turn their bills in to you, you have to say, "Hey, guess what, you can't travel first class." And there's many aspects to the enforcement. It has to do with space, it has to do with use of employees, it has to do with this and that. So it's very easy for an organization to get off the track in terms of being more negative than positive, being the enforcer and seen as an impediment to doing research rather than—

05-01:45:26

It's very easy to cross the line, and ERL was having some problems with that. And in particular, of all people, Don Pederson was doing some work with other people, and he was a former director of ERL. And he was having trouble with ERL, which, in his opinion was not doing what they should. In the opinion of ERL, they were doing everything they could, and they had to go by the rules and this and that. So there was that kind of thing going on there, and it turns out there was a couple of employees who were regarded by everybody as not productive. Mind you, we had a full-time draftsman because in those days, you had to do graphs and drawings, and somebody had to do that. Well, we had a draftsman, and you could get your drafting done there. And we had two or three technical typists, so you could scribble these notes and turn it in there, and you got beautiful, beautiful some equations, equations, and these are tech typists, first class. But some people regard it as nonproductive and so there was that problem.

05-01:46:49

And so one of the first things they had to do was to make some personnel changes so that we got the staff more tuned in to doing what the customer wanted and all that. And I was not that good at that, I mean I've never done that kind of thing, but I did it, and you learn about it and you—the positive side is I got to know fifteen people in Cory Hall that I didn't know that well before. I don't know about you, but I find if you meet fifteen people, there's two or three gems and a lot of other people that are great people that you know, and maybe there's a couple of people that are kind of goof-off but—so it's a very positive thing. So you do that, a little bit less teaching, a little bit less research, and you do that, it's interesting, you know?

05-01:47:51
Burnett: Yeah,

05-01:47:51
Oldham: It's interesting.

05-01:47:52
Burnett: When you said draftsman, the first thing I thought of was AutoCAD, and when you say technical typist, the first thing I thought of was word processing and so—

05-01:48:06
Oldham: It was just coming in.

05-01:48:08
Burnett: Okay.

05-01:48:09
Oldham: It was just. You see in 1980s, AutoCAD was pretty primitive. We had secretaries then. You had secretaries, and like I say, you didn't do your own tickets. So the world was really changing fast then, but it hadn't' changed yet.

05-01:48:35
Burnett: Right, okay.

05-01:48:36
Oldham: And the university had supported us, and when I was director, the university was gradually taking money out of there, and they were under stress from the government who was challenging them on their overhead. There's this unbelievable negotiation that goes on between universities and the government on overhead, overhead. So you have a million-dollar contract, and suddenly there's—three hundred thousand of it disappears out of your million and you never see. The university takes it, and you say, "What did I get?" Well, they were going to give us less people, and I was right in the midst of that, so part of my arguments with the dean were that. Dodge Angelakos had clued me in to this problem and said—he says, "Look, Bill, I think you're going to be offered this job. Make sure that you get a commitment to get a couple of people to do such and such" and so I did with the dean. It's funny, the ERL reported to two people, it reported to the research—head of research for the university was Joe Cerny at that point. And it had reported to the dean. I never quite understood, there were two bosses, and so I negotiated with the dean and said, "Look, if I'm going to take this job, we ought to have two more people to do contract management because when you write a proposal, there's a lot of paperwork to be done, to send it in, and do this and do that.

05-01:50:21
Burnett: Oh, my God, yeah.

05-01:50:22
Oldham: So we wanted people to do contract management, and he agreed, and that was one of the battles he and I had for the first year or two because he wasn't supplying them. And he said, well, he was on a different time scale than mine. I said, "Yeah, you're—we're on a different time scale. You said I was going to get these people—" So we had some pretty good battles. [laughter] Yeah.

05-01:50:52
Burnett: I'm glad you talked a little bit about that because that's—the administration of it is an unsung but absolutely essential component of any successful department or college or university. And you're absolutely right, the overhead goes up, and now, it's close to 60 percent [indirect cost rate] for the federal grants. And it's really onerous. One of things that you mentioned going to Sacramento at the beginning of the eighties to get the lab money and being part of this show with—

05-01:51:34
Oldham: Vasconcellos, yeah.

05-01:51:36
Burnett: John Vasconcellos and going with Mike Heyman who was one of the first chancellor boosters who, I mean in the days of Clark Kerr. I think there's a story about Andy—about Glenn Seaborg. He just called up the state of California and said, "We need a new accelerator," and they said, "Okay," because he's Glenn Seaborg—

05-01:52:02
Oldham: Yes, Nobel Prize.

05-01:52:03
Burnett: —and it's the University of California, and it had such a status, and it had such a place in the economy and the society of California that there were no questions about the support of Berkeley and of UC. But that was really changing by the seventies and that compact—and we can talk about this in subsequent sessions too, and how it affects engineering is unique I think or different at least from the university as a whole. But that compact between the state of California and the university just begins to fray at that moment in the 1980s. And Heyman is the first to go out fundraising for the university, and that didn't happen so much prior because there was an understanding that it's a state university, and it doesn't go out and seek money. I was just talking to someone else about how there was an understanding with Stanford too that they wouldn't—you wouldn't go after that [private] money because Stanford is a private university, and it needed it. And so, the University of California had the support of the state, and that was enough.

05-01:53:20

But you're coming into an administrative position at a time when support can't be taken for granted, when greater and greater chunks are coming out of the research—I don't want to be conflating problems but coming out of overhead. And one of the things I thought of when you were telling these stories about going hat in hand to the state of California for this new laboratory was its engineering and it's engineering in the electronics field. I'm surprised that the state of California was not calling you and saying here's this money. It's interesting to me that you and others needed to go and advocate for electrical engineering in the age of electronics, in the age of information, but you did.

05-01:54:21
Oldham: Yes, and it's more than that. I mean, of course, everybody is after money, so unless you're there, you're never going to get any money—because they don't know that there's an electronics lab [at Berkeley] in Sacramento right? But what's really strange is that we from Berkeley would go there rather than through statewide. That statewide would even allow us to do that.

05-01:54:51
Burnett: Oh, the University Office of the President?

05-01:54:53
Oldham: Yes, I mean there's this—Clark Kerr actually described it best. One time I was talking to Clark Kerr, he says, "You know when I came in, I found that there was a thousand people working in this statewide organization." He said, "What do they do?" He says, "I got rid of half of them." Clark Kerr told me this when he was president. And then he said, "After I left, within two years, it was bigger than it ever was, and it's bigger—" They oversized their building, so they had to move out. Remember they used to be in one building, they built this other monster building? Thousands of people there in Oakland, thousands. I was only in that building a couple of times, and I found it a very depressing place because there's all these people that think they're working for the university, and they don't have a clue what the university is, they've never seen a student.

05-01:55:59

So our concept, I mean my guiding concept after that was like they tried to get us to move some engineering out to the Richmond Field Station. They had this lab—land out there, and I said, "No, absolutely no." When I was ERL director, I said, "No, I'm not going to tell anybody to move out there. And I don't want you to move our administrative offices out there because those people have no connection, they never have seen a student, they don't know what they're doing," and we didn't. Engineering never moved out there; some other departments were forced to. Civil wanted to have their shaker table, and that stuff got out there but—so these administrative things, they just grow like topsy and then they churn among themselves, and they create subsets of people doing the same work and it slows the bureaucracy, slows it down, makes it less effective and, anyway, another subject.

05-01:57:10

So there I was, I was running a little bureaucracy, and in that fight between faculty and administration and—which involved both space and funds and all of that, and it was interesting. I never felt huge stress. I was rude a few times to people, some of my colleagues. I'll tell you an example, and I learned something very well, Karl Pister, this wonderful guy, you know Karl Pister I'm sure?

05-01:57:46
Burnett: Mm-hmm.

05-01:57:48
Oldham: He was dean, and I used to fight with him more than I used to—fight in the sense that I wanted a different optimum than he did. But one time at a meeting, I was rude to a colleague that was in the same meeting. Karl used to have these meetings of all the ERL directors and department heads and this and that, and I was rude to one of his—I think he had an assistant dean that said some things, which I think we're really wrong and mischaracterized, and I was pretty rude. I got a note from Karl, "Come see me," and he says, "Bill, we do not have behave like this, this is collegial," and I realized he's right. I screwed up and so I apologized to the guy and of—one of many times I've had to apologize for things I've done, and I've always learned that apologies are extremely powerful. If the other person is not a sociopath, and there were very few sociopaths, then an apology is very powerful. And when you apologize to somebody, if I apologize to a colleague about something I did, they suddenly are in a position—the weaker position. I've just apologized, and they have to somehow correct that, it's really amazing. So I've had several people I got to know by apologizing to them for something I've done, and I found out what a good person this is, right? It's a very interesting interaction. It's the kind of thing you do as administrator. You make these mistakes, and then you correct and so, well, it's good.

05-01:59:52
Burnett: I think you're kind of an anthropologist here because you were saying that about gifting too. The surprise is that the gift is a reinforcement of a relationship.

05-02:00:10
Oldham: Dan Mote once explained to me, Dan Mote was back here when he was president of Maryland one time. You know Dan Mote too. Do you know Dan Mote?

05-02:00:19
Burnett: No, I don't think so.

05-02:00:20
Oldham: Okay, so Dan Mote was the chairman of mechanical engineering. He was a Berkeley grad and then he left, and he came back and he was one of the really young bucks in mechanical engineering. A very interesting guy, he worked on

ski bindings, and he's a skier and stuff, so we had a lot in common. So, yeah, I was very good friends. In fact, I even skied for one of his experiments, but we're very good friends.

05-02:00:52

And so then he was looking to be dean here. He didn't make dean. Actually, it was the time he was competing with Dave Hodges. Dave Hodges became dean, and that was the primetime for him to become dean. Then [Chang-Lin] Tien became chancellor, and Tien saw something in Dan, I didn't know, and made him development for the campus, and he was gangbusters at development, gangbusters. And then he got this job offer to be the chancellor of the—in Maryland, took that, and then became the president or whatever, he—as high as you can get in Maryland in the university system and stayed there. And then later, he was the president of the National Academy for about ten years, he's finally retired. He's just my age, he's finally retired from that.

05-02:01:50

Burnett: Oh, my God.

05-02:01:51

Oldham: And he didn't come back to Berkeley; he stayed in the East Coast. So Dan Mote was back, oh, it was probably ten years ago. And there would be an event here, and once in a while, he'd come back, and he's one of the good, old boys from Berkeley. I cornered him, this and that, and talking about fundraising. I said, "You know, Dan, I have this problem that people ask me to do to go to some company and get them to give money or to go to an individual." I say, "You're really good at that, and I feel awkward and guilty, and I don't know how to do that. And he says, "Bill," he says, "look at it as a win-win." He says, "It's a win-win, somebody's got a lot of money, they don't know what to do with the money, and you're solving a problem for them, what to do with the money. You get the money and then if you do it right, they get enormous satisfaction out of that." He said, "It's a win-win, always view it that way." And somehow, he not only says that, but he has his mind right and does that, and he's a very successful at it. I mean he was very successful at it. He put the university there on the map in engineering and eventually in larger scale, so he's very successful. So that is, it's a win-win, that's the phrase that stuck with me.

05-02:03:28

Burnett: And in development, you have to really think about what the donor wants and understand it well, but also understand what the institution needs and really believe in it. Like we need this to make engineering better, and I don't need to tell you what the advantages of that are, it should be obvious. But this is important work and you have to—and so it's a given that you're a believer in the work, but it's true that that gifting is an investment. It's not just a monetary investment, it's a social and emotional investment in the success of engineering and in the success of Cal, and that is powerful, right? And I think that's what you've identified, and you and Dan Mote identified. I think we're about out of time for today, and I think that one thing to close it off because you mentioned the National Academy, you're elected in 1986.

05-02:04:38
Oldham: Well, at that time and it's again I—again, this is Dave Hodges, Don Pederson, we used to have a cadre of people here—John Whinnery—who were in the National Academy who would identify other people that they could propose and they knew would be accepted. And they asked me, gave me all this stuff, and they got me in. It's the way I look at it, they got me in somehow. That was this peak time where we had done a lot of good stuff. In particular, this local oxidation work was a big factor in that, and it was important industrial practice, so yeah. So I got in the National Academy then the same year that somebody else got in. I think Lee Iacocca got in about then. I was thinking, but I had another colleague on the Chrysler board who was in that year too.

05-02:05:55
We used to have a wonderful thing that when a new colleague at Berkeley got into the National Academy, then we would have a dinner, and that person and their spouse, usually their spouse, didn't pay. We had a big dinner, and everybody who was in the National Academy came. So Dave says to me, "Okay where do you want to have the dinner?" "How about so and so?" and then we all had a nice dinner together. And that was a nice meeting because people you hadn't seen in a long time that were retired would come. I mean long after they're retired, Don Pederson and John Whinnery would still come to those dinners. Elwyn Berlekamp, all these people. You didn't see them very often, and they're very, very interesting people, so you would do that.

05-02:06:50
And then somehow, about ten years ago in the milieu of EE [Electrical Engineering] and CS [Computer Science] and this growth of the department and then the academy not taking in as many people, so we're not getting somebody every year. Sometimes it's a couple of years before we have somebody in, and it got dropped. And so I've tried to restart it, I even funded one of the dinners myself through some money I had in the grant or in a gift, and I have never gotten those things restarted, the automatic things. Because we have people going on and they say, "Well, let me hear, when's the dinner going to be?" and never happened. So a couple of times, we've tried to make it happen, and it's happened, but then it never caught on again, which is too bad, because it was a great—it's like I can imagine that other people who are in these kinds of situations, I don't know Nobel Prize, not that high, but other honorary organizations actually get together and meet once in a while. I think it's nice, but we don't.

05-02:08:07
Burnett: Yeah. I mean it's not just an honorary society, it is—it's this body of accomplished folks who often do research and report on key problems and—

05-02:08:21
Oldham: Yeah, they're asked to, they're asked to report to the government. And I've been involved in a couple of those studies. In one case, we were asked to do like evaluations of the standards organization in Colorado, what's that—and—what's our—what's the acronym? N—?

05-02:08:49
Burnett: NSO?

05-02:08:51
Oldham: No, I've heard the acronym, anyway, does all the—this US standards. [NBS – National Bureau of Standards]

05-02:08:55
Burnett: Oh, the bureau of standards?

05-02:08:56
Oldham: Yeah, well, it used to be the bureau of standards, but it moved on with a different acronym, but it doesn't matter. But, yeah, so we've done those kinds of studies, and there's a lot of them going on. Dick Muller for years was the local person they would use to find people for the studies, and he would always send out an email saying, "Are you interested in studying this and that and this and that?" I volunteered for very few, I had enough things to do, but, yeah, they still do that.

05-02:09:30
The Academy is not as—it's kind of like they're not as respected as they should be. They're not used, of course, as well as they should be. You should have a place where you finally go to somebody and they say, "NIH, they should say what's true about COVID" or whatever, and we don't really have that. Every one of those organizations has some role but then they say, "Oh, they're wrong about this and this and that, and they're not respected," and the politics comes in, right?

05-02:10:08
Burnett: Yes, that happens. There's the Science Wars in the 1990s, right? I think the National Academy of Science came out with a report in 1991 or two, and it was raising the alarm about public trust in science, something like more people trust alternative medicine than seeing a primary care practitioner. They had a list of these basic things that outline the problem and then they wrote a report about it. And then a number of books were published in the mid-nineties about [public] trust in science declining, and it was an alarm, and now, we see the fire.

05-02:11:05
Oldham: Oh, it's much worse today. I mean it became the political—it became a political trick of Trump's to do that, to pooh-pooh it, and then the impact is just horrific.

05-02:11:17
Burnett: Yes, although the seeds were planted much earlier.

05-02:11:20
Oldham: I never was aware of that science wars stuff. I wasn't paying attention to that back in then when it was happening.

05-02:11:29
Burnett: It's a long story, but the short story is that a mathematician and a physicist sent an article to a cultural studies journal arguing, I think, that speed of light was socially constructed or something like that. [laughter] And it was couched in this kind of poststructuralist jargon, and this journal, which was not peer reviewed by the way, published it, and then they had press releases ready, and they sent it out, and it went around the world. It went through all the talk shows and everything that look at how stupid people are in the humanities that they even don't believe in science.

05-02:12:14
And there's truth to that in this—and a mistrust of science, but it was also a hit job on the humanities, which was an interesting thing. This stuff was going on in a context of budget cuts, right? Everything was fine in the enclosed garden of the academy until real budget cuts started to bite and then people started looking around going, "You're funding that? You call that research?" And fingers started getting pointed, and then outside of the academy, people started pointing at the academy and saying, "It's a bunch of radicals" or "Know nothings" or whatever. That was the climate that was swimming around in this period in the early nineties.

05-02:13:00
Oldham: Yeah, we had a little of that. Lotfi Zadeh got it for fuzzy sets. I don't know if you remember Lotfi Zadeh is the father—

05-02:13:08
Burnett: For fuzzy logic?

05-02:13:10
Oldham: He's the father of fuzzy logic and which was subsequently widely adopted in Japan to run trains, I mean really adopted. In the sixties here, it was pooh-poohed, and there were legislators saying, "What is this? We're funding people to do this?" because he chose this word, *fuzzy*, it's a beautiful word, I mean just a beautiful kind of—and if you're a mechanician, this is exactly and the way physicists choose the properties whether it's color or the properties of particles. These names are so well chosen. Lofti chose fuzzy, but boy, did he get a lot of flak over that on one hand.

05-02:14:00
Burnett: Yeah, the science gets misinterpreted quite often and—

05-02:14:04
Oldham: Deliberately, it's not that these people are stupid, it's deliberate.

05-02:14:09
Burnett: Yes.

05-02:14:09
Oldham: I mean not always, but it's very often deliberate, it's opportunistic politics.

05-02:14:16
Burnett: There's anti-science sentiment out there.

05-02:14:21
Oldham: They know that there's 20 percent of the people that are ready for this and then they'll—you know?

05-02:14:28
Burnett: Absolutely, anti-intellectualism in American life, absolutely, long history of that. Well, we won't solve that problem today.

05-02:14:38
Oldham: Okay.

05-02:14:40
Burnett: But I'm looking forward to our session next time.

05-02:14:42
Oldham: Okay, thank you.

Interview 6: July 5, 2022

06-00:00:13
Burnett: This is Paul Burnett interviewing Bill Oldham for the University History Series, and this is our sixth session. It's July 5, 2022, and welcome back. It's great to see you. It's been a while.

06-00:00:29
Oldham: Yes, missed a year.

06-00:00:30
Burnett: Well, I think it would be a good idea for us to return to the 1970s, and for you to tell us a little bit more about the support that is coming from the state, right, so the federal government. What kinds of grants and research projects and programs did you participate in, in order to move the research forward and to build projects with your students?

06-00:01:09
Oldham: Certainly in the sixties, research was very small-scale compared to today. I mean we're talking about an order of magnitude less money required to do anything. It was $5000 to support a student or something, and tuition was negligible then, even foreign student tuition was low, and equipment, and supplies. More than just inflation, everything was more of an order of magnitude. So if you had a $10,000 research grant, you have enough to do something. Well, today that's a joke. Minimum to support any kind of a student is $50,000, and that would be a student who already has their own tuition, and so on, and all you're doing is paying those research expenses and appropriate things.

06-00:02:21
So what happened is these small grants we used to offer—in fact, when I came here—I think I mentioned—early on, I got a couple of thousand dollars to start my research. Then I could use a machine shop and I could build stuff. So now you need a lot of money. So what happened is then you had a small grant from some organization, it could be NSF or it could be all of the government labs, there were many government labs then. The navy, and the air force all had their own research labs, and they were all giving grants to universities for research of interest to them. DARPA hadn't yet started of course, and the consortia that we're so familiar with now, SRC and SEMATECH, and all those consortia, none of those existed. So there was some money from industry and some money from the university and some funding you could get through these government labs that you went after to fund your research. Well, then as now, I should say, it was certainly true that depended on the individual, your research is impacted by where money is available, so it's a little different than science. If you want to find out how the universe started, you can't go to a company and say, "Well, this is relevant to your program." The air force doesn't care, so, but they do care.

06-00:04:10

When I started out, I did a lot of work on radiation effects in semiconductors, and that's of interest because this was the Cold War, and everybody was worried about bombs going on and there's electronics work and all that stuff, so there was money available for that. So I did that. And so I guess I sold my soul in a certain sense, but these were the days we were trying to understand devices and how devices work and how you can make them better, and so on, and this was not entirely irrelevant to that. So it was okay. I could work on devices, I could build devices, but I had to do the relevant work. I had to irradiate them, hit them with neutrons or whatever particles were relevant, and then see what they did. So I did a fair bit of that, and that kind of research, it still goes on. I mean people still follow the money in their research. The companies do that primarily, the California—Southern California aerospace companies, that's what they do. They're funded by the military, and whatever the military wants, that's what they do, right? Hughes and all these companies. In the old days, it was Hughes, which had a really great research lab.

06-00:05:38

But as time went on—I guess as you get a little better reputation and you can start to say what you want to do and people will listen and then you get some money. And then industry got a little involved as the semiconductor industry developed. In the sixties, when I started, there were only a few companies, but as it developed, and they had their research, they were interested a little bit. So there's a little bit of funding coming from there, and, of course, what you do has to be something that's interesting to them but not competing with them or proprietary that their competitors—because you don't do secret research. So that was attractive, industrial research money.

06-00:06:35

But what happened a little bit later was the formation of these consortia, SIA, the Semiconductor Industry Association. SEMATECH [Semiconductor Manufacturing Company] formed. It's very funny because it was in response to the Japanese coming in. And the Japanese [industrial development] was very much government-driven as later on in the Chinese and the Korean [cases]. I mean very strong cooperation in the capital formation of companies with the government; never was the case here. So this was in response to all that, and so these consortia formed, and some of them realized that probably for their own selfish reasons, they wanted our students. So they would fund us so that we would turn out these relevant students. But, of course, it's better—I mean if you're AMD [American Micro Devices], it's better if Intel funds them and then you hire the students, then you fund them. So a lot of that goes on, right? In other words, not everybody equally participates, but they all participate in the harvest. Not everybody waters the crops.

06-00:07:54

Burnett: Do you see that as a factor in how some of this played out in that there was a free-rider problem that some industries ask why would I invest in that? I'm going to wait for someone else. There's often the story about how I'm going to let the leader in an industry spend all the money on R&D, and I'll clean up behind them.

06-00:08:15
Oldham: Yeah, well that's, of course, a separate problem than the funding of the universities, but I mean a certain amount of that happens. I don't think that's a big deal, but it is an attitude on the part of certain individuals. So there's a certain kind of individual, and it's much more common today than it was then, the selfish individual attitude, well, I'll make America great again. I don't want to get into politics, but what's "make America great again?" That's like, "screw everybody else." It's only about America, and the rest of the world doesn't matter. Certain individuals have that attitude, and if they are in charge of a company, then that company doesn't participate—and that happens, you see it. Some companies are really good; and some companies, you just can't get interested in the universities.

06-00:09:25
But I think, as a whole, industry recognized, and these consortia formed. The California MICRO [program], I think we talked about that and then SEMATECH and SIA and DARPA [Defense Advanced Research Projects Agency]. And DARPA found the universities really useful. Again, you could argue that DARPA maybe corrupted the program by pushing it in something they're interested in, but on the other hand, what we're not doing is basic science. We're not trying to figure out the most basic things about science, we're trying to make stuff work, make things that work, technology. And a lot of what DARPA did was right on the money. They did this autonomous driving thing about fifteen years ago; it's very cool. Can you make a vehicle that drives around in the desert without anybody in it? Well, that was really a pretty profound in that people started to understand the relationship of hardware and software to making technology work and the kind of changes, which were necessary in software development, and so on, and so on. So those are very successful, or my guess you could say the internet is the most important one.

06-00:10:57
Burnett: Right from DARPANET?

06-00:10:59
Oldham: Yeah.

06-00:11:00
Oldham: And we were right in on that in the beginning; it was a wonderful thing. We had the internet way before anybody else. All the universities did because they put us right on it. And so we had all this email and all this stuff and then internet came along more widespread and somebody invented the World Wide Web, which was big innovation.

06-00:11:23
Burnett: And that was what, '93? I'm trying to remember.

06-00:11:25
Oldham: I don't know when that was.

06-00:11:26
Burnett: I think '93, '94.

06-00:11:28
Oldham: Yeah, you know—

06-00:11:29
Burnett: And so how much earlier? I remember my friend's father who was an entomologist, he would dial into the university, and that was '83, had a modem and had a—so had a university connection.

06-00:11:45
Oldham: Yes, so that was in the eighties. Well, we didn't have the World Wide Web then. We didn't have the URLs and then—

06-00:11:53
Burnett: Right, exactly, all the protocols around that.

06-00:11:56
Oldham: Yeah.

06-00:11:56
Burnett: Well, you said a couple of things that are interesting. One is you said "I sold my soul a little bit," and I wanted to unpack that, and the other is that DARPA maybe corrupted things. But in what sense do you feel like there's some kind of compromise that shaped—and whether it is—because those are really negative things, right?

06-00:12:21
Oldham: Yeah.

06-00:12:22
Burnett: Corruption and selling one's soul is pretty negative, right? So is it negative for you, or are you thinking that other people think it's negative but it has—it's complicated?

06-00:12:35
Oldham: Nobody has ever told me that, and no, I don't worry about what other people think, it's about what I think. And I've never had somebody confront me, "oh, you're just working for the bad guys," never, never, never. But I can think about that nonetheless and sure, working on radiation effects. If I were just given a proper million dollars a year for my research when I started, then I would have never worked on radiation effects. I would've done something else. I don't know what it would've been, I probably would've done a better job on trying to do that high-vacuum epitaxy that I was trying to do and couldn't pull off. But on the other hand, no harm was done. I learned a lot. They felt they got their money's worth because they learned a little bit about: neutrons hit a transistor, what happens to that transistor? And it was

published, I mean nothing was secret, so everything is always done open. So I guess maybe selling your soul is a little bit strong language, but it just emphasized that you're compromising a certain amount. You're not doing pure science, you're doing development, and sometimes it's what somebody else wants developed rather than what you think maybe, but it's in the direction. It brings you in the direction you want to go. And gets you there, and you can hire some hands, some students and make some progress.

06-00:14:14
Burnett: Well, some people have argued—I mean historians have looked at situations where it's almost as if at a certain level, the shaping or the corruption, if you want to call it that, is somewhat arbitrary to the end result. So if you push someone in a different direction, it can be in the end positive because they were exposed to a research question they hadn't thought of before, and it stimulated rather than people necessarily going down a path that is internal to the process of inquiry, right?

06-00:14:50
Oldham: Yeah.

06-00:14:51
Burnett: So there can be these. Can you think of pleasant surprises you have where you were "corrupted" in a direction that ended up being really fruitful for you?

06-00:15:02
Oldham: It was only through the interaction with people. I mean my radiation effects, then you meet certain people, you deal with certain people, and then you know those people from then on, and it's great. Yes, you can talk to them, you can pick their brains, or they connect with other people, and so on. The strongest one that I got into was radiation effects; after that, I pretty much did my own thing. I went off in the strange direction of lasers and—because semiconductor lasers were really very hot in the seventies, and I got on that—doing that, and I just followed my way there. I didn't follow the money there, but then, I realized by myself that I'm going off in a direction, which is irrelevant commercially. And I'm an engineer, and I guess I'm one of those engineers that wants to see what you do for sale or have an impact, right? It's like that.

06-00:16:10
Burnett: Having an impact.

06-00:16:11
Oldham: I mean even anybody who's not an engineer but who just fiddles around, they make their car work, they're really happy. Every time they drive their car, they say, "Oh, man, I did something, I replaced a generator" or whatever it was, so that drives you. And I just realized that what I was doing was going off into a corner where there's a very small application and so that's when I got back into the semiconductor business through Intel for a couple of years, and then got into the mainstream and then no problem. There were enough people in

industry then in the late seventies, especially in the eighties, that were very interested in making universities work, and that's why we got all this money from these different organizations like SEMATECH and so on.

06-00:17:09
Burnett: It's interesting. One question I have, I think we talked about Intel in previous sessions, and forgive me if we've already covered this ground. But I do think about that experience of the sabbatical of the year of working, and it was more than a year I think that you were there, and leading a project in fact, right? Comment—this is the most neutral question, right—just tell me about the influence of working at a company, what that does to an engineering professor at a university. What do you get from that experience?

06-00:18:04
Oldham: I think what you get is you get a better idea of what is really needed to make a successful product, not technically, but the ingredients. Like what I got out of that was this reinforcement of the power of collaboration. That's what I got out of that, and it a totally changed how I worked at Berkeley. Now, I could've stayed at Intel as I said before, made a lot of money, I just didn't like the kind of a confrontational life you had there. And to be successful there you had to be confrontational twenty-four/seven, and I thought, not for me, so I came back to the university. But following me, Paul Gray went there, another person went off on their—and Andy Neureuther, he went off to IBM. Now, he didn't go into product development, he went to an IBM research lab, a little different. But going into an industrial research lab is a different enough experience than being here where you have this: professor has a room, and his students sit around in the room, and they have their little project, and so it's different enough that it's a good experience, but for me, running the project was great. I can be a bossy guy, I know how to boss people around—

06-00:19:43
Burnett: Good. [laughs]

06-00:19:43
Oldham: —so for me, it was really good. You get to do that, I was very good at it, I was very successful. We got the product out. Unfortunately, it was not the state-of-art product because somebody else did a better job of the circuit design, not the technology. So you do all of that, you learn all the other aspects of dealing with—like you give endless talks before upper management, right?

06-00:20:15
Burnett: Mm-hmm.

06-00:20:16
Oldham: So you're going not before—like I go to a conference, and I'm talking to all these other researchers around the world, that's one thing. But when you go in, and Gordon Moore and Bob Noyce and Andy Grove are all sitting there, and you're just telling them what your progress is and why you want to do this and the direction you're going to go, which is quite controversial, let's say that—

we had to make some leaps—and it's fabulous, it's just great. So that's a different experience because you don't get that very often. Some people at universities are able to run seminars, which are a challenge, you challenge the people.

06-00:21:04
Burnett: Right.

06-00:21:06
Oldham: I think we haven't ever done that here successfully. I think in the sciences, they do that a little more where you challenge the speaker. We don't do that so much, but boy, in the industry, let me tell you, every time you say something, "Why is that? Why should we do that?" So—

06-00:21:30
Burnett: And you have to be ready—

06-00:21:32
Oldham: Well you have to have a rationale. It's a very different and good experience, and everybody came back pleased and happy and better. I mean Paul Gray, I know you—did you interview Paul Gray?

06-00:21:44
Burnett: Yeah, I did.

06-00:21:45
Oldham: I mean definitely everybody had a—because he had to produce something in a year, you have to make something and make it work. So it's a different experience, and it's great.

06-00:21:59
Burnett: It also helps in mentorship, I imagine, because you're training people who will then go into those companies.

06-00:22:06
Oldham: Yeah.

06-00:22:07
Burnett: And in the academy too, but you also know the difference, so you can say, here's what's working for a company is like and here's what's working for a university is like.

06-00:22:16
Oldham: Yeah, you don't say that, but I guess you could, I mean—[laughter]

06-00:22:19
Burnett: Okay. So that's not the type of mentorship that you do?

06-00:22:23
Oldham: No. The mentorship you do, boy, I got to—if I knew then what I know now. [laughs] The mentorship you do is—and it's just the day-to-day, like a parent,

you don't think about—I mean how many parents read up? I mean when they're young and they get a book on how to raise kids and all or something, they would do that. But then the day-to-day is just an interaction, right? And you're modeling like crazy, and you're not thinking about the fact that you're modeling, right? You're not thinking about that, but you're modeling. Because if they respect you, and kids for a while always respect their parents for certain period of their life, so if they respect you, the modeling is crucial, right?

06-00:23:06
Burnett: Yeah.

06-00:23:07
Oldham: We never think about that in this, and maybe some people do, but that's the most important thing, right? Not saying, well, if you're going to be a professor, here's what's important. You don't discuss that kind of stuff; they can figure that out.

06-00:23:22
Burnett: Yeah, this is a conversation I have all the time with people who are mentors or noted for being mentors. And I remember I gave a talk about this, and one other historian objected to the presentation because she felt that mentoring sets up a power relation where you know something the person doesn't and you're telling them what to do. I disagreed, I don't think that's what mentorship is at all. If anything, it's about listening, and you're listening to the person who has doubts and you're—or they don't know what to do. You listen and you feed back to them their questions, and you help them work through a problem. You're taking it even further and saying it's not that. It's not deliberate or planned, it's about embodying the kind of researcher, the kind of thinker, the kind of collaborator. And you try to do the best that you can, and you hope that they pick up some of what you are modeling, as you say, right? It's not planned—if anything, it has evolved in terms of the relationships between teacher and student over many, many decades, and there are customs associated with it. I'm sure EECS had certain rituals. You might not even have been aware of, but there were cultural rituals in graduate students entering the program, for example. And they would get some kind of onboarding, and there would be some kind of conversation, and there's some kind of ritual around it. I don't know, do you remember any of those details?

06-00:25:14
Oldham: No, I don't remember any of that.

06-00:25:17
Burnett: Someone would want to work with you, you would say yes or no, or you might find that you really want to work with someone, you might—of the pool, you might sort of want to claim them?

06-00:25:29
Oldham: Yeah, and you direct them to other people. Yeah. Thinking of the modeling part, so I was thinking about this the other day when I was looking through—again through what my various students did. And about half a dozen of them I could say became the multimillionaire, billionaire types that everybody thinks Silicon Valley people become, right? I had about half a dozen of those. In other words, they were upper management, they were either CEOs or very high-level management and made a lot of money, and some of them started companies, and so on. Maybe I had half a dozen of those that I can think of, and I'm sure I haven't—there's three or four that I haven't thought of because I haven't followed that well. But only two became university professors in the USA, Charlie Sodini at MIT and [Simon] Wong at Stanford, only two. So I was thinking my modeling wasn't very good as a professor. If I was any good, I should've turned out all professors, right, they all want to be me, but that didn't happen. But so I taught them something else, which is it's not deliberate, you're not—

06-00:26:59
Burnett: Yeah, I mean especially when you think about engineering, right, you definitely don't necessarily want to turn out all professors, you don't—

06-00:27:09
Oldham: No.

06-00:27:09
Burnett: —necessarily want to reproduce the academy because the academy is supposed to be generative, especially in tech. It's supposed to be generative of so much else that goes on in the world that that's almost your measure of success in a way that they have gone on to do interesting things in other areas, whether it's founding companies or working in at established companies and so on. That is really interesting. It sounds like a tangent, but I'm on this theme of shaping and this notion that is there is a way in which the work is corrupted by some outside influence or the way in which a mentor shapes and influences deliberately? And in both cases, you're talking about this kind of serendipity, the unplanned interactions that are generative of new ways of doing things. Do you have to be more open to chance, do you have to be more open to possibility in doing the work?

06-00:28:30
Oldham: Yeah, if you're going in an industry, you don't usually get to choose which project. The company has a need in a certain area, and right now if you go into the automobile industry, they're all desperate to figure out how to make an electric car maybe, so that's what you're going to work on. So when they came to us, I guess about 25 percent may be brought their own ideas, and we tried to accommodate them. Some of them, I just 100 percent accommodated. Interestingly, the two who went to universities brought their own thesis with them. They said he wanted to do this project on his particular kind of transistor that was an oddball. I mean he [Charlie Sodini] brought his own

money and everything, and all he wanted was an advisor. I mean you have to fund a little bit in the lab, but mostly, he did his lab work at HP. And Simon Wong, the same way. He wanted to work on—actually and Simon did a lot of work in the Berkeley lab so that I funded, but he basically funded his own salary out of HP because he came from HP. So HP paid for those two guys, and they both went to university.

06-00:29:50

There's some other guys who brought their own projects and brought their own, and you try and accommodate them because—I think it's great if they bring some ideas. If I think it's a good idea or possibly a good idea, then you make it happen, which is what I did myself. I didn't work on what my advisor wanted me to, so I was a little sympathetic to that. But the majority still, they come in and you finally say, "Well, how about you do plasma etching or something," and okay, and they do that. Now when they go to industry, they're not going to work on plasma etching, they're going to work on some other—if they go in the technology, they'll work on some technology, but they're prepared to do that. They're not so narrow. They don't read just the literature on that one little subset, and the conferences they go to they're much broader so they're—you know? Like I told you about Sanjay Mehrotra, I had him on this—and apologized later—on this photoresist characterization project, but it was okay, he did okay. He's CEO of a big company, and he's not working on photoresist.

06-00:31:20
Burnett: Right. So we have this context especially—when was the big moral panic about Japanese microelectronics? It was like 1980 I think.

06-00:31:36
Oldham: Around 1980.

06-00:31:37
Burnett: I remember there's a congressional panel on this, and they did research too, and they had people testifying as to whether we are losing our edge in memory devices and that kind of thing. Is that really the beginning, the genesis of these research consortia?

06-00:31:56
Oldham: Yeah, I think it was.

06-00:31:57
Burnett: So in the eighties, they're figuring out how we can get industry to pool—that's the model, right? There are several major—I think in the case of SEMATECH, it's fourteen different industrial giants that pooled a hundred million dollars. The US government did a matching grant of another hundred million dollars, and together that would be the annual funding for SEMATECH. Did they realize that competition and secrecy were some of the problems, that they needed to have more of a common front in research? Is that what they were thinking in terms of designing this?

06-00:32:41
Oldham: Well, there is no "they." I mean the problem is there is no "they." And it's a bunch of individuals, highly opinionated individuals that meet and then compromise on what's done, so yeah. I wish you could say that they could meet and come to a consensus on this and that, but it's a compromise, they make a compromise. But they did realize that they're losing. and I don't think they realized then, and I don't even know if they fully realize today how important that funding is to bring them the experts they need. I don't know the experts the kids were interested in. They're smart kids, and they can work in biology or they can work in semiconductors, right? And they can do either one just equally well, right? But if you don't fund them, there are not going to be any coming out in semiconductors. And what we did for years and years, we hired them from overseas, right?

06-00:33:48
Burnett: Mm-hmm.

06-00:33:49
Oldham: And we brought them in, and we educated them here because they didn't have the education in China and in—

06-00:33:58
Burnett: Taiwan.

06-00:33:59
Oldham: —Taiwan, then, they do now, and Japan initially. Until the mid-seventies, the Japanese guys were coming here, right?

06-00:34:11
Oldham: By 1980, they were no longer coming here for their degrees, but there was a whole generation of Japanese top executives who were educated in the US. Like Ernie Kuh had one, who's the head of—what's the pencil company?—and so on, anyway. So I guess the point was that the need for education of kids in college, get them—they're going to do something in graduate school, get them to work in technology and then you have this pool of people you can hire and work in your company, right?

06-00:35:00
Oldham: And they sort of understand that today, they talk about it, but they don't really understand it. If they did, there would be a fund of money for that. I mean look at how important that is for the future of the US versus we're competing with China now in AI for instance and in quantum computing. If China gets quantum computing working, if somebody gets it working, but if China gets it working ten years before the US, that's a disaster because that's a computational ability, which [means] they can break every code we make. It's tremendous. So if the government realized really that you have to have this program where you educate people and then they get interested in this and then they love it. They go to work every day; they love it. It's not like you're doing something bad for them. I mean they can work on a lot of different

things, but if they work on that, it's good for the company or good for the country because of the economic fallout. Look what happened with the semiconductors, the economic consequences of that, that's about—that and agriculture are about the only good things we're good at in the US, right?

06-00:36:23
Oldham: Some of them realize that. To go back to your question, some of them realize that, and that was the smart ones and so I think that's why SEMATECH did fund these big programs and follow on SIA. And SIA recognized—I don't know if they had their own, but the SIA teamed with SRC in some of the—one of our centers I think was, maybe SIA, SRC, I'm not sure but—

06-00:36:53
Burnett: So just to cover, Semiconductor Industry Association for SIA?

06-00:36:59
Oldham: Yeah.

06-00:37:00
Burnett: And SRC?

06-00:37:01
Oldham: Semiconductor Research Corporation. SRC was directly, almost exclusively funding university programs. SEMATECH was not, SEMATECH built their own fab initially in Austin I guess, yeah. They built this fab, which really never worked, but they were going to build a fab and do state-of-the-art research, kind of like [what] was done successfully in Europe in Holland.

06-00:37:39
Burnett: Can I ask just before we go a bit further into the multi-university consortia, when you're talking about the need of getting people interested in the industry or that type of work, are you saying that the effort to fund research at this university level does not take into account the pipeline further down that—in—back down to the K-12 area?

06-00:38:14
Oldham: Well, I didn't say that, but that's true. I mean that's true. That's where American education's been weak, right? We don't do much until the kids get into college. Our kids are way behind. It's better now than when I—I mean we didn't have calculus when I went to high school, right, but it's better now in the better high schools, and that's not uniform.

06-00:38:45
Burnett: Right.

06-00:38:46
Oldham: But we've still never gotten to the point where, let's say, you go into a high school—I guess you can call them girls in high school—where girls have equal interest in the technical things as boys. We've never gotten there, whereas in Eastern Europe or in, I don't know, in Iran or China, there's—girls

do that stuff, they do mathematics, they do physics, they do chemistry, so we haven't, we haven't done anything about that problem, and I don't know, that's a whole different problem. But we fix that in college. If you get them interested in technology, we fix that in college. They're still very smart and can learn all that stuff.

06-00:39:47
Burnett: Yeah, seventeen, eighteen—you have the plasticity of mind to shift gears and think [differently].

06-00:39:54
Oldham: And I always said, the Europeans go to college and loaf till June, and then they work for a month in June to pass the exams. That's because they got in, they got through that tough time. So they did all their work in high school, with this fearsome competition. Where then our poor college kids are just working, the problem sets we give those kids, and they're working every night, and they're playing catchup. But by the end of the bachelor's degree, they're fully the equal of the Europeans and Asian students.

06-00:40:32
Burnett: So in spite of itself, the American education system sort of works in the end by—

06-00:40:40
Oldham: Yeah—

06-00:40:41
Burnett: —it's sort of this—

06-00:40:41
Oldham: Well, it has, and the foreign students came here for that, not so much for undergraduate, but for graduate, because they can come here sort of equals and then they can shine in graduate school.

06-00:41:00
Burnett: Well, let's talk a little bit about the SRC investments and there is—I think you wrote in a note that it's an equipment grant.

06-00:41:16
Oldham: I don't remember now, and I saw somewhere in one of my bios for one year that we got a—our first SRC grant was for a million dollars' worth of equipment and $100,000 for research, so it was very small. But the next year, we got a regular research [grant] and then that continued for, I don't know, how many years. SRC went for ten years or something here before we basically switched to SEMATECH funding and then eventually to DARPA, my group, Andy [Neureuther] and I. And that's not to say that was the only thing, we're also got our microgrants and we got our individual grants from companies, and some people had other funding.

06-00:42:09
Burnett: Was it a kind base loader for your operations that it gave you underpinning?

06-00:42:15
Oldham: Well, for me, it was just the whole thing. I continuously had the micros and continuously had a few industrial. You could get grants, some companies would give you a grant, and there's no contract. You don't have to produce anything, here's a grant to support your research. And that's the most wonderful thing because then you could spend it on anything and there's no overhead if it's a grant. So you get all of the money instead of half of the money. If you want, you can buy office furniture with it or whatever, but that's not the important thing. The important thing is you really have some flexibility. And so somebody needs a little support or a computer or whatever, you just buy it, nobody to ask. So we always try to get some of those. In fact, Andy and I still have a couple hundred thousand dollars sitting in a fund that was never spent. So we have to deal with that—

06-00:43:18
Burnett: Right, at some point.

06-00:43:20
Oldham: Yeah.

06-00:43:20

Burnett: Well, Berkeley will definitely go hunting for it, definitely.

06-00:43:23
Oldham: Yeah, well, they have a way of—

06-00:43:25
Burnett: They have a way of finding these—

06-00:43:26
Oldham: They have a way of finding, yeah. [laughter] Well, I ran these programs too, I like to be a boss, I don't mind that at all. So like the SEMATECH, I became the—Andy and I were co-PIs initially in the NSF and then as we got these bigger programs and we brought people in from other universities, I became the director because I'm kind of natural, and Andy doesn't boss people around well. You got to tell people sometimes, and Andy doesn't like to do that, he's too nice a guy, so. [laughter] He's such a wonderful person to work with.

06-00:44:07
Burnett: So you had to be the heavy sometimes?

06-00:44:09
Oldham: Yeah, well you have to, you know?

06-00:44:11
Burnett: Right.

06-00:44:11
Oldham: You have to do, and that's not the important part, but you got to think about all the different things and aspects and make sure people do stuff on time, this and that and that, you know?

06-00:44:23
Burnett: Right.

06-00:44:25
Oldham: And so yeah. So I just was natural at that and just took it and ran.

06-00:44:32
Burnett: Were people pretty, on balance, self-motivated or was it—were there instances where people, a part of the work was lagging and you needed to lay down [the law]?

06-00:44:42
Oldham: Maybe once or twice we had some people that weren't pulling their own weight. I mean we had people in different—in the end, I had this DARPA thing. Well no, at SEMATECH too, we had three or four universities because we had Texas and Stanford and RIT [Rochester Institute of Technology] involved. Stanford, we had a couple of people; in Texas, we only had one, and then we had like five or six people in Berkeley. And, yeah, once in a while, some people don't pull their own weight and so you want them to maybe get out or produce something but—

06-00:45:20
Burnett: Right.

06-00:45:21
Oldham: That's not a big problem. It's just you're trying to produce a coherent program too. You're trying to get people to talk to each other and do something that it's complementary and so, a little bit of that involved.

06-00:45:37
Burnett: Can you talk to me about that a little bit, about coherence and the development of coherence? We can maybe pick the time period, maybe it's the SRC period in the early nineties or it's later with SEMATECH. As director, how are you shaping the coherence of the program?

06-00:46:04
Oldham: Well, I may not be the one that's doing it, but I'm the one who's supposed to realize and make sure somebody's thinking about that. One question is who are you going to collaborate with? So Andy and I would—we'd have these discussions and we were doing resist—we were doing this lithography, and the photoresists are a very important part of lithography. Right here in Berkeley, we had one of the other experts and the other one was in Texas and so it made so much sense to approach those guys and say, "Look, well how about taking some money from us and working on these programs?" And most people are, "Yeah, okay," as if it's the stuff they want to do anyway.

06-00:47:05

Here, we had expertise on—well let's say in this last program, was a good one because I wanted to do maskless lithography, which is basically you have some active thing, which is instead of a photomask, where you shine light right through and then the light hits your chip and it hits your photoresist, you have something that does the same thing. It blocks the light, but it's programmable, right? I's just like going to the movie theater now, it isn't film there, it's a bunch of mirrors that move, and the pixels, which would be in the film, are created by—this mirror moves and light hits a mirror and goes on the screen at that spot. Texas Instruments makes that multi-mirror system. Well, I wanted to do that for masks, make masks. A photomask set for a modern—today if you want to do, you print a wafer, right?

06-00:48:21
Burnett: Yeah.

06-00:48:21
Oldham: So there's a mask set associated with printing that wafer, and the mask is—corresponds to an area on the wafer, which is like this, a centimeter square plus or minus a factor of two or three, and then it's repeated in some fashion either by scanning or by—anyway. So you have this mask, and light comes through the mask, and it hits the wafer, and you have a shutter, and you expose it so long then you move it. Well, that mask, which is a piece of glass about this big, not glass but some transparent material, that set costs millions of dollars. So you have an idea, well, let's build this chip, and you make the first pass, and you spend say $5 million on a mask set and then has a few errors and then you go and change it, and so on, and so on? Oh my God, it's *very* expensive to do development. Whereas if you have instead a mask, which is digitally created at the moment you want it, then it doesn't cost anything and you can be totally flexible in how you—it's enormous, enormous potential impact right?

06-00:49:45
Oldham: Now, that's how you make a mask. You use actually—mostly use e-beams to hit the photoresist on a mask, or electron-beam resist on a mask and expose it and etch it, and so on, and make it. All I'm saying is you eliminate that whole step so that there was this technology called direct write where the e-beam writes the wafer directly. It doesn't write the mask; it writes the wafer. Well, in the middle of this program, it became clearer and clearer and clearer, and people did not want to believe it, that you fundamentally can't do that. It's fundamentally impossible to do that because electrons are charged, and it's almost this simple. If you put too many electrons in a space, they interact with each other. You put an electron here, the other one knows, because, positive—they repel. So you can only shoot so many electrons at something per unit time because you got to keep them apart. It's really almost that simple.

06-00:51:09

So if you work that through, there's no way you can write a wafer in any reasonable time with an e-beam. It can't be done; it's fundamentally impossible. So the handwriting was on the wall during all this time, but people don't want to believe that because they were big projects to do that, massive, big projects to do that. They don't want you raining on that parade, and some of those are funded by the same people that are funding you, and oh my! So anyway, we fought those battles, but we wanted to do this with photons. Photons, you can put as many photons in a bottle as you want. They don't interact, right?

06-00:52:04

Oldham: So we wanted to do with photons, and our last big project was we had this SEMATECH center called The Lithography Network. And it had two meanings, but one meaning was that it was just like a whole bunch of researchers around the country working on them, so that's what they took it as. But in that project, I was the one pushing this, this maskless lithography. We had Avideh Zakhor at Berkeley who is an expert data compression. She's really, really good, and so. Everybody said you can't get enough data, the data flow, you know it's one thing to get the electrons in, but if you're going to write a whole wafer like this in say ten minutes or something, if you think of the number of bits. It's staggering the amount of data and there's no data streams, so you have to do data compression. Because there's a lot of repetitive things and you can compress data, and she's the expert in that, so we got her interested. This is the kind of—

06-00:53:42

Oldham: —collaborations we did. And she was interested in everything, and, oh man, the first time she came, all these lithography guys, these technical guys, oh, they just pooh-poohed that. And then she showed some stuff, which was just amazing, her results, and finally they woke up to that, this was great stuff. Now, nothing came of that. This was one of our failures in the sense that it didn't produce a product which industry then made. We explored all the different aspects, photoresist, the optics, data compression, all of this stuff, we did all of these things. And I had my students working on this modulator to modulate the light, and light that stuff. So each of those we made contributions in, which are individually I think significant.

06-00:54:42

But the whole thing failed in the end because what happened is in the midst of this, we went to immersion lithography, in which the wafer is actually underwater for optical reasons, and this made the whole thing very difficult. The other thing is the machines to do lithography became so big and so expensive, and now basically one company makes them, ASML [Advanced Semiconductor Materials Lithography, based in the Netherlands], and they're hundred-million-dollar machines. Even buying one tool, a hundred million dollars, that they didn't see this in their—for a while there, they would come to meetings, and they would show you what their machine would look like with this kind of a thing, but they didn't see that in their product portfolio. Anyway, the project became, I would say, impractical at that point. I'm not so sure it isn't in the future with EUV [extreme ultraviolet lithography], but anyway.

06-00:56:02
Burnett: If I understand it, it's analogous to—if lithography is a negative process, right. So you're creating a mask and every—and light shoots through the openings, and that becomes the positive thing on the other side. Now, you're actually thinking of the software or hardware interface that would allow you to direct a single beam to write it all positively the first time without any kind of mask in the way. That's the basic idea. And immersion lithography made that impractical?

06-00:56:44
Oldham: Well, there's a lot of things. I would say immersion was one of them, but there's—the field was fast developing. The result was the machines became very big and complex, and people didn't want this additional thing. They still want to use masks. Now the masks for today, for EUV lithography are the problem, and they're a real problem. I mean to make them, to examine them, how to even know if they have defects in them, it's a real difficult problem, very difficult problem. So this may come back to that ten, fifteen years from now, you may come back to a maskless approach where you do that. But right now, they do the mask, and you just spend $10 million on a mask, and you say, "Well, let's build a certain chip," well, you got $10 million, buy the masks. It's just staggering, it's staggering that you could even do that.

06-00:57:52
Burnett: Right.

06-00:57:53
Oldham: And then you think about, well, how about if the university wants to make a chip, how do they do it? That's interesting. So for while there, we had so-called project chips where the university doesn't need a whole chip this big, it only needs a little piece of that, so they did these multi-project chips. So you put twenty or thirty university projects on one chip, and that was very—I don't know what's done today. I don't know what's done today to do test chips, I really don't know. But it's a real problem because it's expensive.

06-00:58:33
Burnett: Yeah, it's almost like in the days of SPICE, you know there was—to design a chip, you had to build the breadboard, you had to model that first, and with SPICE, you had software that would model it for you. It's analogous in a way because you're talking about [the fact that] you don't actually have to build a mask, you could—

06-00:58:58
Oldham: Yeah, create it on the fly with—

06-00:59:00
Burnett: Yeah, and tweak it, most importantly, right—

06-00:59:03
Oldham: Yeah.

06-00:59:03
Burnett: —I suppose, just realizing, "oh, okay, we've got errors in this $5-million mask, now we need to"—

06-00:59:10
Oldham: A mask doesn't cost five million, it's the fifty masks because it takes fifty masks to make a chip not one, it takes fifty. I mean maybe I exaggerate, maybe it's only thirty-five but—

06-00:59:21
Burnett: You've identified that bottleneck then, you're pointing to it, and there was a workaround in the case of SPICE. It was much easier to use software to do the design and then when you've got it right and you've tested it digitally or virtually, you actually can make the thing. But here with lithography, you're still stuck making the thing each iteration.

06-00:59:47
Oldham: You have to make a mask each time, yeah. Well, the same thing happened with mechanical design. With finite-element design means you didn't have to make the thing ten times and see where it broke. You could calculate where it's going to break and decide how many years the door handle on your car will work before it breaks. That's designed in now, and that was never true before. Before, they had to just make a lot of door handles, and they made them thinner and thinner and they started breaking them, so they made them a little thicker, and then, okay, they got it. Now it's all done by computation, right?

06-01:00:27
Burnett: Right.

06-01:00:27
Oldham: With finite-element design. And so that's analogous in mechanical in what we do in electrical but, yeah. Anyway, we got into that subject through this collaboration and idea, and I think that was good. I think people really did listen to each other, and I would normally never listen to Avideh's talk, right?

06-01:00:56
Oldham: Because I know nothing about that. Even in the resist talk, even Grant Willson's wonderful stuff on photoresist, I would normally not get into that chemistry so much in that. So that's a nice thing about those bigger programs is it's cross [disciplinary] and it's cross-university so that was good too, that was good too. So that's kind of a cross-fertilization, which is good for the country and good for the universities and good for the research because it benefits them.

06-01:01:37
Burnett: Yeah, and by leading this too, you have the excitement of shepherding the projects along?

06-01:01:45
Oldham: Well, I don't know about that.

06-01:01:47
Burnett: No?

06-01:01:48
Oldham: I don't know.

06-01:01:49
Burnett: Putting too much of a gloss on this.

06-01:01:52
Oldham: I don't know. [laughter]

06-01:01:56
Burnett: But you did get to witness this flowering of research. And so was the DARPA multi-university, that happened sequentially, right? So SEMATECH is—

06-01:02:13
Oldham: Yeah, well that was phasing out, and what happened is SEMATECH, there's always this competition between software and hardware. And there was a time around the turn of the century already where there was a feeling that, "oh, all the action was in software, what is all this stuff? What are you guys working on processing? You're behind the state-of-the-art. Look at the industry, they're working on half-micron, and you guys are working on two-micron, you're way behind the state-of-the-art. You can't contribute," and there was all that. "Why don't you work on software?" And so there's a lot of that going on, and that was unfortunate because the funding for then I think SEMATECH—I think SEMATECH basically pulled most of the hardware type of funding development of process out and went more for software stuff through design. Like design software, there was a big push to make—well you think of SPICE, but SPICE is a very low-level—SPICE is if you had a circuit, it'll tell you if the circuit works, right?

06-01:03:35
Burnett: Right.

06-01:03:36
Oldham: But the layout of the circuit on the chip, that's a different kind of software: where the wires run, and you've got a big chip to lay out, not a memory but like a microprocessor—

06-01:03:51
Burnett: A processor—

06-01:03:51
Oldham: —chip, and it's got this, and it's got that, so it's not regular. It's just somebody draws a schematic and you say, "Well, where do I start, where do we start to layout?" Well, then these programs were developed and Cadence and these software companies. They're mostly started by Berkeley professors, Alberto [Sangiovanni-Vincentelli] and Richard Newton are behind most of those companies really.

06-01:04:21
Burnett: Very interesting.

06-01:04:23
Oldham: That is the powerful stuff because it lays these out in a way that they can be built, right? And so SEMATECH put a lot of money into that kind of thing and other kinds of design-related software simulation. We continued to do our processing simulation then, Andy [Neureuther] has done that over the years, and a lot of that—a lot of emphasis on optical simulation because optics aren't perfect. So Andy got much more into the impact of optical aberrations and how to measure them and that kind of thing in the later, later years. But they [SEMATECH] were not interested in processing. So about the time I was retiring, I thought, well, it's going to be grim getting funded, not my problem, I was retiring. Now suddenly, there's a realization that hardware is what made all the software possible.

06-01:05:40
Burnett: It's just a realization? [laughs]]

06-01:05:42
Oldham: Yeah, they're just finally realizing, look if we couldn't run these things, if we couldn't put 100 processors on a chip and run them all at such a speed, we couldn't do these computations, and therefore, what will we do with this software if you can't run it? There's that. So you have to keep improving the hardware, and you improve the hardware not by laying it out better; you improve it by making the processes better so that you can keep making it smaller or stacking it in three dimensions, all of that. So that's what is happening now. So now we've got to fund that again. So there's this big push to get funding, industrial—government funding, so we'll build chip factories in the USA and so on.

06-01:06:32
Burnett: Well, yes, geopolitics plays a role in some of these reckonings, right?

06-01:06:38
Oldham: Well, right now, for sure, everybody's—yeah.

06-01:06:41
Burnett: Yeah, I was having this conversation with folks long before the war in Ukraine and the anxiety over Taiwan, although that was always perennial, I suppose. But I think this idea that you can offshore everything including the

stuff that's integral to your defense capabilities, is just kind of bonkers. But, yeah, that's kind of what we did.

06-01:07:07
Oldham: That's what we did, and I was hoping that was what leads to ultimate world peace. We're all dependent on each other, so we can't have a war but—

06-01:07:16
Burnett: That was the assumption.

06-01:07:17
Oldham: That was the assumption. Well, that was the dream, I would say, and it didn't quite get there, and now, we've interrupted that, and I guess the Trump era is what brought that to light by him saying "stop this, stop this, stop this" and then China has to say, "oh well, then we'll stop this, stop this, stop this," right. Maybe they've got all the rare earths, so we can't make any magnets and we can't make any motors or they've got all the chromium, we can't make—you know? That's too bad.

06-01:07:59
Burnett: Yeah, we lose the benefits of trade—we can't focus on what we're good at anymore. We have to do everything because our trade might be cut off at any minute and so we have a protectionist orientation. But there just seems to be this phenomenon, this economic phenomenon: the market is kind of blind and we just invest in the high-return thing, and software is perfect. It's almost the perfect economic product in that the—there's no unit cost to it. An economist was telling me about this, that it's so attractive because once you've developed the thing that's of value and you sell a gazillion of them, it costs you nothing, but you get a per-unit revenue from it or a subscription revenue. It's so profitable, and it's so seductive, but it sits atop this technological edifice that goes all the way down to raw materials at the bottom, right? But all of these stages of innovation created the possibility for a software industry to start with, and a market for it. And I don't know how to price that. Like the market won't take care of that. Same thing with food: 98 percent of the population does something other than make food, and the food has a comparatively small part of our economy even though the United States is the most productive food-wise in the world. So we need food to live, though. It's the most valuable, it's the most valuable thing that fuels the engine of the human, right? And yet, its dollar value versus a single large software company, I don't even know if it stacks up against Google, the entire agricultural economy of the United States.

06-01:10:07

So we're not good at pricing to incentivize, right? So what's the minimum amount of investment in innovation to keep processing innovation going? And I think of SEMATECH even though there is the specter of Japanese innovation that spurred it, it's almost like—that's a symptom of this larger problem we have is we can't price perfectly the innovation that we need to keep all of the rungs of our ladder of technology sound. And we've got this skewed market that privileges one thing over another, and it—it's going to end up biting us, or it is at this point.

06-01:10:58
Oldham: Well, I view that as the fact that the control of capitalism—I mean capitalism, run free, we know what that produces, it produces a few rich people and a whole lot of poor people. So you have to control capitalism, and we have never developed the mechanisms to control capitalism. We went through it in the—well in the late nineteenth century and early twentieth century, and we went back, and we killed all these big monopolies and set that back, and that's what you had to do. But since then, we've done nothing, and so they're just running away, and capitalism uncontrolled is not a stable system. It's stable in a sense it will go in one direction, but it's not the direction you want the world to go where there's a few rich people, everybody else is a slave, right? And so how do you control capitalism? Well that's all what politics is about today. There's the far right says you don't control, the market solves everything, right?

06-01:12:08
Burnett: Mm-hmm.

06-01:12:09
Oldham: The left says, "bullshit." Socialism, right?

06-01:12:12
Burnett: Right.

06-01:12:12
Oldham: And so somewhere in between or some new system but—

06-01:12:19
Burnett: Have we lost the in-between, though?

06-01:12:22
Oldham: Well right now, we have.

06-01:12:25
Burnett: But I do think that there was a kind of middle of researchers in the fifties and sixties who were economists who had a model of investment in education and innovation, that research provides these dividends, and the dividends accrue to many, if not most people, and that argument then got—

06-01:12:56
Oldham: Well, who was the economist that said the—

06-01:12:59
Burnett: Theodore Schultz at the University Chicago.

06-01:13:00
Oldham: Oh no, there was another more famous one, not Friedman or somebody anyway, who said all the stakeholder stuff is nonsense. All that corporation needs to do is make money for the stockholders, that's what its job is to do.

06-01:13:17
Burnett: Right, it's probably Stigler, George Stigler, I don't know.

06-01:13:20
Oldham: No, it's somebody with a more famous—anyway. That doesn't work, I really believe that doesn't work, but then what am I? But anyway, we got into this by software versus hardware, and processing is part of hardware. You have to keep improving processing, and you have to keep inventing new devices. Well, my career, we did about forty years of we had the device—well actually, we started out with bipolar transistors, but that only lasted maybe ten years. As soon as we went to MOS [metal-oxide semiconductors] transistors, we had the device, and the next twenty-five years, all we did was improve that one device and make a few things around it.

06-01:14:11
Now when I went to Intel, the simplest process I think was like five mask layers. Five mask layers did everything. A mask layer defines the aluminum patterns, or a mask layer defines the holes in the oxide where the aluminum contacts underneath, or a mask layer defines where polysilicon is, but there was only five mask layers in their simplest process. Today, there's thirty-five or forty in their processes, so all that had happened—and devices are—now they're FinFETS [fin field-effect transistor], they're not simple planar FETs. But basically, we've just taken that one device, and we just improved it through the years for thirty years. That's over. So now we had to go to the FinFET, and now we're going to this other device, this all-around FET kind of thing, much more complicated so that you can make it smaller and still works.

06-01:15:13
Oldham: Because we've got to make it to smaller for two reasons: Because it's faster, and we can put more of them on a chip, so we can do more complex operations. We go from giga to tera, right? We got to go from giga to tera, so, and we got to keep the power down, so all those things. So we have to change the devices now, and now, we have to stack them in three dimensions. Well, that's all the kind of stuff we do, that I did, my students did, it's all that, and I think universities need to play a role in that, if nothing else, to train the thinking of the people who will do it. That's the bare minimum, but actually you know the FinFET, which was the last ten years, came out of Chenming Hu and so on. That was their device. That came out of the university, so—

06-01:16:17
Burnett: What is the next device after FinFET? It's—

06-01:16:20
Oldham: Well, oh, after FinFET, it's—the FinFET just means, instead of having a gate on the top and then these electric fields reach all around, you put the gate on three sides. You got a little chunk of silicon, you put the gate on three sides, now you control the electric field, but there's still a bottom. So finally, it's no good, you got to put the gate all the way around, so you completely control the electric field inside this junk that you think you're controlling. So you think you're controlling. If you got it all the way around, it's controlled now, you have it controlled. But putting it all the way around, that's complicated as all goodness.

06-01:17:01
Burnett: Yeah, I bet.

06-01:17:02
Oldham: So, yes. But then after that, we have these one-dimensional devices, the graphenes and the—

06-01:17:13
Burnett: The nanotech stuff.

06-01:17:15
Oldham: Well, I don't know if it's called nanotech. I don't know what you call nano. I don't know what nanotech is, but there's a class of semiconductors, which are basically one-dimensional sheets. You know what graphite is?

06-01:17:27
Burnett: Yeah.

06-01:17:27
Oldham: It's kind of a layer of stuff that's all connected in one plane and then the next plane and they're only weakly bonded. That's why graphite is so slippery, right? Well, there's a whole class of materials like that. I mean moly disulfide is used in automobiles as a lubricant. Molybdenum disulfide, it forms the same kind of stuff. Well, it turns out, it's a wonderful one-dimensional semiconductor too, and it has wonderful properties. It can be metallic, it can be transparent. It's amazing. So these things are just fabulous. And then we had the—the graphite, very tiny, a few dimensions across like this that you wrap a gate around and the they're like fibers, you grow them.

06-01:18:35
Burnett: Like fiberoptic stuff or—

06-01:18:37
Oldham: No, no, you—

06-01:18:38
Burnett: —nanotubes?

06-01:18:40
Oldham: Yeah, is it a nanotube? But it's a nano-structure. It's nanotube I guess, is that what you call them? I don't work on this stuff, so.

06-01:18:47
Burnett: Yeah, but I think so.

06-01:18:48
Oldham: But anyway, you nucleate this, and you can grow this thing, and it grows this hairy-looking thing, like a hair, but it can be a semiconductor or a metal, and that depends on what you call the chirality, how it's stacked. And so these things are wonderful and small, but how on earth do you integrate them all into a chip? So nobody's figured that one out. But the one-dimensional planar ones, the graphenes and the analogues of graphene are really looked to be potential futures. So somebody will figure out how to do that and then we can make, like our brain, a three-dimensional structure.

06-01:19:45
Burnett: So it's modeled after neural networks?

06-01:19:48
Oldham: Well, it somewhat is, you might say that. But the point is, chips are one-dimensional. You think there's thirty layers there, but actually, there's only one transistor layer, right? So you make them, and if you could stack them, and you can't stack them right on top of each other because it has to be single crystal. Once you got this one, you can't put another one top. So to do that—I shouldn't say you can't; it isn't easy. So that's the kind of direction we're going to have to go to get another Moore's Law age where we improve things a factor of two every few years. It will happen, I think it'll happen, but it's going to be a little bit slower and getting it going is going to be tricky, but you need a lot of people working on that, and they got to be trained and interested, and that's what we do.

06-01:20:56
Burnett: Yeah, so a research program, we were talking about K–12 and the poor pipeline that we have into universities, and you think of the National Defense Education Act, which prioritized science education for high school kids or K–12, and its integration into this larger Cold War-era support for scientific research and development, the industrial labs but also the government labs, and that feeding into the support of university research. You see SEMATECH and these things like that, in your view of the scheme of things, are we missing out on a larger, more fundamental research program that the state supports or that industry supports together with the state? Was SEMATECH too small in other words?

06-01:21:59
Oldham: Well, SEMATECH was pretty good. I mean it didn't supply all the people the industry needed by any stretch, but it supplied a lot of the important ones. Yes, something like that, a factor of five bigger or something like that. Let me

say something else that's relevant. You only want to do this and train all these kids in this field with the expectation their career is going to be in that field if there is a career in that field. We're doing that in biotech and there's no career. I mean we're training, we take the most brilliant kids out of high school science, and we put them what it's called molecular biology at Berkeley, and they come out, and they're really bright kids, and they're their brilliant, and they can sequence your genome and they can do all this and that. Then what do they do for living? Well, they fight for university positions, so they become a postdoc and then the postdoc runs out, and they become another postdoc. They try and get a university position. Well, getting a university position, and there's about as many in molecular biology as there are in English, and there's—you don't want to produce more people than you can hire, right? And you might say, oh well, industry will take them. Very limited, very limited job [market]. Whereas in the semiconductor industry, it's so fundamental to everything, okay, that everything has chips in it now, right?

06-01:23:53
Burnett: Yeah.

06-01:23:53
Oldham: You got a couple of guitars here, they're all acoustic, I congratulate you, but most people have a keyboard that's full of chips and everything. So you need all this stuff. Whereas the major application of molecular biology is in medicine. Well, the US already spends on medicine way too much per capita, so where are you going to put these people? You have to fire doctors and nurses if you're going to use the existing money. Where are you going to put all these people?

06-01:24:38
Burnett: So things have gotten out of balance.

06-01:24:40
Oldham: Well, what I'm saying is you really—I hate to argue, I'm not a socialist, I hate to argue for a planned economy. But in deciding where the government's going to spend money in educating kids, you have to think about where the jobs are. So you only want a certain number, you want these brilliant—we do want these brilliant kids in what we're doing in medicine now, in molecular biology, and so on, and it will be important in plants, it will be important. There's nothing wrong with engineering plants, there's nothing wrong with that, it's just what kind of plants you engineer. But you've got to think how many jobs there are before you turn out those hordes and waste those most brilliant kids you have. So you want them in the field where there are jobs and then it's going to help the economy in the areas where you need help, right?

06-01:25:50
Burnett: Yeah.

06-01:25:50
Oldham: Somebody has to think about that. I don't know who thinks about that because we do not have a planned economy, but you have to think about that.

06-01:25:58
Burnett: Economists do, I think they think about it. The thing is it's a dynamic model, right? And so by the time you train someone for this industry need, the industry has changed and is no longer that way. And so the best laid plans, if we push and also if the state for example pushes too much in an area or gooses it in a certain area, then that generates its own kind of internal demand and supply problems, right? It's a bit tricky, and what one thing the economists will say for sure is that you have stepwise technological leaps. So the adage that they have in education is you can't say I want my child to be trained to be X because that X will not be X by the time the child is ready to work there. But what we could do is a better job of the general skill cultivation and adapt it to a particular application let's say, but the more fundamental skills around problem-solving and so on.

06-01:27:11
So this leads me to a more concrete question to bring it back to your work. When you're talking that the students are brilliant, the students are working in these highly specialized areas, and you were saying earlier that you moved from research and simulation to mostly experimental areas, what kind of "bright" are we talking about when we're talking about your ideal engineering students? I imagine it's different things. Some people are brilliant in certain ways and others. Can you talk about the types of skill, the types of personality that are important in doing the kind of work that you worked in and that you were in contact with? What was "genius" in that world? What did you regard as really important to have a skill in or to be skilled at?

06-01:28:15
Oldham: I don't have any idea. Obviously when you talk to somebody and you get into technical things, you can figure out what they know and what they don't know. Can you figure out how fast they learn? That's harder, that's harder to figure out. You learn that over a period of a year working with them, right? I'm useless at that, of taking ten people and then saying, oh, which one's going to be the—

06-01:28:58
Burnett: The next genius or whatever.

06-01:29:00
Oldham: You don't know. Some kids are just so stunning, but it's still a combination of things that they've already done and then how fast and how confident they are and how they deliver on things, their confidence. And some kids are very confident but then don't deliver, but you don't know that right away, right? It's like I am clueless in interviewing, clueless. I don't claim to be, and I'm skeptical that most people think they're good interviewers are good

interviewers, I'm a little skeptical of that, so I really have no answer to your question.

06-01:29:34
Burnett: Yeah, but that's an answer, that's an answer. I think it also speaks to the—in education, trying to identify the metrics of excellence and how that plays into the outcome, right? The SAT scores that are relatively good predictors of the first year of university, incredibly poor predictors of success in completing the degree, right? SAT is a proxy for some kind of aptitude, but in the really near-term. Figuring out how well someone's going to do over the long haul is very, very hard to do.

06-01:30:22
Oldham: Yeah. Well, these tests I think are good. They're really good at minimal. You don't have to have—I don't know what the numbers are—is it 800 on SATs?

06-01:30:32
Burnett: I think so.

06-01:30:33
Oldham: You don't have to have 800 on the SATs to become a star, but on the other hand if you have 500, you're probably not going to become a star. So they're really good at that, of setting some minimal, but as predictors of who of this cadre of really smart people is going to be most successful, of course, I don't—I'm clueless. Over a period of years, you work with them and then you realize, hey, this person could really do something. You still can't predict if they are because then it depends if they really want to and they do, and I can't. I mean certainly I have some students who I thought would—when I first worked with them, this person is really, really going to set the world on fire, and they didn't. And other people who just kind of plugging along and were—they were just terrific. So I'm not good at that, I don't know, I don't know anything about it.

06-01:31:38
Burnett: Well, I do want to talk a little bit more about the DARPA work, and you said that SEMATECH petered out in the mid-nineties, then DARPA took over from the '96 to 2003. Can you talk a little bit about the DARPA multi-university research consortium?

06-01:32:04
Oldham: DARPA funding was at Berkeley for a long time in the computer science area, and I guess in some of the other areas, maybe communications I'm not sure. We never had any, but we were really good friends with those guys from all the conferences over the years. And then just about when SEMATECH was petering out and SRC was there, but SRC was limited and SRC—you only want so much of your money at SRC, the way they run their program. So DARPA was—would entertain a proposal and so I said, "Okay, let's—" We got all these guys together and said, "Okay, let's write a proposal on this lithography network," and we got it, and that lasted the last five years or so or

at least that I would say before I retired. They were wonderful, and I don't think—we never delivered an internet kind of thing for them. We never delivered an internet, but I think most DARPA funds—the proposals most DARPA research projects don't deliver an internet. It's the rare one.

06-01:33:31
Burnett: Right.

06-01:33:33
Oldham: But it was great and reviews were great, uh, and we'd have these annual reviews, we all come together, we normally had them here. I think maybe once we had them at one other place. SEMATECH we had them a few different places, but they usually come to Berkeley, and it was a good time for everybody. All these people and people are happy and doing their work and stuff, it makes for a great interaction, and so it was very good, I must say. It was a very good time, and there were some good things done, but we didn't deliver big, single innovation that changed the economy of the US.

06-01:34:20
Burnett: No, but is it that you have this community that's built around this? It only lasts for a few years, but those relationships presumably lasted longer, then you can then have—

06-01:34:41
Oldham: Oh yeah.

06-01:34:42
Burnett: In other words, there may be innovations that you're not aware of that came out of that, but maybe twenty years down the road.

06-01:34:50
Oldham: Oh, yeah, like Jeff Bokor was a member of this. I don't know if I mentioned. He was a member of this network too, and he then—after I retired and that program ended, within a year after I retired, I think that network, the Lithography Network ended, I forget exactly, and I stayed on. After I retired, I stayed on for a year I think running that, and I may have retired when the DARPA network ended but—

06-01:35:19
Burnett: I think 2003?

06-01:35:21
Oldham: Yeah, it may have been, no, but I mean I may—I probably stayed on for a year at least because I still had some students to finish up. But I think the DARPA network ended around then, probably '03 or '04, '05, I'm not sure. But then some of these people then formed other collaborations that are relevant and related, right?

06-01:35:42
Burnett: Hmm.

06-01:35:43
Oldham: Sure. Yeah. these are friends for life, some of these people, you know? Some of them but unfortunately even older than me, so they're not around anymore. [laughs]

06-01:35:57
Burnett: Maybe we should just take a quick break, and let's come back and continue talking about this work because I think it is really—it's much broader than the research itself, but the processes and that the larger social, economic context around it as well.

[BREAK IN VIDEO]

06-01:36:29
Burnett: Okay, so were we were talking about the long-term multi-university research grants that you had, but you also had a lot of other small grants as well that helped you to work with students and postdocs through this period. You talked a lot about maskless lithography, and we had a little bit of a conversation about failure. One of the phrases I think that comes out of engineering is the importance of failing well. You describe these as failures that weren't failures. So I'm wondering if you could walk us through a couple of examples of the ways in which that you didn't ultimately have an outcome that you necessarily wanted, but that it was somehow productive in other ways or beneficial in other ways?

06-01:37:32
Oldham: Okay. So I use failure in a very, kind-of sense of an engineer who wants to see everything he does eventually for sale. You can buy it in the local RadioShack, but the RadioShack doesn't exist today. The maskless lithography idea was one, which would have had huge impact had we—and it's we can't be successful—had the idea caught on and the industry adopted that as a viable approach to mainstream. There is maskless lithography, but it's a really, really tiny effort. To make that mainstream, it's a many, many billions of dollars investment, and so we don't do that. Like I had a conference on maskless lithography, I actually named the field because it used to be named "direct write." Direct write is a much—a very visual idea that you don't use the mask, you just write directly on the wafer, it's a wonderful thing. But unfortunately direct write was adopted by the people who use e-beams, and if you said direct write, it meant you're trying to write on the wafer with an e-beam, and that's the wrong thing to do. As I said before, we showed you that's fundamentally not possible. So we needed a new name and so we—I just said, okay, we're going to call it maskless lithography.

06-01:39:26
That was an example of one which, for various reasons having to do with investments and so on, did not get adopted by industry in any significant way. But there are a lot of small projects were really interesting that could have become mainstream technologies and didn't. I'm trying to think when it

happened. There was something called "soft errors" that happened, was discovered around in the mid-seventies, and what it turns out, it turns out that—you don't realize it—but everything is radioactive. You don't realize it. Like any metal, any metal is radioactive, and why is that? Because mental, nickel, or steel, they're not radioactive, but it turns out that all steel has been contaminated. Steel is reprocessed. Steel is one of the things we recycle. Well, if you throw one radium dial watch into molten steel, then that radium is distributed through all the steel and then that steel is radioactive forever. And so everything is radioactive, and some materials contain significant amounts of—like thorium is a common [occurrence of a radioactive element in materials].

06-01:41:06

So what happened in the seventies is that in Intel, I was working at Intel, I think I was a consultant when this came up, I think I was no longer working there, but they made—they decide to make a memory out of a CCD. And a CCD is a charge-coupled device, and it was one of the more dense devices in terms of the number of bits you could put in a small area, and that was used, as it is today, as an image sensor. So you can make 2000-by-5000 pixels and then each one of those, you can sense the photons that hit it, and a charge-coupled device will do that. Also, you can use that as a memory because when those—when they go there, they'll sit there for long time. They can be stored there, so it can be a memory. So Intel had a group making CCDs, memories, and they worked, and they were dense. I was doing DRAM, this other group was doing CCD memories, they were denser than we could make. It doesn't compete exactly with DRAM because of the speed and so on, but it's potentially a very interesting memory.

06-01:42:22

And then they them put in a system, and you put them in a system, and you run them and run them, and they had something called soft errors. What is a soft error? It means you store a bit there and you come back and read it later and the bit's changed. You say, wait a minute, there's a failure there. And so then you store it again, it doesn't change, it works fine, that bit works fine, and it's a soft error, it's not a failure of the device. And it turns out it was alpha particles because they put these in a package, which had a metal lid, which was sealed with a low-melting point glass, and that glass had thorium in it, and thorium emits alphas [radioactive alpha particles] and alphas were hitting that. And that amount of charge from one alpha particle will change the bit, okay?

06-01:43:14
Burnett: Oh, my God.

06-01:43:15
Oldham: This came out, it was one of the reliability physics symposia in like '76 or '77, this was like "wow!" When they first saw it, they didn't know that it was the alpha particles. They were thinking cosmic rays, and there is a cosmic ray, but

they're orders of magnitude less of a problem. So it became important to test for soft errors, so it's really cool. So I had an idea, I said, "Okay, why don't we make an alpha particle emitter and we'll scan the device?" So we scan, the question is how sensitive you can make a memory. We were making memories, I want to know how sensitive it is, how many alpha particles it'd take to upset it because it depends on how much layers of stuff is above it, et cetera. And in principle, you could compute it, but it's kind of cool to measure it. So we made these scanning-alpha-particle devices. We actually just took the radio[-active material] out of your smoke detectors. Some smoke detectors use a radioactive—I forget which material they use—but it's an alpha emitter, and it used photoionization to detect dust or detect smoke. So we could take that thing, and we put it in, and we put it in a capillary, and we have a beam and so we put a scanning device.

06-01:44:57

And I had a student do this for master's project, and it was great. He built this little device, you could scan it over and just measure any chip, how sensitive it is. So he went and gave a talk at a conference, and somebody came up to him and said, "Ah, what a great idea, I want you to join me and we're going to make a company, and we're going to do this." So the student came back to me, Francois Henley, says, "What should I do?" He says, "This guy wants to start a company, and—but how am I going to do my PhD and all that?" And I said, "Well, you've got to decide." I said, "You may want to do this." I said, "If you just say no and do your PhD, you may kick yourself the rest of your life saying I wish I had done that." I said, "So you got to decide what you want to do," and so he thought about it. So he went and he went and—well, that wasn't a business, but he made a company that did something related to that. It was testing for something quite similar and then he ran this company, and that was a moderate success, that company, but it wasn't doing scanning. So scanning alpha particles was never used. It turns out it's easier to test them in other ways than the scanning thing. So that was a failure in that, but it was cool, he got a best paper award at the conference, and he got a job, he got a company to do that. But it was a failure in a technological sense, because it didn't make a new way to do things that was important.

06-01:46:45
Burnett: Well, you facilitated the creation of an entrepreneur.

06-01:46:49
Oldham: Yes, and then he went out to found another company, so he never came back. He tried to come back to Berkeley, and I knew it would be a failure. I mean he was going to work a day a week, and I said, "Look, you're running a company, there's no way you can do a PhD," and so he—I said, "I won't take you as a student because I know it's going to fail." So he tried working for Professor Shih Wang for a while and that didn't work and so he never did his PhD. It didn't matter. He started another company, which was a completely different object and was successful, and I think he's now retired. But anyway, it's the

kind of thing, I say that a lot of your projects are not successful, but nonetheless interesting.

06-01:47:38
Burnett: Generative, they're generative, they generate talent, they generate the ability to innovate and go in a new direction, and that ultimately leads to something.

06-01:47:50
Oldham: Yeah, anyway, I had some students. I had two students come in with their own thesis projects, I've mentioned to you earlier, and they were the two that went to become faculty members elsewhere.

06-01:48:04
Burnett: That was Sodini and Chu?

06-01:48:05
Oldham: Yeah, and neither of those devices—well Sodini's was a device, a JMOS device, and—no it was Simon Wong. He wanted to do a certain kind of dielectrics. I can't remember what his idea was. Maybe it was nitride-oxide-plasma-produced insulator. I can't remember, but he did that, and we funded that. But I don't think that was an idea that was supposed to lead to a whole new industry or anything. Oh yeah, and one of my much more self-directed students, T-Y. Chiu, he was the guy who wanted to come in and do nitride implant to make silicon nitride. So silicon nitride is an important material in processing in chips. Silicon nitride is an insulator, it's beautiful colors because it's resonant, optical resonance. But it's an important insulator because it's—you can use it to stop the oxidation of silicon. If you put nitride on silicon, then you oxidize the silicon, it doesn't oxidize under the nitride and so that makes what we call selective oxidation. That's a very important process, which was invented by Else Kooi at Philips and a very important part of IC technology. Well, TY's idea was instead of depositing the nitride, you will just implant nitrogen in the silicon and make the nitride that way. He wanted to do that. And then he was also the guy who followed me to Europe. I took a sabbatical in 1980 in Europe, and he said, "Well, you're taking a sabbatical, I'm going too," and so he—I was going to—

06-01:50:17
Burnett: Was that the Siemens work?

06-01:50:18
Oldham: I went to Siemens and I said, "Well, I think I—let me see if I can get you a job." So I got him a job at the Technical University in Munich where I had spent a previous sabbatical, and a friend of mine ran that. He got a job there and had his experience for a year in working there. They had a lot of implantation stuff, so he may have been able to do some of that there, but then he came back to Berkeley and did that. I had a big group then doing oxidation and the structures with silicon oxidation, so nitride is an important thing. And so he played into that very well, he and a couple of other students, John Hui and I forget who else. We produced a lot of pretty good papers and a process,

which was used. Actually, out of that came a process, come to think of it, but it didn't use his implantation. We had a process called SILO and actually Motorola adopted that process for a while and ran the process that we published. But the silicon nitride to best of my knowledge has never been—I don't know, never been used.

06-01:51:41
Oldham: Again, it's the idea of you have an innovation, you work on it, it doesn't work, but stuff comes out, right, stuff comes out?

06-01:51:52
Burnett: Yeah.

06-01:51:54
Oldham: So it's a failure, but it's successful failure.

06-01:51:58
Burnett: And sometimes, something is a success but the industry—there's no room in the industry. We were talking off camera about Betamax and VHS, and the way in which Betamax is superior, but the market was in favor of VHS for other reasons that had nothing to do with the inherent value of the technology. You mentioned MESFET circuits, which I never heard of before and—

06-01:52:25
Oldham: Yeah, that was Case Hartgring, and I think that was his idea. I can't imagine that was my idea because I wasn't that much of a circuits guy to think. I think Case Hartgring probably said let's—we could make entire integrated circuits with MESFETs. I think he got Tektronix to fabricate the circuits and so he spent a lot of time up in Oregon making his stuff up there, did his PhD up there, and of course he did his PhD and all that. Of course, silicon was on this march. You don't get in the road of MOS silicon circuits because they will run over you, and that's what happened. There were still people late as the eighties promoting bipolar transistors. Oh, IBM, IBM was—they had a couple of really good people pushing bipolar because bipolar can do amazing things, but it had no chance, and the steamroller ran them down, and that was it. You never heard of them again.

06-01:53:42
Burnett: Just because of the market dominance of that? How does a steamroller work?

06-01:53:47
Oldham: The way it works is you have made your products like all memories are made at MOS because it was denser than bipolar and it's lower power, and the power is lower, right?

06-01:54:02
Burnett: Mm-hmm.

06-01:54:03
Oldham: And so the market in certain products was there and so that said investments are coming in. So then people are doing development to make that more effective and then we're making it smaller and denser, and this market dominance of it means that ten times, say, the investments going into that compared to bipolar. So the innovations in that are way outpacing the bipolar guys. I went on the board of a bipolar circuits company right in that time period in the eighties, '82 called BIT. A very brilliant guy named George Wilson, who had been a lecturer, he came in as a visiting professor at Berkeley and was a good friend of mine because we bicycled together and stuff. He started a company, he had a brilliant idea of how to make small, dense bipolar circuits, and it was called BIT, Bipolar Integrated Technology. And at the time, he could make a—I forget what it was—it was a particular circuit. I think it was like an A-to-D [analog to digital] converter or something like that. He can make a better one than you could make in MOS that year. So he founded this company, got investors, I was on the board for about two years or three years, and silicon steamroller was coming by, and we watched them go by, and it was over. By the end of the eighties, the company was bankrupt and was sold to China. Even though they had a very clever way of making bipolar very dense.

06-01:55:52
And the other problem that was happening is MOS got so dense. This actually happened while I was at Intel. I realized that the power level in our memories, 16K, was okay, you're going to get half a watt or something or some small amount of power. But if you're going to go to ten times that, the power one chip consumes starting to get to be ten watts or something awful, and that makes a whole—and you got hundreds and hundreds of these things, this doesn't work. So I started a CMOS project while I was in Intel and in the whole world, I was the only one who figured out. But the point is MOS, to go from nMOS to CMOS, it was like, okay, I had a mask, probably two masks, process is 10, 15 percent more complex, but the power drops by an order of magnitude or two orders of magnitude. And so the whole world just went bingo to CMOS. Well now, bipolar had no answer, so it was over with. But that was just this—had MOS not come along, had Intel not—because Fairchild invented the Silicon Gate and then Intel made it happen. Had that not happened, bipolar might have lasted another three or four years before CMOS buried it.

06-01:57:28
Burnett: Do you think it was inevitable given the path dependence, there's so much investment in MOS technology that the rate of innovation is going to be so much higher that—that's what you mean by the steamroller. It's not weight or mass, its speed.

06-01:57:49
Oldham: You can't stop it. And so, when I was consulting in the seventies, I was off consulting in gallium arsenide and all other things, [Dave] Hodges just kept

reminding me that silicon is where the action is; he kept saying that. He was so right, and I kept saying, "No, but this is so fast, you know this gallium arsenide is so fast, it'll just run silicon off the map." Well it never did because it couldn't, it couldn't.

06-01:58:21
Burnett: But that's a reminder—

06-01:58:22
Oldham: Hodges just kept reminding me.

06-01:58:25
Burnett: Yeah, that's a reminder that an engineer can look at any set of parameters, and it's a question of optimization and what are the trade-offs, right? And so its speed in one particular axis, but it's not just the total set of parameters, but you also have to include the economic parameters and the other—the outside of the system, the political influence or whatever. But you trust that something that was truly optimal would just naturally surface, but you're talking about maskless lithography and these systems, the fact that a single machine as part of a foundry, that single machine costs a hundred million dollars to build and the foundry costs $3 billion to make.

06-01:59:19
Oldham: Twenty billion now.

06-01:59:19
Burnett: Or $20 billion—

06-01:59:21
Oldham: Now, it's 20 billion.

06-01:59:24
Burnett: It's that just, and the cost of doing it and the speed of change, I wonder if it doesn't breed a kind of conservatism, that it's too risky to go outside of a system that has so much investment in it.

06-01:59:43
Oldham: Absolutely. Absolutely.

06-01:59:44
Burnett: You know?

06-01:59:44
Oldham: For sure, yeah, but it's a funny kind of conservatism. It's a funny kind of conservatism because—

06-01:59:50
Burnett: Born of rapid change.

06-01:59:52
Oldham: Yeah.

06-01:59:53
Burnett: Right?

06-01:59:54
Oldham: Yeah.

06-01:59:54
Burnett: Like that's the funny, weird thing about it. It's not that they don't want things to change, they're just constantly trying to skate over—

06-02:00:01
Oldham: It has to be proven to be workable, yeah.

06-02:00:05
Burnett: That's interesting. So you specialized for long time in what you would describe as experimental work. You were trying stuff that was often outside of the marketable stuff.

06-02:00:20
Oldham: Well—

06-02:00:21
Burnett: Maybe not.

06-02:00:22
Oldham: —I don't know about marketable, but I just believed you've got to do measurements. We were doing a simulation of oxide growth, right?

06-02:00:34
Burnett: Mm-hmm.

06-02:00:34
Oldham: Okay, so what do you compare it to? So I had a couple of students, I had one student, it was done by master's projects because I had a—we had bought a really nice little of SEM, a little scanning-electron microscope. It was easy to use and so I just had this guy who spent nine months oxidizing. So what's to learn about oxidizing? Well, a lot because when you put a mask over silicon, so you put this silicon nitride on silicon and then you put it in an oxidizing atmosphere, so it's like—that's like rusting, right?

06-02:01:10
Burnett: Mm-hmm.

06-02:01:10
Oldham: That's oxidation. So the oxide grows here and it doesn't here, well what happens at the interface? Really amazing, because it's tremendous stresses as it turns out because growth is three-dimensional if you think about. If you add oxygen and silicon, it expands, right, because what air—what was air, the oxygen in the air plus the silicon, makes a larger volume than the silicon was, right? So if you grow an oxide like this and you stop it right here, it wants to go like this too, and it just doesn't want to go straight up, right? And so there's

all these stresses here and so we got into that and we started looking and finding really weird things. Nobody had seen these things. So Stanford was doing the simulator of oxidation; we didn't do oxidation, Andy and I did plasma etching and deposition, no, we didn't do oxidation. Stanford had a program called SUPREM [Stanford University Process Engineering Modeling]. Later on, one of my students Pantas [Sutardja] did the simulation of that, and it just went to the Stanford simulator, but these were the data for that. Without that, we wouldn't have realized, my goodness, that's really how complex that is and there was flow. So this hard glass, this—way harder than this stuff, very brittle glass is flowing, it's flowing. It's what you call viscoelastic.

06-02:02:48
Burnett: Right.

06-02:02:48
Oldham: And so that was really interesting, and without doing the experiments, you don't even get into that. So he had to do finite element simulation of viscoelastic flow without the experiment. I like to do experiments.

06-02:03:05
Burnett: And you can discover something consequential as a result.

06-02:03:08
Oldham: Yeah, you do.

06-02:03:09
Burnett: This has consequences.

06-02:03:10
Oldham: Yeah, well just like the biologists do, right?

06-02:03:12
Burnett: Right.

06-02:03:13
Oldham: They got into all that. I don't know how much they do simulation now, but I mean everything is about protein folding, right? All the action is in the complexity of that. We know what's in the protein, we know what's in the gene, but how did these things interactive, and it's all with this folding and then they interact physically like that. Well, that's really cool. That's all got to be done experimentally, right? Some not all because now, we can compute some of that—

06-02:03:42
Burnett: Yeah, I think so.

06-02:03:43
Oldham: —but very interesting. So I was the experimentalist, Andy was the theoretical mostly, you know?

06-02:03:51
Burnett: Right. So a lot of your students were associated with these. Some of them were successes and led to companies, and some of them were less successful. You've assessed failure in terms of not leading directly to something, but your successes have been in all of these kinds of indirect impacts on the field and with your students.

06-02:04:17
Oldham: Yeah, they all got their PhDs and got jobs, so there was no failures in that sense, but we didn't, and I guess I didn't ever had the intention of starting a company. That was not a thing at Berkeley to start a company at that point.

06-02:04:42
Burnett: At that point, yeah.

06-02:04:42
Oldham: Now, my colleagues now all have started two or three companies, but I never felt that was part of my interest.

06-02:04:54
Burnett: When do you think that started? I mean you students who started companies, of course, as we just said, and Sutardja, Pantas [as opposed to brother Sehat] was one of your students.

06-02:05:03
Oldham: Well, they went out, and they worked for a couple years before they started. They worked at IBM those, the Sutardja boys.

06-02:05:08
Burnett: They started Marvell, is that what the—?

06-02:05:10
Oldham: Marvell, they started Marvell, but I had other good friends who've started companies. I mean a lot of my friends from Intel, they left and started other companies. So I'm a pretty knowledgeable about guys starting companies, and I got on a lot of advisory boards and things on these companies that people started. And I was on board of directors of start-ups, right?

06-02:05:36
Burnett: Right.

06-02:05:37
Oldham: But I didn't start them myself.

06-02:05:40
Burnett: You were on one for a really long time or a couple for a really long time. Nanometrics for fifteen years almost.

06-02:05:47
Oldham: Well, yeah, Nanometrics, I was on Nanometrics. I was hired. Nanometrics was a typical company where the owner of the company, one guy, it's owned

by one guy, Vince Coates. He started the company, and he still owned like 75 percent of the company. When I first time I went on the board in ' 86 or something, he went on the board, and he says, "Well, why don't you—?" He said, "Why don't you come be a consultant for me?" And I said, "Well, I don't know what I'd consult on" because he was a measurement company, and one of the things I did in here was some ellipsometry work back in the sixties because I needed some research results. I'm supposed to be getting research results, so I did ellipsometry, and it's a wonderful thing, it's a fabulous tool. So I did some work on ellipsometry and then through that, I got interaction with Vince because they made tools, measurement tools that did what ellipsometers do and got to know him. And so he says, "You come be a consultant." Well, it turns out he wanted me to be a board member, but it was a private company, so I went on his board for about three or four years, and then the company went public while I was on the board. Well, you don't want to be on the board of a company when it goes public because it's going to get sued. Every company that goes public always gets sued, and he didn't have directors' insurance or anything. I was so naïve, I did—

06-02:07:19
Burnett: So you got named in a suit?

06-02:07:21
Oldham: No, no, I didn't know about this stuff. So I just stayed on the board, and we never got sued, but I mean it was amazing. Then now, we're a public company, right? So now, we're a public company, I'm on the board and we're—I was on the board for like two years when it was public, and we'd have these meetings. Vince owned the company, so the board meeting is a kind of a funny thing when he owns 60 or 70 percent of the stock because stockholders vote, but he had all the votes. So at one point, I said, "Vince, I don't think you need me on this board. I don't think I'm really contributing," so I left in about three years, in about, I don't know three years later, maybe '89, I don't know. I had it written down somewhere, so let's see. Board of directors Nanometrics, '86 through its IPO—oh, '82 through '86, yeah, I was on that board. Then I said, "Vince, you don't need me," so I left. And then turns out later on, much later, he came to me in 2000 and said, "I need another person on the board," and I checked, and he didn't have 50 percent of the stock, he only had like 40 percent or something, so I knew that there had to be a real board of directors and so on, and so I joined that board. And I stayed on that board through—yeah, through 2014, which evolved. The company evolved enormously during that period. The stock went from five dollars to ten dollars to fifteen dollars to one dollar to thirty dollars, I mean it was amazing. But the company became quite a good company, and I left it in 2014. They didn't want somebody who was—I figured, I got the sense they didn't want somebody who's in their eighties on the board. Only Warren Buffet can have that.

06-02:09:28
Burnett: Right.

06-02:09:28
Oldham: He's the only one who can handle that.

06-02:09:30
Burnett: Why do you think the age matters in that?

06-02:09:33
Oldham: There's criticism if you look around, and I said, they don't need that. Nobody said anything to me or anything but nobody said—I said. "Look, I'm eighty-something," it shows. You have to put all that stuff on the—every year when you do the thing. I said, "It's time, I'm—I've been on this board a long—" and the company's evolved. It was a stable, good company, and they didn't actually all do all the things I wanted them to, so I wasn't having my way. So I said okay.

06-02:10:04
Burnett: Right.

06-02:10:06
Oldham: Time to get off.

06-02:10:07
Burnett: Sure.

06-02:10:08
Oldham: But it was great. I mean that was a long-term one, yeah.

06-02:10:11
Burnett: Yeah. You were on the Monsanto's board?

06-02:10:17
Oldham: No, that was—

06-02:10:18
Burnett: No.

06-02:10:18
Oldham: —a technical advisory board.

06-02:10:19
Burnett: Technical advisory board.

06-02:10:21
Oldham: I got into that which was a wonderful thing. Again, people, it's all just—it's all having the luck to interact with the right people. It was Jim Meindl at Stanford. He was the guy behind the Stanford lab, right? I mean I interact with a lot of his students and so on because [James] Meindl and [Robert] Dutton and—well Saraswat were the technical guys in my field at Stanford, so we interacted. And one day, he called me and said, "Well, I'm forming this advisory board on Monsanto—for Monsanto." Monsanto, well Monsanto made silicon wafers, that was their thing and so I was interested in that, and so

I joined that advisory board, and that lasted about five years. And it was interesting because we got talks from—what was his name—the guy who started the bio work there and got them into Roundup and all that stuff. He came in and gave a talk to us and said, "Here's the future," and he's telling us that, and sure enough, five years later, they were making—

06-02:11:41
Burnett: Glyphosate and—?

06-02:11:42
Oldham: Yeah. But anyway, they did wafers and then they did photoresist because they were wonderful chemists. Monsanto like Grace Chemical, there were some of these classical chemical companies around the US, which were world-class. They had research labs, they had good people—none of that anymore. All these places that had these great research labs with great chemists, just allowed to do basic stuff, it's gone. We don't do that anymore. They were making wafers, and they were looking at what does our industry need that a chemical company, and they looked at photoresist. These guys knew their organic chemistry, and they came and made a presentation to us, and that was really interesting to me because I was very knowledgeable about photoresists at the time and so very strong interaction. I loved that and then they made a successful photoresist for a while, then they gradually got out of that. There was too many people for this size of the market. It's one of those fields where too many people come in, and you divide the market, and so nobody has got enough money to do the research you need to do the next product.

06-02:13:04
Burnett: That's interesting.

06-02:13:05
Oldham: So that started a series of things. I did a bunch of advisory boards for T.J. Rodgers at Cypress had a start-up he had bought to do optical modulators [Silicon Light Machines], and I don't know. There were several where I was just on a technical advisory board not on the board of directors. And actually Cymer approached me then. Cymer is what became the—my major, I would say, technical where I was on the board for about ten or fifteen—ten—over ten years.

06-02:13:50
Burnett: Over ten.

06-02:13:50
Oldham: I was a technical guy on the board at Cymer. Cymer made all the lasers for lithography for the companies making—chipmaking machines, making lithography tools. And we just happened back when one of my students was—we had just—Andy and I were starting this, well, we were running, getting students in, and looking at all the problems said, "Can we simulate this, can we put this in our program?" and we were doing that. We needed a laser, so I bought a Cymer laser, this brand-new company, and there were three laser

companies. Cymer was the brand-new one, unproven product. I wanted laser, a deep UV laser, and I went and stuck my neck out and bought theirs just because, you talk to people, they have a feeling, this is and that, the other thing, and it turned out they made a reliable laser. The other guys made lab lasers. They didn't know what a reliable laser was because everybody's using lasers in their lab, and it lasts for 500 hours, and then you'd get it fixed and then nothing. But if you're using it in production, it has to work day in, day out, thousands of hours and so they were focused on that.

06-02:15:24

I didn't fully appreciate how that was true until later when we had a failure and I got a glimpse of their procedures to deal with that, and we had done the right thing. Then later, one of my students Bill Partlo who worked, using that laser at the time, he went to work for another company but then he went over to Cymer later on, and the he and the CEO approached me to be on a technical advisory board there, so I did that. We formed one good group of guys, oh terrific, and we used to meet then, and then suddenly, they asked me to be on the board, so I was on the board of directors then. They want a technical guy on the board and then I was for many, many years through the really interesting times when we're developing EUV [extreme ultraviolet lithography], which was very challenging.

06-02:16:22
Burnett: EUV, sorry.

06-02:16:23
Oldham: Yeah, EUV. EUV was the advanced—it's advanced lithography. See, lithography, the idea of lithography is you print something and to make—print something small, you got to use a smaller wavelength. We got the wavelength of visible light, microns and then red is 6328 so that's 0.6 microns, right? And so how can you print features that size when the wavelength is that big, right? So then you use a shorter wavelength. So then we went to UV and then we went to deep-ultraviolet which is 193nm, which is the limit. It turned out that was sort of the limit because of transparency of glasses. Quartz is still transparent at 193nm, fused silica. But any of the classical glasses, you know how lens is made with many elements of different kinds of glass to correct for color? A typical lens in your camera has ten elements.

06-02:17:36
Oldham: Well, it turns out, you can only use one kind of glass with the 193, so the whole approach to lenses was different. Anyway, then we wanted to move on. We did some experiments in other wavelengths and so on and then some guys at Bell Labs and the other places proposed this EUV. They proposed what's called soft x-ray lithography. There was a window at thirteen nanometers. Thirteen nanometers so that's fifteen times smaller than the wavelength of light [at 193nm]. So you got a factor of fifteen, that's wonderful in the wavelength size. So there is a window at thirteen nanometers and so that became the focus of some research of Bell Labs and at—where else were they

doing that? Well, I think Bell Labs guys, and one of our former students Obert Wood, who was student of Steve Schwarz's, came around talking about that one day. They used to come back to Berkeley and recruit, and they started talking about that. What on earth are you talking about? Anyway, they called it soft x-ray lithography as opposed to x-ray lithography because x-ray lithography shadow casting. You take a hard mask with holes in it, and you send x-rays, and if it's a lead mask, it stops the x-rays, and the x-rays go hit, and so they have a very short wavelength. X-rays are very short wavelength, but the only way to mask them is with this hard mask.

06-02:19:28

Well, Hank Smith at MIT was the—a guru of—he pushed soft—he pushed x-ray lithography for many, many years. It was going to break the one-micron barrier and all that stuff and very unattractive, very unattractive. These guys at Bell Labs proposed what they called soft x-ray lithography, thirteen nanometers, so it's a different kind x-ray, and anything stops it. You think of x-rays go through things, soft x-ray, I mean anything stops this thirteen nanometers. So you can't run it through lenses, you have to focus it with mirrors, but you can make a mirror with a multilayer. Say, how do you make a mirror? Well, you use a multilayer. Well, you know about Bragg mirrors, Bragg mirrors made—if you take alternating indexes like you take a high index, low, a high, low, and then you shine a light on it, it'll get reflected because these—at certain wavelengths because these thicknesses compare to the wavelength. So you can make a very good mirror with the so-called Bragg mirror, and at thirteen nanometers, there's a couple of materials you can make a mirror out of. They're transparent enough. So that's why this thirteen nanometers and then the question is how do you get thirteen-nanometer light? Well, that was the problem, but if you got thirteen-nanometer light, you could make lenses and you could make lithography with that.

06-02:21:14

So we started on that, and it was called soft x-ray lithography. We hated the x-ray lithography thing, so we changed the name to EUV lithography and it actually stuck. I'm pretty sure we changed the name because Jeff and I were talking in my office one day, and I'm pretty sure we said, "Look, we can't call this anything—x-ray can't be in the name," so we called it EUV lithography, and we started putting out this stuff. Everything in our publications, in our writing, everything was EUV, and it stuck and so it became—and EUV lithography, so it was invented in—by 1995 or something, and it was going to replace 193nm by 2005 or something. It was like, oh, it's going to take a long time, it's going to take like ten years. Well, it's just in production now. It took till 2020.

06-02:22:17

Burnett: Wow.

06-02:22:18
Oldham: This company, Cymer, I was on the board, this is a company, which is only—I don't know what our revenues were, but they were a billion dollars or something. We had spent over a billion dollars on that trying to make a source because we made the source, we made the light source. It's almost impossible, it's almost impossible, it's this close from being impossible. Hank Smith, mister x-ray lithographer said, "Ha," he says, "soft x-ray lithography, that's about as workable as the nuclear airplane." That's a quote from Hank Smith.

06-02:22:59
Burnett: Okay.

06-02:22:59
Oldham: And he's a good friend of ours. Yeah, Hank Smith is one of the good friends of ours, but he did not believe in that. He believed in hard x-ray lithography, and it's actually happened. All the big companies are using it today, it's very expensive, it's very difficult. Cymer almost went broke trying to make the source, Zeiss to make optics for that, you can't believe how hard it is, it's just really hard. So the light source, just the light source, the light bulb for the stepper is millions of dollars. I mean when we used to think of buying a stepper, it was $50,000 to buy a stepper. The light source for the stepper is million dollars or $2 million now. Anyway, so I was on that board, I was the technical guy, and all through that period, there was a question of whether our investment in this was going to be wasted. I mean it was really—it's touch and go.

06-02:24:06
Burnett: And where was the money coming from to make that investment, just VC?

06-02:24:10
Oldham: Out of your profits, yeah.

06-02:24:12
Burnett: So they were selling microscopes, and they were successful—

06-02:24:15
Oldham: Well no, Cymer sells light bulbs. They are light bulbs for steppers, and they're the best at it. There's a second company, there's one company in Japan that's sort of second in the world and they are selling 30 percent, Cymer is selling like 70 percent or something like—market share like that.

06-02:24:35
Burnett: So they're low-volume, very high-cost machines or equipment to be used for—they're essentially machine tools, machines for making chips, machines for that, selling a stepper. You've mentioned ASML.

06-02:24:53
Oldham: ASML, they bought Cymer in 2013. They wanted to own the company that made their light bulbs, they bought us.

06-02:25:06
Oldham: And so they own the whole thing. And they already had on the other steppers, which use—like, say, 95 percent of the lithography is still done with—you call it light but it's in the UV, deep, deep UV, 180—193 nanometers. ASML makes the overwhelming bulk of those. They probably make 80 percent or 90 percent of those already and then they make 100 percent of the EUV steppers, and I cannot see anybody else ever doing that. It's just the expense, you'll never get your money back. It's like Boeing quit building 747s and decided not to build the next generation, right?

06-02:26:01
Burnett: Yeah.

06-02:26:01
Oldham: And Airbus went ahead and built it, and now they stopped building it. You know that Airbus 3—that model

06-02:26:07
Burnett: Three-two-oh, whatever?

06-02:26:08
Oldham: That monster Airbus that is bigger than 747? [A380] They quit making that a year ago or so two years ago. They didn't recoup their investment on that, you can't. If you build an airplane like that, it's going to take you ten years of selling those airplanes to recoup your investment. So the chance of somebody else building another stepper—so ASML is by the way, if you like the stock market, I mean it's—

06-02:26:39
Burnett: It's a safe investment.

06-02:26:39
Oldham: You can use the word—they're dominant in the marketplace, you can't say monopoly, but they're dominant in the marketplace, so they set the price. So it's a nice position to be in.

06-02:26:51
Burnett: And that's an American company?

06-02:26:53
Oldham: No, that's a Dutch company.

06-02:26:55
Burnett: A Dutch company?

06-02:26:56
Oldham: Yeah, yeah.

06-02:26:56
Burnett: Interesting. So you're in the space of we're talking about the way the industry is. I don't want to pull it off into this abstraction, but you seem to be interested

in the smaller companies that make the equipment, that makes the chips, that make the software possible.

06-02:27:24
Oldham: Yeah, because that's my expertise.

06-02:27:25
Burnett: Yeah.

06-02:27:26
Oldham: Yeah, that's how my expertise developed by accident. I could've been in something else but—so then that's who I deal with, yeah.

06-02:27:36
Burnett: Yeah, and—

06-02:27:37
Oldham: I did a lot of other legal consulting for many years too in the same field.

06-02:27:43
Burnett: In the same space?

06-02:27:43
Oldham: But I don't even mention it just because people call you up and want you to be an expert witness.

06-02:27:50
Burnett: Right, right. I'm not sure if we talked about your senate service?

06-02:28:05
Oldham: Yeah, I don't think we did, a little bit.

06-02:28:09
Burnett: A little bit.

06-02:28:10
Oldham: But maybe in parallel with all this. I was moving in my research from, like—as I said in earlier time, I used to be in the lab itself, then I'm directing people in the lab. Then I'm the program director for these large programs, and my consulting moved from being a technical consultant for years at Intel and other companies, Xerox, whatever. It moved more to like the board of directors. Everything became more to the higher view of things. Again, the same thing happened in the university service. Of course, it's important at Berkeley to do university service because that's how Berkeley works. That's what makes it work. What makes it a good university is the faculty. Well, they used to run, it's less true today, but it's faculty run, and that makes better than a dean-run or a president-run university. But as time went on, I got into higher and higher levels of that, naturally, so—

06-02:29:40
Burnett: Well you began on the—at the senate level at the budget committee.

06-02:29:44
Oldham: Yeah.

06-02:29:44
Burnett: That's a real baptism often for UC folks, right?

06-02:29:51
Oldham: Yeah.

06-02:29:51
Burnett: Can you talk a little bit about the budget committee and what that's like?

06-02:29:54
Oldham: Yeah, the budget committee was just great. I mean it's one of the great experiences. It's an overwhelming job because you—the amount of work is way too much, way too much. So they do give you some reduced time, so I probably only taught like one course a year or something like that because you're just spending all your days in that office. We called it in the cave there just doing—what you do in the budget committee is 90 percent of your effort is on faculty promotions, hiring and promotion. So everybody gets hired at Berkeley or promoted at Berkeley, so a significant promotion is done through the budget committee. And so there's a dozen people there, not even that many, maybe eight, I can't remember, eight or nine people, and they process every advancement. In Berkeley, there's a lot of advancement. You don't just get advanced from assistant professor to associate. There's many steps in each level, and each step requires a recommendation from the department to the dean to the budget committee who then makes a recommendation to the university. And 99 percent of the time or I'll say 95 percent of the time, that's what follows, it happens.

06-02:31:23

What it does is it homogenizes the quality of the university. So if you look, Berkeley is really unique in that every department at Berkeley is expected to be in the top ten in the country. Whereas if you go to—I don't care, go to Oregon or something, go to another university or go to a Big Ten school, they're more comparable high-quality public universities, they'll have half a dozen great departments and then you go over to history or go over to comp lit or something, and they're just—you never heard of it. We have this uniformity of standards, which is entirely, in my opinion, due to the budget committee. The consequence of that is you work hard in the budget committee because you—every single promotion of every single person on campus gets a memo. We write a memo. On the budget committee, you write a memo, you get all this stuff from the recommendations, now you write a memo why this person should or should not be promoted, and that's in like a two-page memo. So you learn to write, you learn to talk to your colleagues in the budget committee, and so on. it's a great experience and you meet wonderful people there. That's all I can say—

06-02:32:53
Burnett: I don't think there's anything like it. What's interesting to me is that engineers and chemists and historians and economists and sociologists are sitting in the same room determining together what constitutes excellence in any one field.

06-02:33:15
Oldham: Yeah, and you learn what that is, yeah.

06-02:33:18
Burnett: Right. It actually is kind of a good breeding ground for moving up into larger university administration.

06-02:33:27
Oldham: It has been, a lot of the vice chancellors came out of there.

06-02:33:31
Burnett: Yeah.

06-02:33:31
Oldham: Paul Gray moved. I guess he moved from budget committee to dean, but a lot of times, they moved from budget committee to directly into the—one of the—

06-02:33:40
Burnett: The VC [vice chancellor] spots.

06-02:33:41
Oldham: Yeah, one of the VC spots.

06-02:33:42
Burnett: Yeah, were you ever interested in that?

06-02:33:43
Oldham: Just from the from the light side to the dark side because I call that the dark side.

06-02:33:48
Burnett: Well, maybe you've answered that question then. [laughter] I was going to ask—

06-02:33:52
Oldham: I was asked at that point to run for system wide. I think Karl Pister, I believe his career path, he was never chair, like me, he was never chair. I believe he was chair of the [University of California faculty] senate and then I think he went to be statewide chair for a while, I think, I may be wrong. Whereas I was asked to run for that and do that, whatever. I forget the process, but I said no because I was a few times into that building in Oakland [UC Office of the President] and found it a very depressing place. I said, I can't, I can't be part of this bureaucracy, I mean—

06-02:34:32
Burnett: It's just too dead?

06-02:34:33
Oldham: Oh, it's just awful. They have no connection with the academic. Everything is—whether it's—I don't care if you're worried about gay people or if they're worried about—

06-02:34:52
Burnett: It's policy.

06-02:34:53
Oldham: —equality or they're worried about—yeah, it's everything. It's just—and it's—and they put six people on it and it's way overstaffed. It's just a dead place. It's just an awful place, depressing place. I was in there a few times, I was like, oh man.

06-02:35:14
Burnett: So kind of the opposite of the budget committee where you're all day every day engaging with—

06-02:35:19
Oldham: Well, you're not spending—you're only doing that. We only met one day a week for three or four hours. The rest of time I'm in there—

06-02:35:29
Burnett: Reading.

06-02:35:29
Oldham: —reading and writing all these things, which I have to present to a bunch of people who are way better writers than me. [laughter] And some of them, you're talking about pretty good people, so it was really good.

06-02:35:46
Burnett: It sounds like it was nourishing for you. That's really amazing.

06-02:35:52
Oldham: And I'd mentioned there these key people. I said Carol Clover, she I think—over the period, I was on there two years. It's a normal two-year stint, and I was on there by two years. Carol was I think the chair the second year. I had to go back because Paul Gray got made dean or something and so I spent another six months substituting. I saw three chairs, and she was she was just so great, outstanding, she did the job. We had some weaklings, so we had a weakling, and he had bad judgment and couldn't write. So what in the budget committee you do? You make good judgments and you write well. He couldn't do either, so Carol ended up—she wrote all his stuff for him—

06-02:36:42
Burnett: Oh my God

06-02:36:43
Oldham: —besides her stuff. I mean you had—

06-02:36:44
Burnett: I can believe that.

06-02:36:45
Oldham: —as chair, you have to do that, right? And you have to not offend the person because they're important person on campus.

06-02:36:51
Burnett: Oh dear.

06-02:36:52
Oldham: Anyway, but it was great. Budget committee was great, I made friends in there. I've got to call Carol and find out—I think she's back around in town, so. Yeah, and then—

06-02:37:09
Burnett: And then into senate, vice chair of the senate?

06-02:37:12
Oldham: Yeah, then this guy Quigley calls me one day and said, "You want to—you're interested in being vice chair of the senate? You could be vice chair for a year and then you're going to be chair the next year." I said, "Sure." I had no idea, I've never done any serious senate. I mean I had done the little bit of committee work but none of the heavy-duty committees. There's some heavy-duty committees that really do a lot of work, especially the ones that have to do with the courses and curricula. And so I said sure, and that was another great experience. I put down in my notes Bob Brentano because you play some role in selecting the next person. I think the committee on committees selects—it's not an elected position. The committee on committee is elected, and they select who becomes the vice chair. I was never on the committee on committee, so I don't know exactly their process for that, but they do consult with the chair, and they consulted with me about Bob Brentano who I didn't know. And he's this wonderful, wonderful guy, Italian history, and he taught I guess religious history, and so on. He became vice chair when I was chair, and so you get to know these people, just fabulous people, right?

06-02:38:36
Burnett: Right, right. And you were an ombudsman in the senate—

06-02:38:42
Oldham: In consulting, I had done some dispute resolution work, and I saw the power of dispute resolution, and, boy, if there's anything this campus needed was some process for—there were some bad things, inequities happened here on campus. I won't say what they were because it involved personnel but the—Berdahl was the chancellor then, and there were some things where—things you can't let this go on. I knew things are going on and so you really need a place where—I'm an ombudsman, that's what ombudsman do. The

ombudsman doesn't take a side. They get the individual, the "wronged" individual, the unhappy individual, find out—and then they find what—who the people that impact that thing and then they talk to them. Maybe they had meetings, whatever it takes, maybe you have to. Many times, I just go to the chancellor and say, "Look, you've got to do something about this. You can't let this happen to this person." A lot of times, only the chancellor can fix things.

06-02:40:12
Burnett: And this is faculty? So it's—

06-02:40:14
Oldham: It's all faculty.

06-02:40:15
Burnett: It's a faculty stuff.

06-02:40:15
Oldham: It's all faculty.

06-02:40:16
Burnett: So there's faculty in a department and they're unhappy.

06-02:40:18
Oldham: Yeah, maybe a faculty member versus a dean or it may be two faculty members, it may be a student and a faculty, it could be. There's a lot of things, their promotions aren't going right, or there's a million things. Faculty get really, really mad, and we have a faculty who have opinions, right, strong opinions. They're used to getting their way, and they do get their way. It was a great job. I loved that job, but I did a couple years, and they want to move people through that, and so I did that. Just about the time that I was retiring they did the—we had these great people who were secretaries. Oh, we admired the secretary in the senate. I said, "Well, I can do that." So I did that only for about six months, and I said, "You know I can't do this because I'm going to travel, I'm going to—and I can't travel because there's these things I have to do here." So I said, so that's it, so I only did that one year. It was another great job because what I learned as—in the budget committee then as vice chair and the chair is you meet these people across campus, these amazing people we have. That's like their life—once in a lifetime experiences.

06-02:41:40
Burnett: Yeah, it's this enrichment, I mean it's the thing that—and you've put people at the center of your whole story. I think you've talked about students and colleagues and people you've met at Siemens and places like—that everything is an opportunity to have a new relationship with someone.

06-02:41:57
Oldham: Exactly.

06-02:41:58
Burnett: And that's what drives people anyway, right?

06-02:42:01
Oldham: Yeah.

06-02:42:02
Burnett: So it's good that you've kind of latched on to that as a way to make sense of and meaning of your career, you know?

06-02:42:12
Oldham: Yeah.

06-02:42:14
Burnett: We could do more detail on any one of these things, but I think I do want to leave you with some—are there other folks that you want to lift up, mention, other particular projects that we have not discussed?

06-02:42:41
Oldham: Not really. Of course, the risk of mentioning anybody's name in anything you do is other people will feel they should've been mentioned, right? I take that risk because I'm sure I forgot, and I apologize, I forgot you [laughter], but you only can remember so much especially if you're my age and your memory kind of sucks. [laughter] If I forgot somebody, it's, like you say, it's all about the people and your career is a lot about luck, luck. In my case, luck and dealing with the right people and knowing people you can count on and people who—there's somebody who—like I was this consultant for Chrysler all those years for Lee Iacocca. I still don't know who—I mean Lee Iacocca didn't find me in the phone book. I don't who turned him on to and I would love to know who'd recommend me because it was a great job. I mean I'm a car guy, and it was a great job.

06-02:44:05
Burnett: We haven't talked about your—I mean because we—I had the good fortune to—you have a few of your cars here, in fact all of your cars are here and not in Hawaii, right?

06-02:44:15
Oldham: Yeah.

06-02:44:16
Burnett: So tell me a little bit about being a car enthusiast and how that fits into your—did it feed another creative outlet for you or another community outlet? Is it because in a way those machines are a bit simpler than working on devices or are they not, maybe they're more complicated?

06-02:44:41
Oldham: I don't know, the difference is of course—with a vehicle or a car for instance or a lot of other hobbies like that, people build steam engines and people do all these kinds of things, is that you can complete something and it's

functional and you use it and you play with it and stuff like that, which in the chip industry is not the case. You contribute usually at some part of a process or some part of a chip or something. So it's a completeness that you can get, and it's funny, I realized when I was a kid, you—maybe when you're a kid you had model trains, like little miniature trains, right? I don't know if you ever had them in your family.

06-02:45:28
Burnett: Yeah.

06-02:45:29
Oldham: So I used to build these train sets. I'd get the papier-mâché out and I'd build these mountains and I'd build buildings and little people and of all that. And then when it's all done, I've all done I never run the damn thing. It was that—

06-02:45:45
Burnett: Process.

06-02:45:45
Oldham: —the process was the fun, it's the damnedest thing. But with the cars, actually I'm here because we just went down near Santa Barbara with the MG. I have a '55 MG, which I've rebuilt the engine and all that stuff. You do that stuff, you maintain it, and then we'd drive it, and a bunch of other old time—they—it's the only group that I belong to where I don't raise the average age. These are seriously old people that drive these old MGs, and we go down in there. We drive down there, and we talk about cars things, [laughter] whatever.

06-02:46:28
Burnett: But a fun, a really fun outlet for you and a pastime, you know?

06-02:46:34
Oldham: Yeah, it's one of those things. It uses your visual skills. I think good engineers, primarily it's related to your visualization skills. Trigonometry you know how things—relationships, physical to each other, and it's true in electronics as well as mechanical engineering and so on. So it's just a place to practice that and have some fun. You can buy big machine tools, I've got a garage, I've got a lathe then I've got a milling machine, and I can make parts, build engines and it's—yeah, it's cool. You can do that, but I think it's just you get to practice that stuff. I don't know exactly, but I don't mind being ten hours alone in my garage, whereas I don't like to go out in the world and sit out in the world alone. If I go to the coffee shop, I'm going to try and find somebody to go with me and talk to, right?

06-02:47:34
Burnett: Right.

06-02:47:34
Oldham: But I don't mind being ten hours alone in the garage working on my car. I don't know why that is, but anyway.

06-02:47:41
Burnett: I know there's a calm that is just—life is so complicated and wonderfully so, but it's not simple. But it's this deep engagement with one problem at a time or how two or more problems fit together that requires your full attention and losing yourself in that is a—I mean it's a joy to do that I think.

06-02:48:11
Oldham: I think it's true.

06-02:48:13
Burnett: Oh, let me ask you this about it. Is there principle of fidelity when you're working with vintage cars? When you machine a part, are you making it exactly the same to spec to the original or are you tweaking to make it a little bit more optimal or—?

06-02:48:34
Oldham: I think more the latter. You generally try and make things more reliable and a little more performance maybe because there's been things learned since that was designed, right?

06-02:48:46
Burnett: Right.

06-02:48:46
Oldham: So yeah. The engine in my Porsche is—this is a 1960 Porsche—it's a so-called Super 90 engine, which was ninety horsepower, this was a big engine. This is more than ninety horsepower because I increased the volume. The maximum you can is limited by certain physical parameters, so you do that. That's kind of fun, you get a little more power out of it, and you're still trying to make it as reliable.

06-02:49:22
Burnett: Right, right.

06-02:49:24
Oldham: Yeah, yeah.

06-02:49:26
Burnett: But it's a joy.

06-02:49:27
Oldham: Yeah.

06-02:49:29
Burnett: I'll leave you with the last word, are there anything—anything you would like to add to our conversations about the Berkeley, about innovation, about the larger trajectory of things with respect to innovation in the United States?

06-02:49:50
Oldham: Well, I didn't prepare for that so I'm—I can't say anything very profound. I would observe that that there's been a trend that's happened since I've retired,

which is now almost twenty years, nineteen years since I quit teaching, and I retired from consulting maybe ten years ago, but teaching twenty years ago. And so the teaching has changed both in the use of the teaching aids, visuals, and all that stuff, and online, and all that. But what's really changed is that the kids who became engineers when my generation became engineers were generally kids who had hobbies like that. They made radios, electrical engineers typically they build radios and they did all that kind of stuff. That's not true today. The kids who come into school haven't done that usually, but—and things got really complicated to make stuff. You can't make a radio today, radios are digital today, they didn't use to be digital. But this whole new thing that happened in the last ten years is the sort of maker—the maker era, and so. And it had to do with what was called it's called additive patterning. It was also called—

06-02:51:32
Burnett: Additive—like the—

06-02:51:34
Oldham: Additive manufacturing but it was also called—

06-02:51:37
Burnett: Three-D printing.

06-02:51:37
Oldham: —some kind of 3D printing, and it was called stereolithography. It was called stereolithography, which was strange in the beginning, but it really had to do with additive patterning, and that made it possible for people to make stuff. In parallel with that, software came out that if you had a structure, it became possible to define it, because it takes enormous, good software to do that. You want to make a sphere intersecting a cone out of titanium or something like that, well you can now with a few strokes define this and define that, and then there's software to take that and instruct the machine. So you don't have to write the details, move here, drop some powder or whatever the technology is. Usually, it's like a shine a laser and fuse this stuff together, then you put another layer of powder on. If you're doing like metals, then it's usually fusion of powders or something like that. Well, it's where you shine the laser, then you dust the other metal off, and so on. All that software became available, and those tools are available, so kids can—

06-02:53:02

I've seen it and I went back seven or eight years ago to Carnegie Tech for an alumni thing and asked for a show through the maker labs. And these kids are designing parts for airplanes out of titanium to replace these machine parts that are better, they're lighter and stronger. Oh, because they also design them with finite element design, so instead of just making them by classical beams and I-beams and stuff, you actually make them, put the stresses where—put strength where the stresses are, and so on. And that's happened, so you go in there, there's these girls, well, I don't know they're women now in college, they're girls in high school, but college I guess they're women. But the women are in there doing this. I love that. I mean you've got those brains in there, and they're actually making stuff. The boundary conditions are changed a little bit, and we have some maker labs here. I've never gotten into them at Berkeley, they developed after I left. I would love to get in them and make stuff myself there, but I haven't done that, but I could do that, I'm sure I could talk my way in but—

06-02:54:18
Burnett: Yeah, they'll let you in.

06-02:54:20
Oldham: So that's changed, and I think that will really—I think that's a real positive development that you can get people, young people who have not been toying with it their whole youth into this.

06-02:54:35
Burnett: I think you're right, and I think that that engagement with the nature of engineering as an engagement with the natural order, right, just physical principles, the principles of electrons and all of that, it's such beauty. We're not very good at getting kids excited about it because there's so much competition for their attention and there's—people are so good at attracting students to the dazzling things. But underneath that are these principles that allow those dazzling things to be made. And we want to get students to think about being creative in that way, you know?

06-02:55:29
Oldham: Yeah, and I guess I'm saying that you get into it later. They don't have to spend their childhood doing those things to be interested.

06-02:55:40
Burnett: Right.

06-02:55:41
Oldham: They can get into it later. If you provide the tools, so you don't have to do all the dirty work, you can just do the creative part of it.

06-02:55:51
Burnett: Dr. Oldham, I want to thank you for sitting and taking the time and talk with us.

06-02:55:57
Oldham: Thank you for doing this.

[End of Interview]

Appendix: CV and Publications

Current Position:

Robert S. Pepper Distinguished Professor, Emeritus
Department of Electrical Engineering and Computer Science
University of California, Berkeley

Education:

B.S. Carnegie Institute of Technology, 1960
M. S. Carnegie Institute of Technology, 1961
Ph.D. Carnegie Institute of Technology, 1963

Research Interests:

Research in semiconductor materials and process technology. Current research focus: optical and EUV lithography, and maskless lithography for application at feature sizes smaller than 100nm.

Professional Experience:

At Siemens Research Laboratory, Erlangen, Germany 1963-64. Industrial leave 1974-75 at Intel Corp (Program Manager for Dynamic Rams -Technology Development and Circuit Design). Consultant to various electronics and automotive corporations. Consultant to various legal firms on intellectual property matters. Member, Board of Directors, various public and private corporations.

University Activities:

Faculty, University of California, Berkeley, California since 1964. Director, Electronics Research Laboratory, 1985-90. Principal Investigator, Joint Services Electronics Program, 1985-90. Director, California SEMATECH Center of Excellence, 1988-1996. Director DARPA/SRC Research Network for Advanced Lithography 1996 - 2005. Vice Chair Academic Senate, 1996-97, Chair 1997-1998. Chair, Senate Ombudsperson Committee, 1998-2002.
Secretary, Berkeley Division Academic Senate 2003-2004.

Honors and Awards:

National Science Foundation Senior Postdoctoral Fellow at Technical University, Munich, 1970-71; Fellow of IEEE 1981; Guggenheim Fellow, 1985-86; National Academy of Engineering, 1986; SRC Technical Excellence Award, 1997; SIA University Research Award, 2003; IEEE Cledo Brunetti Award, 2005; SPIE Career-Long Contribution Award, 2015.

Publications and Patents:

More than 200 publications and patents in semiconductor electronics.

William G. Oldham

RESEARCH PUBLICATIONS 1963-2011

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