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The Bancroft Library

University of California
Berkeley, California

Paul Gray:
A Career in Electrical Engineering, UC Berkeley Administration, and Private Sector Leadership

Interviews conducted by
Paul Burnett
in 2017 and 2018

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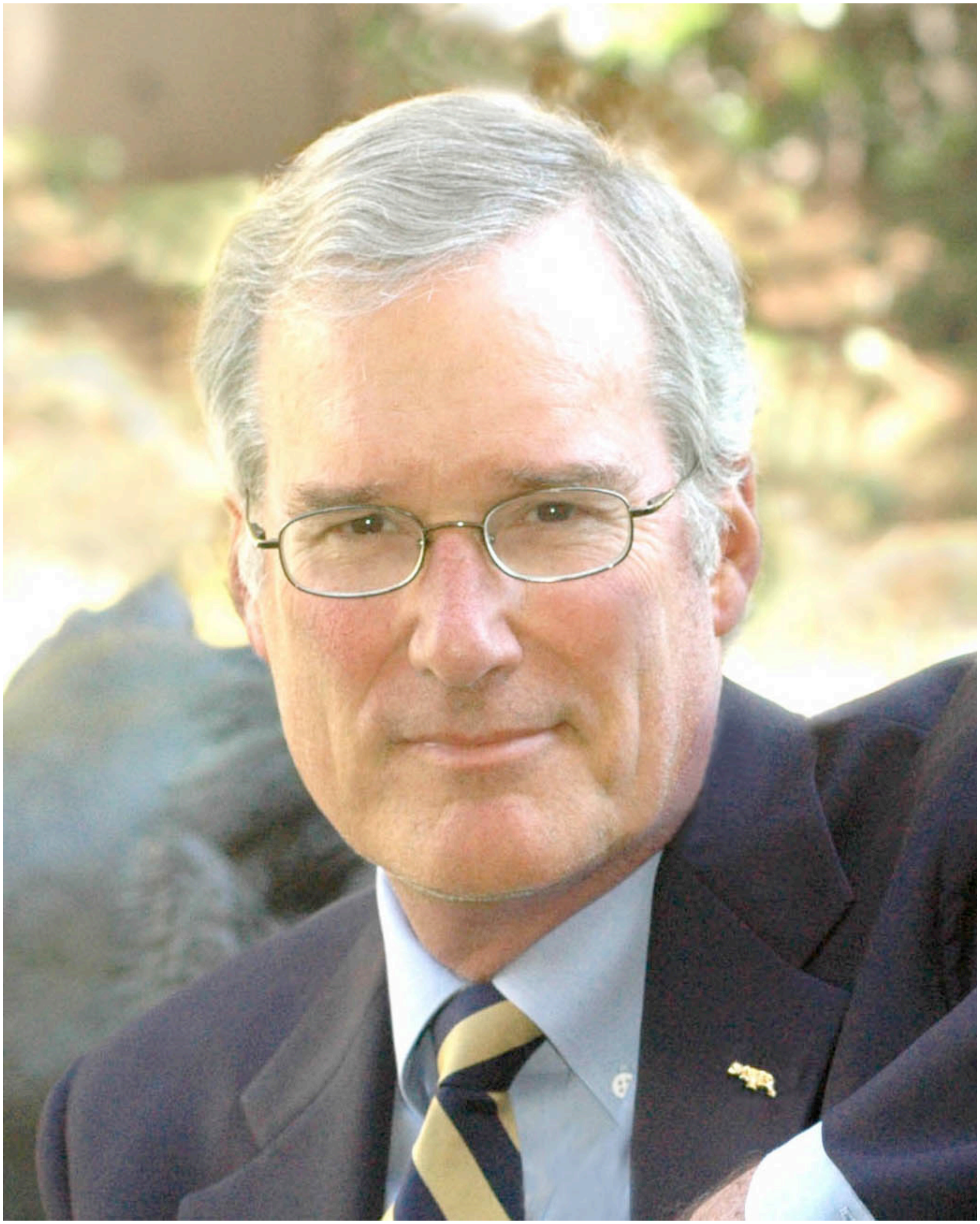

Paul R. Gray, 2005

Paul Gray is Professor Emeritus of Engineering in the Department of Electrical Engineering and Computer Science at UC Berkeley. A graduate of the University of Arizona, Dr. Gray worked at Fairchild Semiconductor before joining UC Berkeley EECS in 1971. There he developed a multi-decade research project on digital-analog conversion and the thermal properties of integrated circuits, which laid the foundation for digital telecommunications, scientific instrumentation, and digital representations of the analog world. He served as Chair of EECS (1990-93), Dean of the College of Engineering (1996-2000), Executive Vice Chancellor and Provost of UC Berkeley (2000-06). He has served on the boards of several corporations, in addition to the board of the Gordon and Betty Moore Foundation.

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Interview 1: November 1, 2017

01-00:00:21
Burnett: This is Paul Burnett interviewing Paul Gray for the University History Series and it's November 1, 2017 and we're here at the University of California Berkeley. Dr. Gray, welcome.

01-00:00:35
Gray: Thank you, Paul.

01-00:00:36
Burnett: So it's customary in a life history to begin at the beginning. So I'm wondering if we can talk, I think quite a bit, about your family background, where you're from, where you grew up.

01-00:00:47
Gray: Happy to do that, Paul, and thank you for doing this. I'm looking forward to the process. I was born in Jonesboro, Arkansas, which is a small town in northeast Arkansas, population about 15,000 at the time I lived there. A rural, idyllic town in the mid-south. The main local industry was cotton farming. It was really a wonderful place to grow up. Most people wouldn't know of that town except for two things. One is that it's in the heart of tornado alley in Arkansas, so you see it featured on the evening news every couple of years because of catastrophic tornadoes. I can talk more about that a little later. The other is that it is home to a college, Arkansas State University, which at the time I was there was a small agricultural school. The campus did have a kindergarten that I happened to attend. More recently it's become a division one football school, so they actually are covered on national TV on occasions.

On both sides of my family, the ancestors were European immigrants who arrived on the East Coast in the late 1700s, early 1800s, in one case Pennsylvania, in the other case North Carolina. And those folks, after a short period of time, made their way west. My mother's family name was Stuck, my father's family, of course, Gray. They made their way west and settled in Arkansas, southern Missouri, and in some cases in southern Illinois. Over time a number of those on my mother's side ended up in Jonesboro. Most of these folks were farmers, with quite a few preachers in there as well. In the case of my mother's family, the last four generations prior to her lived in Jonesboro and had a series of businesses. They owned a lumber yard, a brick factory, savings and loan, a cotton brokerage, and my immediate grandfather, my mother's father, had a chain of Piggly Wiggly grocery stores and at one point in time was the national president of the Piggly Wiggly chain. They had the distinction of being the first, or one of the first, grocery stores where you actually go to the shelves and pick out your own items — “help yourself” was their motto. So my mother's family were merchants and businesspeople.

My dad's family also ultimately ended up in Arkansas. They were also mostly farmers, but with quite a few preachers thrown in and a lot of teachers. My grandfather on my father's side and his wife were both schoolteachers. My granddad was a principal in the Little Rock school system and actually worked for a period of time in the Arkansas state school system as an administrator under Governor Orval Faubus, something we may touch on later on. As a group both sides of my family were rugged pioneer stock, very independent people. They had made the journey west, as was common in the south at the time. Very focused on their church life, very religious. A lot of them on both sides were officers or leaders in their churches. So that's the general background.

My mother and my father met in the late thirties. My mother graduated from the University of Arkansas in 1941, June. My father was a West Point grad in 1941. They met and were married in Jonesboro in that summer and, of course, Pearl Harbor happened six months later. Following that my dad moved all over the country and later on was stationed in Germany. I was born in December of '41, my brother was born in '43. We spent the war years living in my grandmother's house there in Jonesboro with my mother and my aunt while my dad was stationed in various places during the war. Unfortunately my mother and father became estranged in those years and he met another lady, married her and established a separate family. As a result of that, other than a few visits, I never really saw much of my father until thirty years later when we reestablished contact. My brother and I ended up being raised by my mother, aunt and grandmother there in Arkansas. I remember those years as idyllic. I didn't particularly feel disadvantaged not having a father at home. We had a great life but we were raised by a house full of women. They were wonderful and we had a great time there.

01-00:07:00
Burnett: So I'd like to back up a bit because I'm interested in your story and you as a witness to the transformations that were taking place and what you heard from your relatives in this time period. So it's Arkansas and it's the cotton south. One of the stories that happens while you're young is the mechanization of cotton picking. I don't know if you know, because it sounds like your family were the townsfolk, but you were serving a larger farm community. Can you talk about the transformations in the local economy of Jonesboro?

01-00:07:55
Gray: My classmates in both grade school and junior high school there in Arkansas were gone frequently for large parts of the year because the typical family there used their children as a labor in the field to pick the cotton, along with farm labor that they hired. That era has passed due to mechanization, but at the time I was there and had a chance to experience that, I didn't see the impact of mechanization of cotton picking (as opposed to ginning, which was mechanized). We left in 1957. It may not have hit that particular part of the country that quickly. I certainly saw the impact of what it was like to grow up in a farming family in the south in that era. We didn't enjoy many of the benefits financially of being in a well-to-do family, but we had all the other

benefits, like a lot of the focus on education and so on. But I went to school with an awful lot of kids who didn't have that. They were mainly expected to help out with the labor force on the farm, to get stuff picked and whatever had to be done. That made a pretty deep impression.

01-00:09:47
Burnett: It would have been just beginning and I think it would have been taken up in different places in different ways. And, of course, there were government supports for cotton so there may have been less of an incentive to innovative in that respect. Can you talk a little bit about race in Jonesboro? What were things like at that time?

01-00:10:11
Gray: Well, the town was absolutely segregated. This was a typical southern town in the fifties. Total, complete segregation, including schools. It was classic. We had a set of railroad tracks running through the middle of town, and the white people lived on one side and the African American people lived on the other side. Again, my family were college educated people. They were, I think by the standards of the South, pretty enlightened about these things. I don't remember any significant discussion of racial issues in my house. I observed what it was like to have the lifestyle that the African American members of that community had and it was pretty bad. It was all the things you read about in the rural South. There were areas only whites could go and things like that. We did have in my house a housekeeper/maid who came every day from the other side of the tracks. Her name was Pearl. She helped raise my brother and I, did all the household chores, cooked all the meals. Wonderful woman. For whatever reason, and I don't have this history, she stopped working with us when I was probably like nine or ten years old, so I didn't have any later life sense about her, who she was and how she saw the world. I certainly remember her as somebody who worked extremely hard. I didn't know where she went at night. I can imagine but I just had no consciousness of the impact of the town and the environment and the segregation that was a fact of life for her at that time.

01-00:12:44
Burnett: Right. I think that's what is said about the Jim Crow South, is that it was a system that was so pervasive that it was rendered invisible. Until you crossed it. Until you violated that system and then you certainly knew about it.

01-00:13:00
Gray: That would be consistent with my experience there. That's right.

01-00:13:03
Burnett: Yeah, yeah. And you said your father was a West Pointer.

01-00:13:08
Gray: Yes.

01-00:13:10
Burnett: Is that a family tradition in the Gray family to—

01-00:13:16
Gray: No. While there were some military figures from the Civil War in both sides of the family, that wasn't a pervasive factor. There wasn't a pattern of military careers. I don't know why my father chose that; his father and mother were teachers. He went to West Point, graduated in 1941, and went on to have a career in the Army, retired as a colonel. He was stationed in Germany. He never was in combat in World War II but he was in combat in Korea and commanded a battalion there. Later on he got involved in missile technology. He was at the Bikini Atoll when the first atomic bomb tests were set off and his later career involved development and deployment of missile and atomic bomb technology. He retired as a colonel, and went on to several defense industry civilian jobs after that. Later on I got to know him and his second family and became pretty close to them so that was a nice outcome. But that was much, much later.

01-00:14:30
Burnett: And so you didn't find any of that out until thirty years later?

01-00:14:33
Gray: My father would stop by once every three or four years for a day's visit, so I had a little bit of contact, so I knew generally about his career and family.

01-00:14:47
Burnett: I think we're talking about you being twelve years old, so that's like 1954. So that's—

01-00:14:56
Gray: Well, I should tell you a little — just to give you a little more about my family. My brother and I were living with my mother, grandmother, and aunt there in this large nice home in a nice part of Jonesboro. But my mother was a very intelligent, capable, and high achieving woman who had a very strong independent streak. She did not like living in her mother's house. She went through a long series of jobs. She was a real estate agent for a while, and then grew and shipped mail order African violets for a while. She was the administrator at the local church, and a number of other things. And finally she decided to go back and get teaching credentials, so she then began to teach in the Jonesboro schools. That got enough resources for us to move to a very small house on the outskirts of town and she insisted on financial independence. In Arkansas they have a saying of living high on the hog. We weren’t even anywhere close to the hog. We were living on lima beans or something. But anyway, she was doing her best to raise us in a financially independent way. So now we're living on the outskirts of town in a rural environment. It was wonderful. We had ponds and streams all over the place. We'd go on hikes. We just had a wonderful time out there and we lived there for four years. Fifty-three to fifty-seven. I have really fond memories of that. It was a wonderful time, walking to school every day. One thing that the

financial situation did do is create a lot of financial pressure. I worked early on. Mother was a big believer in young kids having jobs so I had a paper route the whole time. I'd get up at four o'clock in the morning, ride my bike into town, get the papers, fold them up, take them out, deliver them, and ride home. And I did that all the way through those four years. But it was a wonderful experience, growing up in a rural small town in the South, other than some of the aspects we touched on earlier, was a pretty nice thing for a young person.

01-00:17:35
Burnett: Right. And did she remain active with the church that she was—

01-00:17:40
Gray: She kind of drifted away from the church. And had more other interests and things. In fact, now that you mention it, was not a regular churchgoer after we moved out in those years. We were not very active in the church at all.

01-00:18:03
Burnett: So she wasn't taking kindly to pity or something like that.

01-00:18:10
Gray: No, that's right.

01-00:18:13
Burnett: Yeah. She was very proud and independent.

01-00:18:14
Gray: She was a very independent person. So those were great years. I really treasure those. My brother and I talk often about those experiences. We got very involved in those years in hobbies. We built model airplanes and model trains, and got in trouble the way kids do. I remember once trying to build an electromagnet from something in a *Mechanics Illustrated* article and I wired it wrong and plugged it into the wall socket and everything melted and we almost set the house on fire. We did a lot of those kind of things. But we learned a lot doing that. It was fun.

01-00:19:12
Burnett: Boys were a hazard in those days. I suppose they always are. In my family, my father's friend blew his thumb off building a rocket. The kinds of dangerous things that were available. But it was considered to be, "That's what boys did." Chemistry sets, working with kind of popular mechanics and learning how to build things from scratch. I always ask folks this. Is there a modern equivalent? Is it software design? What are young people doing now that's—

01-00:19:53
Gray: I have two grandkids, four and six now, who are going through this. They have incredible creative outlets. They have Legos. There's a software program for kids called Minecraft, which is a program that allows you to build things. I think it's just a different form of creative outlet. They have a lot of ways to be creative and explore things. It's not as hardware oriented. It's more games and

software. But I'm not sure it's worse in any way. There's no shortage of creative outlet for these kids today, which I think that's the important thing. The other thing that strikes me as very different—when I was growing up we would get up on a summer day and say, "What are we going to do today? Let's go down and organize a sandlot baseball game." Or "Let's go hike to the next town?" or "Let's go shoot birds with a BB gun," or let's go do something else. We made it up every day and we had a great time. That's changed, at least for middle and upper middle class kids, at least in the areas I've been exposed to. Kids are so programmed. They have soccer games, they have summer camp. I'm sure it's great and I guess time will tell what that's done to our culture. Of course, it's very rich and all that. But the creativity and the fun of just getting up on a summer day and saying, "What are we going to do today?" and making it up as you go along, has been lost for many kids. These kids don't get to do that anymore.

01-00:21:28
Burnett: Yeah. Friends of mine talk about our parents just gave us, "Go to the backyard," and they took two sticks and they took some mud and they made a game out of it. Not attached to some set of special equipment or necessarily an organized sport or something like that. But there's something spontaneous about the play that encouraged creativity because there was literally nothing there for you to do. You had to decide what to do and that had an impact on you and members of your generation, you think.

01-00:22:10
Gray: Yes, I think so. There were a couple other things that come to mind now that I'm thinking about that era. I got my first experience in organized sports. We did little league and I was on a little league team for a couple of years. The main benefit that gave me was to make me realize that sports were not going to be my career calling. I was not very good at that. But it was fun. We did all that fishing. And then the other thing I should tell you about. So my mother and grandmother were great influences but my mother had a sister and a brother. The sister, my Aunt Connie, was a University of Arkansas graduate in journalism. She went on to be a career foreign service officer and a wonderful mentor to me. My mother's brother Howard was a newspaper editor and ran the newspaper in the neighboring town along with his wife Dorothy. As I mentioned, northeast Arkansas is tornado alley and so whenever there was a tornado he'd get the job of going out in the car in the immediate aftermath and taking pictures for the newspaper of the devastation. And he got in the habit of asking Howard and I to come along with him. That made a deep impression. When you ride through neighborhoods that have been devastated by a tornado and you see what those natural forces can do and the devastation it brings about, that gives you a real respect for Mother Nature. That's a vivid memory of going with him on those trips. He and his wife Dorothy, ran that newspaper for many years. Later on Dorothy got to know the Clintons when they were in Arkansas and became the head of the Arkansas office of the Department of Housing and Urban Development. She went on to do a number of other things,

including writing biographies of various people like William Fulbright's mother. So she was quite a lady in her own right. But I still remember those trips with my uncle to see the tornado devastation. Quite remarkable.

01-00:24:40
Burnett: And I think it, I guess, gives you an appreciation for fate and fortune?

01-00:24:40
Gray: Serendipity, yes.

01-00:24:46
Burnett: Right. Yeah. You don't take anything for granted, I suppose. And so there are these figures in your life who awaken you to different kinds of possibilities. So, as you say, there was a kind of socioeconomic—not socioeconomic but just economically, there was some privation there. But you had these tremendous family connections and friend connections that showed you different pathways that you could embark upon. You didn't feel like socially excluded from that. Okay. So now we're in about, say, roughly 1956, '57.

01-00:25:29
Gray: Yeah. As I mentioned, my mom was trying to keep us going on a teacher's salary. In Jonesboro, Arkansas, in the fifties a teacher made about $2,500 a year. We were having a lot of trouble making ends meet. So she decided to move somewhere else. During the war years she had spent some time in Tucson because my dad had been stationed there and she made one trip there. Tucson was growing rapidly, had a need for teachers and were paying salaries roughly double what Arkansas was paying. So she packed us up in our old Ford and we drove out to Tucson. This was the summer of 1957. We rented a house on the east side of town. She started working at one of the local junior high schools there. Howard and I were suddenly in a new environment. I spent three years then in a high school there in Tucson and then three years getting a bachelor's degree at the University of Arizona. So those six years I lived at home with Howard and mother in our rental place there in Tucson. Those years had a lot of impact on me, having showed as a bumbling fifteen-year-old Arkansas small-town guy with a thick accent. Lot of "you-all"'s and that sort of stuff and no friends. I developed a lot of sympathy for transplanted teenagers from that experience. It's a tough thing to make a move like that when you're at that age. It was a challenge, but a lot of things happened during those subsequent six years that really had a positive impact, so I'm very appreciative.

One of the things my mother got me involved in very quickly was something called the — Civil Air Patrol, is a volunteer organization of private pilots that go out and do search and rescue supplementing the normal first responders when an airplane's gone down or when some other kind of natural disaster or emergency happens. Many of those chapters have cadet auxiliaries for teenagers. It's similar to the Boy Scouts and the Sea Scouts. A little bit more military oriented than the Boy Scouts in that you wear a military uniform and usually the organization is associated with a local Air Force base. It just fit what I liked. It had a lot to do with airplanes, which I really loved. It had a little bit of discipline to it; you had to be organized. It was just what a fifteen-year-old kid needs. They had two week summer encampments, and I went to two of those. I made some lifelong friends and that was a big plus. The overall experience was a lot like the Boy Scouts.

01-00:29:31
Burnett: Yeah. It sounded like a really smart move on her part because it's an organization that has some structure but it's also a group of boys and men—

01-00:29:46
Gray: And girls. It was mixed.

01-00:29:46
Burnett: Oh, it was?

01-00:29:47
Gray: Yes.

01-00:29:47
Burnett: Oh, it was co-ed? Great, great. But there's that exposure to the kind of structure but also camaraderie. That was a common path for all kinds of folks to get kind of a built-in community. And that's kind of what you needed at that time, right? So the other piece of it that I'm thinking of is you've described Arkansas really well and Arizona's a different state and it has a different economy at this time. Can you talk about what Arizona was like? What it had been through? It had transformed itself in the previous twenty years before you arrived. It was a completely different place. Can you talk about what was the economy of Arizona? What was going on in Tucson that you noticed that had an impact on your life?

01-00:30:47
Gray: Yes. Tucson was dominated by, and still is, really, by two big economic drivers. One is the Air Force base, Davis-Monthan Air Force Base. Huge place. It's where the graveyard is, the airplane graveyard.

01-00:31:03
Burnett: Yeah, the Bone Yard, right?

01-00:31:04
Gray: The Bone Yard. And then Hughes Aircraft had a very large plant there that made air-to-air missiles and other kinds of weaponry. The plant still exists under Raytheon ownership and is still a major employer in that region. Also the University of Arizona is a big employer. It's a major university town with a heavy component of folks who are at the Air Force base and Hughes Aircraft. My experience was that compared to small town Arkansas it was a very much more worldly set of people. That cultural part was what I felt mostly. Life was really different at a small town junior high school in

Arkansas than it is in a large high school in Tucson — we had 2500 students. It was quite a change.

01-00:32:07
Burnett: Well, in 1957 is Sputnik and then the following year is the National Defense Education Act. And so you were ahead of the curve, I guess you and your generation. You were already invested in science and technology, weren't you?

01-00:32:19
Gray: Yeah. Pretty much pure serendipity, though. By the way, I should go back. Can I digress for a moment?

01-00:32:25
Burnett: Yeah, of course.

01-00:32:26
Gray: I was going to mention during those last few years was the year of Orval Faubus and the Little Rock standoff at Little Rock High School. That happened in '57. I think the *Brown v. Board of Education* was '54—

01-00:32:52
Burnett: That's right.

01-00:32:52
Gray: The whole issue about segregation of schools in the South was boiling over in those years when I was in junior high school. I remember reading the newspaper about the standoff at the high school in Little Rock and thinking, "Boy, this is pretty serious and I'm really worried about this." For whatever reason we didn’t talk about these matters in my family much. I think it might be that my family had a spread of political opinion about this and it's best just not to talk about these things, at least not around the kids. It's hard for me to even understand that now because we always talked about such things a lot with my own kids. It certainly was on my mind watching the news and what was going on because it was very much a part of life in Arkansas, as I mentioned earlier. It was something that I distinctly remember being very aware of.

Getting back to Tucson, it was a much more sophisticated environment, for sure. My mother was pretty independent minded and she gave us a lot of leeway. Arizona's got a lot of wildlife so we had lots of pets. We had a pet porcupine, pet snakes, pet lizards, pretty much everything in this little tiny two-bedroom house. I don't know really how she ever put up with that. Howard was a big snake collector for years and years and we had lots of fun with that. As I said, Mother always wanted us to have jobs. We arrived in Tucson the summer of '57. In the paper we found out you could work selling ice cream. This was summertime in Tucson, 105 every day. Think of the ice cream salesman- the guy that pedals around on the cart with a big box on the front. So shortly after we arrived, Mother drove us down to the place in the center of town where you signed up for that. They give you a cart to drive and they give you a box full of ice cream cones and popsicles and stuff to sell. On the first day Howard and I get out there and we're pedaling around Tucson, and we were out all day. It feels like about 110. It's really, really hot. And in order to keep cool we'd keep nibbling on the popsicles. [laughs]

01-00:36:15
Burnett: Dipping into your own supply.

01-00:36:17
Gray: And we didn't sell very many. So we come back at the end of the day, four o'clock in the afternoon, we're totally exhausted. And we do our accounting with the guy. Well, it turns out the two days we did this we ate more popsicles than the profits, so we ended up paying the guy. So we ended up losing money on this. That lasted a mercifully short two days. These kinds of experiences are great for kids because they give you an appreciation of you're so lucky to have opportunities in life, to get an ability to do things that allow you to reach your potential. A lot of other people are not so lucky. So anyway, that was the first. Then we mowed lawns the rest of that summer and then I got a job as a carry out boy that fall in the grocery store nearby and I did that for a couple of years. Then I got into retail and I sold sporting goods at a department store and then another store and then I got into men's clothes. But I basically had a job all the way through. My brother Howard was more or less the same way. I've always valued that. The motivation was mostly economic, but those jobs give you a sense of where your place is in the world and a sense of what the real world is like — it just grounds you a little bit. So we tried to have our kids go through those same kinds of experiences. Not as much but they did their share.

01-00:37:57
Burnett: And I imagine you're developing soft skills at this time, as well, in those jobs. You learn how to work with different kinds of people, right?

01-00:38:07
Gray: Yes, right.

01-00:38:08
Burnett: Customers? To deal with stress, manage your time. I'm wondering if I'm missing anything in there. But those are kind of the basics that I think of with those kinds of jobs. And you moved up, right? You got more responsibility with the department store, for example. Arizona, it explodes during World War II because I think in southwestern Arizona there's something like fourteen air bases built in about five or six years. And so it is the center in the United States, a major center for aviation, bombers in particular. So that must have been, not to lead a question too much, it must have been in the air, so to speak, in terms of your friends at school. It's the ultimate kind of cool thing for a young teen. Were the bombers roaring overhead? Was this part of daily life?

01-00:39:17
Gray: No, that's true. It was literally in the air. The landing pattern for the air base was right over the center of town and there were planes in the air all the time. In fact, I mentioned that Mother was pretty liberal in terms of letting us try things. When I was a junior in high school, I decided I wanted to learn to fly. I don't know quite where I got enough money to do this. But anyway, I was just starting to drive, so I drove out to Tucson Airport, signed up, took eight hours of flying lessons, soloed, flew around, did a couple of cross countries. Did six or eight hours of solo flying and then ran out of money and so it didn't go very far. There aren't very many parents who would turn their kid loose to do that. But it was a great experience. I wouldn't trade that for anything-I really loved that.

But I was lucky in that in the high school I was in — I had some teachers who really took an interest. There's so much serendipity in most people's life story. The teachers you happen to come in contact with, the ones that take an interest in you. My high school geometry teacher at one point was really good about making sure I was trying to develop skills as I should. That had a big impact later on. I think that may be how I ended up in engineering. And I had a journalism teacher who took me aside. I was a writer for the high school newspaper. He just took an interest and encouraged me. It made a huge difference — just somebody taking the time to say, "Hey, that's a pretty good job. Why don't you do more?" Just somebody that encourages you. Just a few words of encouragement here or there can make a big difference.

01-00:41:44
Burnett: Yeah, yeah. Absolutely. And there's this tremendous emphasis on science and technology. It's a national emergency. Do you remember the news about Sputnik?

01-00:42:00
Gray: Oh, yes.

01-00:42:00
Burnett: And conversations—

01-00:42:02
Gray: Oh, yeah.

01-00:42:02
Burnett: —that people were having? Like what was that like? It felt like a defeat, didn't it?

01-00:42:07
Gray: I remember the concern and the discussions about it. It was the Cold War era, when the teacher would teach you how to duck and cover and you'd get under the desks and all of that. In high school you're sort of nose to the grindstone, get it done, pass the courses and do all this day-to-day stuff. I guess I can't remember lying awake at night worrying about it but I can certainly remember

being aware of it. Particularly Sputnik. Who wouldn't remember that? I was very interested in that flight and airplanes and Sputnik was just, "Wow, what a cool thing." It had a big impact in what happened later on with the university and Silicon Valley and so forth. But those were the early years of that.

01-00:43:15
Burnett: Right, right. And so there is a kind of Cold War climate in a kind of militarized space. Tucson and that area is kind of chock full of military personnel. So how did that impact you in some of the choices that you made?

01-00:43:47
Gray: Well, that's interesting you should ask that. Well, I had been through the Civil Air Patrol experience and started at the U of A in 1960. I had assumed I would do something in the military, and I was very active in ROTC that first year. In those years, at Arizona, ROTC was mandatory. Every freshman male, had to enroll in ROTC which meant you got a uniform, marched in formation once a week. I was a platoon leader as I recall and planned to do ROTC all the way through. My real ambition in those years was to be a pilot — after the flying lessons I thought I would go in the Air Force. Turns out my vision was so bad — I'm nearsighted — and I couldn't do that. I still wanted to be active and involved in the military so I applied to West Point. What made me decide that I'll never quite understand. But I got a congressional appointment and passed the written exam. This is 1961, spring of '61. I was all set to go but when I went and took the physical and they discovered a bone fragment in my knee. I couldn't go in unless I had it operated on and went through a whole bunch of stuff that could take a long time. So I didn't go. And that was kind of a disappointment. But, in retrospect, best thing that ever happened to me. I wouldn't have been a good Army officer.

01-00:45:55
Burnett: Why do you say that?

01-00:45:57
Gray: Oh, I don't know, probably the regimentation would have grated on me. As I mentioned, ROTC was required of all male students at the U of A. It was very unpopular on the U of A campus' the students didn't like. It wasn't Vietnam War yet. This is still '61, '62. The students hated ROTC. Very few of them in that era were interested in military service and most of the kids didn't really want to be there. They were just getting out there and marching around. There was a lot of apathy and it just wasn't very effective. It wasn't really accomplishing much of anything. And after a year or two of participating in it I thought it was actually kind of a waste of time, too. The kids that really were enthusiastic, great, let's have ROTC for them. But to require every single freshman to do it wasn't really accomplishing much. So there was a budding protest movement, student protest arguing to get rid of mandatory ROTC. So one day that spring, not long after I learned I wasn't going to West Point—

01-00:47:20
Burnett: Sixty-one?

01-00:47:22
Gray: Sixty-one. Spring. They decided to hold a protest in front of Old Main. There's a big fountain in front of the oldest building on campus, at the center of campus. So eight or ten protesters are marching around carrying signs. They weren't unreasonable. But the conservative student groups on campus, the pro-ROTC crowd and a whole bunch of other folks that probably thought this was communism on the march, didn't like this protest and staged a counter protest. The crowd developed probably seventy-five or a hundred of these kids. They found hoses and water faucets nearby and began hosing down these poor eight kids that are marching around with these signs. I thought, "This is terrible." So I and a buddy of mine who had the same thought found another hose and started dousing the counter protesters, the conservative guys. And this got really ugly. These guys were going to beat us up, do all kinds of crazy stuff. It was kind of like some of our recent protests here at Berkeley. Anyway, it all settled out and everybody went home. I think that's when I realized maybe the military path isn't really what I should be doing. Something about just the dynamic of that situation got me started thinking. So the result of that was I ended up not doing ROTC. I ended up staying in engineering and spending another 8 years after that on campus.

01-00:49:17
Burnett: Yeah. *Conscience of a Conservative* by Barry Goldwater, I think it comes out in '59, '60. There's the John Birchers. There's Students for a Democratic Society. Port Huron statement is 1959. So there are fledgling elements of a kind of fragmentation of American politics at that time. And you might have been witnessing something of that. Because Barry Goldwater, right, he's a famous son in Arizona and in '64 he runs. You were probably witnessing some of the tensions. There were student groups that were against what they saw as the excessive militarization of American society and of university life and a move for greater tolerance of different ideas. The university was a special place for that. So that foreshadowing of the free speech movement here at UC Berkeley in '64. So there's something going on there that you witnessed. It's interesting. You just came up with this story spontaneously. That moment, did it make something clear for you in terms of—

01-00:50:52
Gray: No, I just think it got me started thinking. I realized maybe I ought to not be so quick about making a career choice like that. It was one of those things that probably made a difference. We can talk some more about the Vietnam years but that's later on.

01-00:51:33
Burnett: Right, exactly.

01-00:51:36
Gray: Oh, I forgot one thing. I was going to mention a couple other teacher stories. I got into the U of A and started in engineering largely because I was good in math and engineering had a good reputation as an occupation. Also I loved airplanes and wanted to do aerospace and design. If I couldn't fly airplanes, I'd help design them. So I chose mechanical engineering, which is what you normally do if you're going to work on aerospace engineering. Early in my sophomore year I took a class from a fellow named John Wait, now deceased. Every engineering student had to take an electrical engineering course for breadth. Wait was my teacher in this course on electric circuits. He was an electrical engineer but never had worked on anything like circuits; he was a control theory expert, I think. He approached this intuitively, asking "Now, how does this circuit work?". Rather than starting out writing a bunch of equations he would try to reason through the way the thing was working sort of intuitively. It just resonated with me and I understood a lot that I hadn't understood before. But, more importantly, I understood that intuitively understanding something is way better than just being able to write out the equations that describe it. And I liked that course so much I switched majors and I became an EE and that's sort of a serendipitous thing. I don't think I would have done that if I hadn't had such an inspirational guy teaching it.

01-00:53:36
Burnett: He was really young, wasn't he?

01-00:53:39
Gray: Yes, I think he was a young assistant professor at the time. But he had a big influence on me. It's another illustration of a serendipitous encounter with people that influence you in ways you wouldn't have necessarily predicted.

01-00:54:01
Burnett: Mentors are absolutely crucial. And we're going to talk a lot about this as we go forward. But this is your first exposure to engineering education. So I'm wondering if you could talk a little bit about that. I love this contrast between intuitive and kind of — I think you're talking about rote learning, right?

01-00:54:20
Gray: Yeah.

01-00:54:21
Burnett: Just memorize the formulas. And that's what people used to say about engineering. And then other stories about engineering are, "But then you get these cool projects where you're required to be creative. You have to show some initiative and problem solving." So those are two kind of almost contradictory portraits of engineering. Can you talk a little bit about your encounter with engineering in that time?

01-00:54:49
Gray: Most of my recollection of my engineering education in the sixties era is that it was not very intuitive and experiential. It was memorization and formulaic

rules. Sometimes I wonder how they got as many kids through as they did. There wasn't very much, especially in those first two years, that answered the question “why am I really learning all this?” both the motivational and the intuitive side, really understanding how that works. When you intuitively understand what's happening you can often predict, without writing down a bunch of equations, what's going to happen if you change the stimulus or configuration. John Wait was one person who taught that way. I am sure there were others that I'm not remembering. But later on we'll talk about graduate school and Doug Hamilton, who was my PhD advisor. And that was his mantra. He thought that creativity and intuition were dramatically under stressed and under discussed in engineering education at all levels. You've got to have the analytical side — the equations, you need that. But the more important thing is just the intuitive understanding of what's happening. And the creativity often comes from that, of that intuitive understanding.

01-00:56:55
Burnett: Well, speaking of intuition, did you and your classmates, did you have an understanding of this as the “Age of Electronics?” Did you think that this was going to blow up? Things are changing quickly. Or was it just part of the fabric of modernity? There's other paths, as well.

01-00:57:23
Gray: This was still the early sixties. Even up to Apollo, the moon landing in 1969, few people could foresee the impact of information technology was going to have 20-30 years later. EE [electrical engineering] was just another engineering discipline, like ME [mechanical engineering] and CS [computer science] was a narrow specialized branch of mathematics. And, yes, in the mid-to-late-sixties we were writing programs and doing FORTRAN, but I don’t think people appreciated the upcoming explosion of information technology and all the things that enabled that, integrated circuits, advanced communications, and so forth. We just didn't see that coming. Some of the visionaries did, but the average engineering student sitting there, going through an engineering program, I just don't think they would have been able to predict what's subsequently happened. And those of us that happened to choose that course of study were just lucky. We just happened to pick a path where there's been an almost unbelievable explosion of technology and capability.

01-00:58:42
Burnett: So in terms of everyday person's encounter with electronics circa 1963, what do you have available to you? You've got the transistor radio. That is the little crystal oscillator thing.

01-00:59:02
Gray: Yeah. TV.

01-00:59:05
Burnett: TV, which is fairly old at that point. But it's maturing as a technology. So there are some everyday devices and there's some sense of the miniaturization. What used to be a tabletop or a standalone radio is now something you can have at the beach. And that’s something in the air at the time and people have phonograph records and those RCA consoles. And those are all big expensive consumer durables. But there's beginning to be some evidence of some kind of spinoffs from all of the tremendous — because in the background, you may or may not have been aware of at that time, is this massive investment by the federal government in high technology research to do with defense applications. Or not just defense applications but just scientific research funding. And so I imagine, if not at the undergraduate, at least at the master's level, that there were conversations about — certainly EE projects are being funded — you were getting NSF grants. Were there foundation grants?

01-01:00:32
Gray: That funding really started to flow, at least at the University of Arizona, in the sixties, and helped them build their programs including a microelectronics lab, which we'll talk about, and which I worked in. A lot of that was Sputnik driven. All of the NSF funding and DoD funding that flowed to universities as time went on had a big effect. I never had one of the DoD fellowships but I was sponsored almost throughout my graduate program on NSF grants, which in effect were part of that same picture.

01-01:01:57
Burnett: In terms of attending university, just backing up a little bit, you said you had mentors in high school who encouraged you. Was there a person who was particularly keen on your attending college or is it something that you wanted to do and it was coming from you internally?

01-01:02:26
Gray: That's a good question. I think it was a given in my family. I think my mother assumed from day one I would be going to college and the only economic option available to us was the local university, which was the U of A [University of Arizona]. I could just get in the car and drive down there. Tuition was a hundred bucks a semester or something like that and it was a no-brainer. I never even considered going to any other university because there was no financial possibility of that. But I think the idea of not going, I don't think it ever entered our minds. My younger brother went for a year or two and then he went into the Air Force, completed in the Air Force, and then came back and ultimately got a master's degree in computer science. I think that was a foregone conclusion. It was kind of programmed into us. And it's just serendipity again. I come from a family in which many generations have been to college. If your parents didn't go to college, then the expectations are often very different and it’s a big challenge to make that first generational step. Certainly a lot of inspirational people have done that.

01-01:03:47
Burnett: It is. And so you're finishing your bachelor's degree in engineering in '63. Now, in terms of graduate school, the master's and PhD, is that package graduate school or is it a standalone degree?

01-01:04:09
Gray: No. I just didn't feel ready. I went to summer school and got my bachelor's degree in three years. I'd had the requisite courses but found myself saying, "Why would anybody hire me?" I didn't feel like I knew enough to enter the job market. It was relatively easy and I decided I'd say another year-and-a-half and get a master's degree. It was very fortuitous for a variety of reasons. I met my wife during that time and I met Doug Hamilton and Fred Lindholm, who ended up being my PhD and MS advisors, but to answer your question, I was only going to get a master's degree and then leave. They were not linked together at that time.

01-01:05:41
Burnett: When I've talked to other folks, and going to school in that time period in engineering, who went on — I mean, that was pretty uncommon, right, because you could get your bachelor's of engineering and go to work. You could get hired by a company. There's a recession, '58 to '60. So was the job market kind of rough at that particular time? Is that the reason when you said that you didn't think you had enough skills? Did you have evidence that the market was not going to pick you up?

01-01:06:24
Gray: I just don't remember that. I don't remember actually applying for any jobs but I could have and I could have just forgotten. But I think the main thing I remember is just thinking, I really needed to know more. I didn't think I knew how to design anything.

01-01:07:08
Burnett: And perhaps the sense that you needed to have some questions because you just—you graduate with the bachelor's. You have a tool kit but not any kind of experience grappling with challenges or questions.

01-01:07:22
Gray: Well, yes, that's right. In that era there were no senior projects — or at least I didn’t do one. That's a standard thing now in engineering. I didn't do any team-based things. I didn't do any projects as an undergraduate in those years where I worked in a team and solved a complex, semi-constrained problem, ie an engineering kind of experience. In those days you took a laundry list of courses and you had a set of requirements. When you finished those courses — these were classroom lecture classes and labs you were done. Engineering education has improved dramatically since those days.

01-01:08:06
Burnett: I guess the other piece of it, too, is that the industrial laboratories, the companies, did a lot of formation.

01-01:08:17
Gray: Yes, that's right.

01-01:08:19
Burnett: And so you would get your bachelor's of engineering and then you'd go to work for a company and it'd be almost like you'd be in graduate school on the job training for what they actually needed in their specific institution.

01-01:08:29
Gray: No, I think that's true.

01-01:08:31
Burnett: And I think that's another thing that shifts, is that the universities start to take on more of that role, this kind of industry-university imbrication or set of partnerships where that kind of pedagogy and training is shared. And so you decide to stay and do a master's degree. Is that a different kind of experience? Do you feel like you're a graduate student at that point?

01-01:09:05
Gray: Yes, it was different in one important way, which is this was an academic master's degree track. They didn't differentiate at Arizona at that time. To get a master's there and I think most universities at that time, you did a master's thesis, which was an independent research project, meaning an outcome could potentially be published as an academic paper. Shortly after I enrolled I had classes from two Professors, Fred Lindholm, who subsequently was a long-term faculty member at the University of Florida, and Doug Hamilton, who ended up being my PhD advisor. They worked on transistor physics and circuit design respectively. I can't remember exactly how but I ended up doing a master's thesis working with Fred Lindholm on transistor physics for a certain kind of device that's used in integrated circuits. This was an independent project in the sense you have to read the literature, define the problem, figure out how to attack the problem, get the solutions, and then test the solutions with some simulations or some measurements. It was a great learning experience. We did publish those results actually. Fred was a great mentor; I got through with that they said, "Hey, you really ought to get a PhD. I think you'd learn a lot and it'd be good for you." So I did.

Doug Hamilton is a real visionary who had just completed a sabbatical here at Berkeley in this department, in this building, and he came here for that sabbatical because Berkeley had started the country's first laboratory in which you could fabricate an integrated circuit. And that was in the about '63, '64 timeframe. Doug wanted to learn about that, and he got to be friends with Don Pederson who was the faculty member here who really spearheaded the establishment of that laboratory. Doug came over and spent some part of a year learning all about that, and went back to Arizona and decided to start one there. In that era Stanford and MIT also were starting labs — I think Berkeley was the first and then Stanford and MIT, some a year or two or three later, also got on the same track. But Arizona wasn't a university people think of as a high-tech powerhouse, but Doug got them on that track. This is a facility where you start with silicon wafers, do the masking and the processes of putting the impurities into the wafers, dice them up and thereby make an integrated circuit, a chip with, in that era, ten or twenty transistors on it. I benefited from that immensely because I just happened to get involved with Doug and I did my PhD with him. Talk about a fortuitous accident. Wow. So that was a great experience. And, again, both of those two people were so influential and supportive and I wouldn't be where I am without them. And they were real visionaries. Berkeley and Stanford and MIT continued for the next several decades as the main institutions with this fabrication capability. And we still have a big lab. That building right there, the CITRIS building, has a huge fabrication lab in it, which is the fourth generation successor to the original one.

01-01:14:09
Burnett: I wonder about it being as accidental as all that. Military aviation is crucial to that economy. There's Hughes Aircraft.

01-01:14:32
Gray: Motorola in Phoenix.

01-01:14:33
Burnett: Right. And missile design involves guidance systems, which involves miniaturization, which involves chips. Because there is no market for chips, commercial market. Military funding is making chip research possible for the first sixteen years, I think, after the transistor is developed. I don't know for sure but I think it would make sense that the laboratories would be Berkeley, Stanford, MIT, and a place like Arizona. Not guaranteed to be at Arizona but—

01-01:15:18
Gray: I suspect that the presence of Motorola there in Phoenix was a factor because in that era Motorola, Fairchild, and TI were the big three. Doug also, when he was here at Berkeley, made close contacts with some of the people at Fairchild in Mountain view. Starting one of those labs required a tremendous amount of technical handholding with people in industry who'd already been through that because it's an incredibly finicky and difficult technology. That helped him a lot.

01-01:16:10
Burnett: Going back to the master's project. Can you talk about the process of discovery and then compare it to say, what's going on — and this is what you would describe as an early micro-electronics lab. So back in your master's thesis project, is it an iterative process where you've got a kind of experimental unit and then you're working with formulas to describe what's happening and then if something doesn't fit you have to go back? How does that research play out for you?

01-01:16:47
Gray: That would be a good description of the PhD project I did and we'll talk about that later. But this master project had to do with the behavior of a particular type of field affect transistor. But back then there were basically three types of transistors that you might contemplate. One is a bipolar device; the first integrated circuits were made with bipolar technology. The second was what's called an MOS field effect transistor, which uses a conducting electrode and a thin layer of oxide and then semiconductor underneath. Most ICs made today use MOS technology. A third type is called a junction field effect transistor. You might have come into contact with this in some of your audio work. A junction field effect transistor has a channel and two junctions that surround it and the channel semiconductor material gets depleted as a voltage is applied to the junctions. Up until that time the only analysis that had been done of field effect transistors was for the case in which the gates on the two sides were connected together electrically and had the same voltage applied to them. That is called a three terminal field effect transistor. Fred carried out a series of research projects out of analyzing field effect transistors where the two gates can be at different potentials, called a four terminal field effect transistor. My job was to come up with a model of this device, meaning a lumped model that could be used in a computer simulation, which contemplated the two gates being independently controlled, so you could have different voltages on the two gates on two sides. There was a pretty good analysis of those devices already in existence. Modeling that properly on a computer requires that you use a lumped element model. That technique approximates the behavior of a distributed channel by a discrete set of nodes which can be simulated easily in a computer simulator of that era. We developed this model and compared the model predictions with some experimental results from actual measured FETs and they compared okay. So to answer your question more directly, you've got to model this device so a computer can simulate it. You create that model and then you verify it by using the computer to simulate a response and you compare that to what the real device does and see if it agrees or not. That was basically the project.

01-01:20:47
Burnett: And in the computer simulation are you basically developing a function that would describe, for example, the depletion of a value over time?

01-01:21:01
Gray: Yeah, yeah. That's right. I'm trying to think of an analogy. An analogy might be let's say you're going to predict the weather in the Bay Area. On a computer to do that you can't really simulate the continuous variables of temperature, humidity, all the other atmospheric variables at every single microscopic point. It would take too big a computer. So you separate it into blocks of reasonable size. Maybe the blocks are a square mile each. And for each mile you have a value for the average temperature, the average humidity and the average wind in that block, and all the other relevant variables. And so now you have a set of numbers. And if you have a ten mile by ten mile area to simulate, you have a hundred blocks and so you have a hundred sets of

numbers and they link to each other through some relationships like conservation of energy and conservation of mass and all that. So you have a set of equations that describe how these variables relate to each other. Then you just put it into a computer that can crunch those numbers. Then it can tell you, in response to a certain amount of sunlight and a certain amount of influence from elsewhere, over time, given a set of initial conditions, the climate's going to do this. That's a simplified example of lumped modeling of a continuous system. The smaller the blocks, the more accurate the simulation approximates reality, but the more complex the computations get. We were doing essentially that same kind of modeling but it was in the context of a device, a microscopic device with electrical variables like current and electric field. If you put a sudden change at one part of the device it takes microseconds to propagate through the whole device and that's what we were trying to model, how long that takes. The transient response or the time response is what we were trying to model.

01-01:22:52
Burnett: Right. Yeah. And you're talking about a change in voltage.

01-01:22:54
Gray: Yes. So you change the gate voltage, the drain current changes, but it doesn't change instantaneously. It takes time to change limited by the dynamics of the device.

01-01:23:02
Burnett: Just a word about processing and the computer. Do you remember the model of computer that you were using?

01-01:23:12
Gray: It was an IBM I think. Maybe was the one before the 360. Or it could have been a CDC6400. Maybe that's what it was. I don't recall. One of those big old mainframes of that day.

01-01:23:38
Burnett: But just in terms of the actual work that's required. So you get time on the unit, right? So you have to sign up and get some time to work on it.

01-01:23:48
Gray: Well, it was worse than that. You've heard this a thousand times. In that era you created a big deck of cards, each card being an instruction in the program. You'd take it over there in the afternoon or evening, stick it in the hopper and come back the next morning. During the development of the analysis program, for the first tries there would often be an error message saying it didn't run right or this didn't work or that didn't work. But finally, after enough times, you found all the bugs and it worked. One day per bug fix.

01-01:24:11
Burnett: Yeah, yeah. But that still at that time replaced however many human beings working Marchant machines trying to calculate something.

01-01:24:21

Gray: It was the start of what became a huge technological change. It was having tremendous impact. Well, that's a whole other story we'll get to. One of the most important developments that came out of this Berkeley EECS department in the sixties and early seventies was the simulation capability for integrated circuit electronics. [phone ringing]

01-01:25:03

Burnett: So we're still in the era where mainframes are doing a lot of the heavy lifting in these kinds of things. The PhD work is a result of joining up with a number of younger scholars, right, both — well, one of them was retiring so he was more of a senior scholar.

01-01:25:35

Gray: Yeah, right.

01-01:25:37

Burnett: So there are these two individuals who take you on. So can you say more about these two individuals and their work?

01-01:25:49

Gray: Right. Well, I think when the phone rang I was going to tell you about the activity here in this building about computer aided design and how important that was to Silicon Valley. You had asked me about the influence of these mainframe computers, and whether it was it starting to be felt in that era. I was trying to emphasize even back in those days, when all you had was a big machine in the basement, the impact was incalculable. Just to give you one example, that of Don Pederson, the same person I mentioned who invited Doug Hamilton here to learn about the micro lab. His greatest contribution was the creation along with his graduate students of a simulation program called SPICE, it's called Simulation Program with Integrated Circuits Emphasis. SPICE and its derivatives became the industry standard for simulating a circuit made on a piece of silicon in much the way I described that we were simulating that field effect transistor. This was a critically important capability because you could determine how the circuit was going to behave before you actually built it. Nowadays we're building circuits with a hundred billion transistors on them. The simulation capabilities now are light-years more sophisticated. But we couldn't have ever gotten much beyond maybe 100 transistors without that capability. So it was critical for the development of the semiconductor industry as we know it.

Fred Lindholm was a young faculty member at the U of A [Arizona], and later moved to the University of Florida. For most of his career his research focused on doing this kind of device modeling for a wide variety of different kinds of devices. I haven't had any contact with Fred recently, in recent years, but I know he did some great work over the course of his career. Doug Hamilton was a long-term U of A faculty member. He started the microelectronics lab there, as I described. He had a number of different research projects over time, all relating in one way or another to the design of integrated circuits as that technology came to the fore. After my year-and-a-half with Fred doing the project on the field effect transistor, I got to know Doug. He engaged me in one of his projects, which involved analyzing the thermal behavior of a chip. The transistors within an integrated circuit dissipate power which in turn causes a temperature rise in the chip as a whole and also temperature gradients across the chip because the transistors are localized in different regions of the chip. At that point in time nobody had really thought much about that, people were starting to build integrated circuits for applications like audio power amplifiers, that have to dissipate a lot of power, in fact many watts of power in a little very small space. In that case the issue of temperature rise and particularly the issue of thermal gradients become very important because the other components on the chip are strongly affected by both temperature rise and thermal gradients. My project was to first analyze the statics and dynamics of this on-chip thermal interaction, and later to develop yet another lumped model to allow computer simulation of that given arbitrary chip layout. The latter took the chip and divided it up into a matrix of nodes, each one with a specific temperature associated with it and a simulation and then run a simulator that predicted in the response to dissipating power over here what happened to the temperature over there, both statically and dynamically. We even went so far as to think about building low frequency filters. In other words, if you can electrically vary the power in one of the transistors, maybe you can sense that temperature variation. Since temperature varies slowly, you should get something that behaves as a low pass filter, passing low frequency signals but blocking out the high frequency signals.. Well, that was an interesting idea but it turned out that there are lots of easier ways to build a low pass filter. But the more important impact was that based on that work one of my Berkeley graduate students, Kiyoshi Fukahori at Berkeley a few years later created a simulation program that we made available free to the outside world. Today there are commercial examples of that kind of simulation program that are used in various applications. For example, if you're building a high-powered CPU to go in a laptop, thermal management is a huge issue. So thermal analysis of that whole system is a very, very simulation intensive thing. So I guess you could argue these are forty-, fifty-year-later incarnations of that same basic idea. In the PhD project, we verified the accuracy of the simulations by simulating some configurations and then I experimentally verifying that by going in the lab, building some chips with those same configurations and testing those chips to see if we got the kinds of thermal interactions that we were predicting. And that turned out to be in agreement. We published that work in several different venues.

01-01:32:00

Burnett: Was it neat in the sense that you built the test device and it got the results that you wanted or were there some false starts or some trickiness that you had to work out?

01-01:32:17
Gray: Was it neat? No, it was far from neat, but not for the reasons you're thinking. The basic physics and mechanics of what's happening are actually pretty simple. It's just: dissipate some heat over here and stuff heats up and measure that, so that was easy to get right. What was hard was actually building the device itself. We're talking about building a chip in a micro lab in a university. I think I might have been the third or fourth person that had ever built a chip in that lab. Just getting it to function was a huge challenge. Things had a tendency to go wrong. Sometimes the furnace wasn’t at the right temperature. Often the photo resist didn’t develop correctly. The package sometimes didn’t work right. Just a thousand things would go wrong. And I can't remember how many tries it took to get a chip that actually worked correctly. That part was challenging. But the actual experimental part, once we got a chip that functioned properly, turned out fine.

01-01:33:22
Burnett: I've seen some photographs of these experimental chips from that era. Can you talk about the dimensions, just to give us a sense of the physical nature of this?

01-01:33:31
Gray: I'm going to pull numbers out of the air because I don't remember. It was probably maybe fifty mils by a hundred mils. A mil is a thousandth of an inch. So that would be a tenth of an inch in one dimension and one-twentieth of an inch in the other dimension. Something like that. And I think it had, I don't know, five or ten transistors on it. You didn't need any more than that because we were really just testing the thermal behavior. We only needed a chip to dissipate heat and a chip to sense the temperature gradients. And we did look at the dynamics and experimentally test some filtering functions and things like that. By the way, there is one area where that technology did get used a lot. One of the things you need to do in an electronic instrumentation system is create a voltage reference. That is something that has an absolutely known and constant voltage so that you can measure something else relative to that. And there are lots of different ways of doing it, but in the semiconductor world it's hard to get an absolute voltage reference that's insensitive to temperature variations. You want it to be constant even when the ambient temperature is varying. One way to do that is to put what's called a temperature stabilizer on the chip. So you build a little thermal regulator right on the chip and you put an insulator under the chip so that the chip is held at a constant temperature no matter what the external ambient is. It's called a temperature-stabilized substrate. And if you're building one of those you need to know what happens with the gradients and everything when you vary the power dissipation. Back in those days there were quite a few of those commercially available and used and they were widely used. Those people used a simulation program, either ours or one like it, to design those typically. Nowadays they've gotten much, much better at building temperature-insensitive references in circuits so it's not so critical anymore.

01-01:35:27
Burnett: Right. An integrated circuit does what? It's a power device? It amplifies signals? Could you say that?

01-01:35:44
Gray: Let's move up a little bit, let's say 1966 or '67. Fairchild and TI began selling integrated circuits in the early 60s, and by 67 or so were providing digital and analog integrated circuits with complexities of perhaps 50 to 100 transistors. In that era the circuits world was digital or analog, virtually all implemented in bipolar technology. For the digital ones, which had complexities on the order of 10-30 gates, there were a number of logic families but the most important one was a technology called TTL, meaning transistor-transistor logic. The analog chips available in that era were operational amplifiers, voltage regulators, and other relatively simple building blocks with complexities of perhaps 50-100 transistors. There were audio amplifiers I believe. Of course, over the next twenty years, as Moore's law unfolded, the complexity levels increased very dramatically.

01-01:37:35
Burnett: And so was there a sense at that time of dramatic improvements in miniaturization? Were you already sensing that the processing power was increasing?

01-01:37:48
Gray: Yes. You could see that happening. It was far from obvious that Moore's Law was going to be a long-lived phenomenon, but you could sort of see every couple of years that the dimensions got smaller as the lithography got better. The device understanding also got better and the result of that was more components on a chip. More components on a chip meant more functionality and, most importantly, more cost effectiveness. You could put a lot more functionality per dollar on these things.

01-01:38:25
Burnett: Yeah. When did you first encounter Moore's Law?

01-01:38:29
Gray: His famous article, oh, boy, what year did that appear? That was—

01-01:38:37
Burnett: Was it '65?

01-01:38:39
Gray: Yes, 1965 I think. I don't think I was aware of that article at that time. I was very aware of Fairchild and Gordon and what they were doing and sort of what was happening in Silicon Valley, because that was part of the picture of what I was working on. By the time I finished by PhD in '69 and came out here, people were beginning to see that this is more than just one or two of these generations. We'd seen multiple generations. I'm not sure when I first heard the term Moore's law but it was certainly obvious that things were moving along pretty rapidly in the complexity dimension. Especially on

memory chips, what really got your attention is you'd read the different conference proceedings, like the Solid-State Circuits Conference, the leading conference in the field, and you'd see that about every year or two there'd be a factor of two increase in the memory density. And they were going from one-K memory to 4K, sixteen-K, etc. They just kept going up. And it was just obvious that there was going to be a lot of increase in density over time.

01-01:40:09
Burnett: And so in working on the dissertation, that was the full thesis that was undertaken?

01-01:40:22
Gray: Yes I should just mention a couple other things that I got involved in that turned out to be wonderful experiences for me. In 1963-64 I was a lab TA while working on the MS degree. I taught an undergraduate electronics lab. The following summer I got hired as an engineer at the lunar and planetary laboratory at the U of A, a world-renowned astronomical center. They do experiments connected to the big telescopes, like the Keck, and a range of other astronomical observations and experiments. They do a lot of instrumentation for satellites, observations from satellites. And the particular project I worked on was a balloon-borne polarimeter for observation of the moon and planets. The experiment was a telescope about 6 feet long measuring light polarization, mounted in a large high altitude balloon. The astronomer I worked with, whose name is Tom Gherels, was trying to measure the polarimetry of the reflected light from the moon and from that they were trying to deduce the makeup of the materials on the surface. There was a lot of information from the polarization that they could get about the rocks and what they were made of. This was 5 years before the moon landing. I was the lead and only engineer on this project. Here I was, a kid. I barely felt adequate to do anything. I learned a lot from that experience! These types of balloons are launched from unusual places. One of the launch sites is immediately below Glen Canyon Dam at the upper end of the Grand Canyon. They need windless places to launch these high altitude balloons, and the deep canyon right behind Glen Canyon Dam fits the bill. So we'd trek up there, drag all this equipment down to the canyon floor and launch this huge balloon in the middle of the night. That was pretty exciting. There is another site in Texas, south of Dallas, where we launched a number of these also. That was a fabulous experience — it was real engineering. I adapted a preexisting design for the logic sequencer that controlled the observation and designed the pointing control that sensed the moon and pointed the polarimeter. So anyway, that's something that I really remember fondly. I did that for a couple of years and then I got supported by Doug on a research assistanceship to finish the dissertation research and I finished up on that.

01-01:43:29
Burnett: Yeah. In the dissertation you acknowledged NASA, right?

01-01:43:34
Gray: That must have been a NASA contract. I had forgotten who the sponsor was.

01-01:43:39
Burnett: Yeah, so it would make sense, given some of the—

01-01:43:44
Gray: I think the reason they were sponsoring that is they were looking for a way to build functions that were radiation intolerant, since in outer space you have a very high-radiation environment. They were exploring technologies that wouldn't be degraded by the radiation environment. And they thought these low frequency filters that you might be able to build with thermal effects could be a candidate for that. Turned out there were way better ways to do it than that.

01-01:44:43
Burnett: I'm not sure if this is covered in the dissertation but is there something about optimal thermal range for the operation of these circuits? Is there something about having it operating at the right temperature that has—

01-01:45:04
Gray: Integrated circuits are designed to operate either in the “commercial” temperature range — 0 to 70 degrees Centigrade, or the “military” range -55 to +125 degrees centigrade. That’s been true for many years, so I didn’t make any particular contribution to that in my dissertation.

01-01:46:12
Burnett: We can sort of switch gears here a little bit to personal life. Can you talk a little bit about someone you met around that time?

01-01:46:26
Gray: Yes, certainly. My wife Judy and I met in 1964. She was born and raised in Chicago, in Evanston, in particular. She came out to the U of A as a student and I met her on a blind date in 1964 around Thanksgiving time. We were pretty much inseparable after that. We dated for a long time and then got married in June of 1966. She majored in art and later on in interior design. She picked the U of A partly because she's a horseback rider, and had always ridden horses at home. Her family encouraged that, and she had a horse at a stable there near Evanston. She brought her horse to Arizona with her, so when I met her she was a horsewoman. I do remember not long after we met she took me out to meet the horse and the horse took one look at me and could see competition. The horse didn't like me very well and all I can say is a year later I was still there and the horse was gone, so I guess I won. But I never liked horseback riding very much after that, personally. Anyway, we got married in '66 and then she worked as an interior decorator all the way through the rest of my PhD years and helped pay the bills. She’s always a great partner, supporter, and advisor in everything for me. And we've been married now fifty-one years. Another example of serendipity — meeting your lifelong partner on a blind date. I think if there's any theme it's serendipity.

And then our two sons, we'll get to this later, but I have two boys, one born in '71, Matthew, and one born in '75, Ryan.

01-01:48:26
Burnett: Wonderful. Well, perhaps we should take a pause right now and we'll continue next time.

01-01:48:30
Gray: Okay, great. Thank you, Paul.

[End of Interview]

Interview 2: November 13, 2017

02-00:00:23

Burnett: This is Paul Burnett interviewing Paul Gray for the University History Series and it's Monday, November 13th and this is our second session. We last left off talking about your dissertation project and it's the end of the 1960s, 1969 it's published. Prior to the dissertation being completed I imagine you were working with your advisors on the job market and what was out there. Can you describe what you were facing in 1969 in terms of career options?

02-00:00:59

Gray: Sure. Thank you, Paul. I thought I might mention one other thing that happened in the 1960s that made a big impression on me. As I described earlier, I had a lot of interest in military things, participating in ROTC and so forth, and didn't have negative feelings about the military. In 1967 I got a draft notice classifying me 1A and that was right in the heart of my PhD dissertation work. I really didn't want to leave Berkeley and go be drafted at that particular time. I didn't mind the idea of going later. So I decided to appeal that, made an appointment with the local draft board, and went down to have an interview with the board. It was a memorable experience. I took with me samples of different kinds of integrated circuits to try to explain and make the case that if I could finish my PhD I would be able to contribute more to the war effort. The Vietnam War was just then in full swing and I asked them to give me a deferment until I finished my PhD, which was going to be a couple of more years. I guess I made a good case because they agreed and gave me a deferment, allowing me to stay in the PhD program. By the time I finally did get out in 1969 the war had tapered down and the draft rules had changed. Later on, because of my job at Fairchild [Semiconductor], I didn't ever actually get classified 1A again. That experience made an impression on me, particularly the experience of going down and making the case in front of the draft board. And there was some justice to it because later on at Fairchild I actually worked on the design of a chip that got used in a control system in a military helicopter.

Anyway, getting back to your question about interviewing. By late 1968, I knew I wanted to work in industry. I didn't really have any interest at that point in an academic career. I'm not sure why that was, but I really wanted to get out and design something, wanted to make a real product. I interviewed with seven or eight companies around the country and I've told my students many times in the years since then what a rare opportunity that is to make connections that will be valuable later. I'll just rattle off some examples. I interviewed at Bell Laboratories, the three-day interview that they did in those days, and I met Dave Hodges, who turned out to be a lifelong colleague later on. I interviewed at Motorola, where I met Bill Howard and Jim Solomon, two leading industry figures. Both had Berkeley connections, it turned out. At Sprague Electric I met Bob Pepper, who was a Berkeley PhD and later on I served on his board of directors when he founded a semiconductor company twenty years later. And other companies. And, of course, Fairchild, where I met lots of people I'll talk about in a minute. But the point is, it's a rare opportunity when you're a young person that the interviewers are trying to get to know. For many of the people I met, those relationships became very useful and valuable later on in life.

02-00:04:59
Burnett: Bell was the longest. It was three days?

02-00:05:03
Gray: Yes.

02-00:05:04
Burnett: Okay. And at that time did you get a sense of the work culture of the different companies? Did you notice differences?

02-00:05:13
Gray: Yes.

02-00:05:15
Burnett: And can you talk a little bit about that? Because Bell is very different I think.

02-00:05:16
Gray: Well, Bell Labs was an iconic place and, of course, still is. But especially in those days was an iconic research institution. I did get an offer there and most people would have said, "You should take that. You're nuts if you don't take that." It was very much like being in a university environment; it was a research mission. For the most part they didn't do product design — they did basic and applied research. And it was just an amazing place, a wonderful work environment. The emphasis was on publishing and creativity. The rest of the companies were chip companies making products to sell. That was a very, very different environment. Fairchild was a little different. I'll get to that. But the semiconductor companies wanted, for the most part, someone who could hit the ground running and get products out the door pronto. So it was different. After a lot of thought, it was going to be either Fairchild or Bell Laboratories. Bell Labs not only was an iconic place but I could work with Dave Hodges, and it was obvious he would be a wonderful mentor. But it was one of those serendipitous things. On the three days that Judy and I went to Holmdel they had the worst ice storm of the decade. You'd walk out the front door of the hotel and the sidewalk was a sheet of ice. You literally couldn't walk to your car. So as a Tucson person, as an Arizona person, that had a big impact. So for that and many other reasons, most of which I probably don't remember accurately, we ended up deciding to go out to Fairchild. That was one of those serendipitous crazy things that ends up changing the direction of your whole life. Maybe it's worth saying a little bit about Fairchild.

02-00:07:49
Gray: Let me give a thumbnail sketch of that situation. I should back up a little bit. Fairchild was founded in '58 by Gordon [Moore] and Bob Noyce, who had

left Shockley, along with Vic Grinich, who was at Berkeley for a while and who I met but never worked with. Fairchild was founded to make discrete components, silicon transistors, a descendent of the early transistors that enabled transistor radios in the early fifties. These were discrete components. They started out that way, as a small company. Shortly after that, about 1960, they realized that the processes they were using to make those silicon transistors, with a lot of enhancements, could be used to make something with more than one transistor on a single piece of silicon: the integrated circuit. Bob Noyce got the Nobel Prize for that invention, along with Jack Kilby. Then as the sixties progressed they began to sell integrated circuits, initially one or two logic gates, perhaps ten transistors on a chip, and then that progressively got more complex. So that by the time I arrived there in 1969, in terms of the digital circuits, they were making probably a hundred to two hundred transistors, the equivalent of eight or ten logic gates, something like that, on a single integrated circuit, selling those mostly to computing and military applications. On the analog side, they had gotten to the point by 1969 where they were building operational amplifiers, voltage regulators, different kinds of functional blocks, again complexity on the order of fifty transistors, and those were also commercially very successful. The lead person at Fairchild doing the analog design was a fellow named Bob Widlar, who was an iconic figure in the analog chip world and who brought a tremendous amount of creativity to that enterprise. One of the reasons I went to Fairchild was having read his papers and seeing that degree of creativity, which was really quite phenomenal, because the constraints on the design in a single IC are very different. When you're building something with discrete components you can choose precision resistors and all kinds of transistors and other kinds of components that are matched to the job. On a chip you have to take what the process technology gives you. Taking advantage of those other degrees of freedom, for example, the close matching between components that you get, is a different set of design constraints and Bob was a genius at that, just incredibly creative.

Now, Fairchild itself is well-documented in Gordon Moore's biography and the various Noyce biographies. By the middle of the sixties Fairchild was having a lot of problems with the business, management problems really. They were growing the business but they began losing money towards the last part of the sixties. They had very strong competition from Texas Instruments and Motorola. In 1968 Noyce and Moore left to found Intel and I arrived in '69, shortly after that. They had brought in a fellow named Les Hogan. Les was the former general manager of Motorola's semiconductor operations. And, by the way, Les, who I got to know later, became a great friend of the department here and helped us with many things. But anyway, Les had become president. But there were still a lot of problems. So for the two years I was there — I arrived in '69 and left in the fall of '71 — the company was in turmoil. My most vivid memory is a long series of all-hands meetings where the topic was the latest reorganization, the latest layoff or whatever. I was a survivor of a very large layoff there in 1970, partly attributable to the 1970 recession. That was the downside. But the upside was mainly due to the fact that Gordon Moore, the technology vice president, before he left Fairchild had moved all of the research and development out to Palo Alto to a facility in the Stanford Industrial Park called Fairchild R&D. And that's where I went to work. When I arrived there, a great many of the people who would move to Intel and later become Intel executives were still there and I got to work with a lot of them. Ron Whittier, Albert Yu and Sun-Lin Chou and people like that. They were the people who helped build Intel later on. They subsequently left Fairchild but I got to work with them for a period of time. It was a great environment and I learned an awful lot there.

The reason they recruited me was because they wanted to get involved in power devices, audio amplifiers, one you'd relate to, Paul, for example, but others, too. And voltage regulators. If you're delivering power to a speaker for example you have to dissipate power on the chip and that causes the chip temperature to rise. Those thermal effects become important to performance. I had just finished a PhD on thermal effects, so the idea was that I would help them with that. Through the course of that I worked on it with a team, led a team to design and build a power operational amplifier that was the first of its kind at that point. The chip subsequently went into production. That's the one that ended up in a helicopter. It would be wonderful if every engineering graduate early on in their career could get involved in seeing a real product through to an actual market application and transition to manufacturing. It's a great learning experience. It was terrific working with all those people. I wouldn't trade that experience for anything.

02-00:14:30

Burnett: Could you say more about the culture, which is kind of famous? The culture at Fairchild, it's thought to be the first instance where you have a group of people packaging the *group* as a phenomenon that can have market value. What's the significance of Fairchild? What was its reputation as distinct from, say, Texas Instruments or Motorola? What was special about it, in its reputation, at least?

02-00:15:03

Gray: Yes. You have to be a little careful because there were a lot of moving parts in the industry at that time. You had the strong sense there that this was an industry in the birthing. You could really see that. We mentioned last time Gordon had written his paper in '65 about scaling. MOS [metal oxide semiconductor] technology, I'll get to that in a minute, explaining about MOS, but it had become clear that through MOS technology, things were going to scale, meaning the number of transistors per chip was going to grow dramatically over time. And I think the realization was sinking in that this was an industry that was really about to take off. The microprocessor hadn't quite been invented yet but you could see that things like that were going to happen.

As I mentioned Gordon had established this R&D laboratory out in Palo Alto. I would guess there were several hundred people out there. Device physicists, computer aided design people, circuit designers, analog and digital, process technology people. The whole spectrum of people rubbing shoulders every day. A lot of the management problems in the company came from the fact that all of the people designing real products were down in Mountain View. By that time Fairchild was a pretty good sized company, and there wasn't a good coupling between the two. The R&D people liked to publish papers and do that sort of thing and the people in Mountain View viewed them as country club types playing around. They didn't really contribute much to actually getting products out. The one I worked on was an exception to that but most of the time there wasn't a good coupling between the research people and the product people. But that was only one of a whole host of problems. There were also other management issues associated with product definition and marketing and things of that sort.

I think Fairchild R&D was a unique thing in the semiconductor industry at that time; it was like an emulation of a Bell Labs really. It ended up having this fatal flaw that people could be picked off. This technological knowledge could be hired away so easily. That was really a serious problem. A lot of people left, many to found or join new companies. The people whose names I rattled off, including Andy Grove by the way, went to Intel. He was like employee number two I believe. And they carried with them a lot of the investment in knowledge that had been developed there that Fairchild had made. But it was a great culture. I think the accurate way to describe it is that in the late 60s people were still trying to figure out how to manage this evolving industry. The pure R&D lab model that Gordon tried with the Fairchild R&D lab, didn't actually work too well. It continued for a number of years after that, but it got scaled down and they began to develop a lot more products out there. And then, of course, Fairchild itself didn't prosper after that. There were many reasons and contributors to that. But anyway, it was an exciting place.

02-00:18:59

Burnett: Well, external to the company, I think Bob Noyce, at the beginning of the sixties, was thinking the problem was the first chips were really uneconomic. They were 120 bucks each. They were thinking about a market and he was thinking the military would be a steady client for the birthing years. But there's a hand-off at a certain point, where they're looking at a larger commercial market. Is it at that moment where they're facing those market challenges that then were forcing them to rethink management?

02-00:19:46

Gray: As an employee I didn't have very much visibility into a lot of those issues at that time. But if you read the biographies, it's clear that the transition to industrial and consumer marketing, product definition, and low-cost manufacturing was a challenge for them, but there were a lot of other issues also. The interference of the parent company, Fairchild, was a big issue. There was tension between Noyce and Moore and the people of the parent company. I'm sure that what you're saying was a contributor but I think there were a lot of other contributors. Maybe the other players at that time, which were primarily TI and Motorola, managed those things better.

02-00:20:35
Burnett: So you mentioned there were key figures that you were working with there. Apart from David Hodges, were there important people that you met when you did your initial tour before you were hired there who are worth talking about, at Texas Instruments or Sprague even?

02-00:20:51
Gray: Well, I think I mentioned them briefly, Bob Pepper and those people. But maybe I'll mention them later on because in each of those cases I did do things with them later on. So maybe I'll mention that when we get that far.

02-00:21:09
Burnett: Sure. And you're also there in the Valley, I suppose the Valley before the fact. Can you describe that climate a little bit in terms of the proximity to Stanford? What were some of the factors that were really powerful there?

02-00:21:29
Gray: That's an interesting question. I do remember having a lot of connections with universities in general, Berkeley and Stanford, on various topics in those years. Of course, we were in an industrial park created by Fred Terman, owned by Stanford. We were on their land. But I don't remember having a sense of a Stanford dominance of the landscape in terms of university engagements. For reasons I'm going to explain in just a minute, we had a lot of interaction with the Berkeley people because of the computer-aided design activity. So yes, of course, there were a lot of Stanford people around and I worked with a lot of them. I don't remember a strong sense of being totally dominated by Stanford, the presence of Stanford. It was broader than that. It was a pretty eclectic place. We had people there from all over the country, a lot of different kinds of people, a lot of different kinds of backgrounds.

02-00:22:42
Burnett: And you mentioned earlier in this interview that you were not so interested in the academic environment. [laughter]

02-00:22:50
Gray: You asked about the sense in the Valley. I spent quite a bit of time down in Mountain View at the main plant going to meetings, seeing things in the factory down there and the fab [fabrication plant], interacting with people, going to the Wagon Wheel for a glass of wine, and so forth. There was an excitement. If you told those people that we'd be putting a hundred billion transistors on a chip in 2017 they would have thought you were crazy, but there was a real excitement in the air, a new industry. Most of the people came from backgrounds that were different from chip design or chip technology.

They were learning on the job and it was exciting. But, as I mentioned, because of the era, 1969 to 1971 was a very tough time in the semiconductor industry. There was a recession going on. As an example, when I went to Fairchild R&D I joined a group doing analog technology, chip circuit technology development. About a third of those people got laid off in the 1970 layoff. Many were PhDs. That was a shock. I don't know how I survived but I did. It was not all fun and games.

02-00:24:35
Burnett: Yeah. You have a son in 1971. That's a little bit later but were you thinking about stability a little bit?

02-00:24:45
Gray: Yes. To move on a little bit, in another one of these crazy serendipitous things I met Don Pederson sometime in the spring of '71. That came about because we were building chips that had on the order of a hundred transistors on them. It's very difficult to predict by building a physical breadboard or a prototype out of discrete components how a chip like that's going to behave electrically. You really needed circuit simulation even at that point, a program that would simulate the electrical behavior of a circuit. Don and his group here at Berkeley were developing that kind of simulator. We needed that. So we got a connection going and we got one of the early versions of SPICE, I think it was called something else at that point, and used that.

02-00:25:46
Burnett: CANCER, I think.

02-00:25:46
Gray: Yes, correct. That's how I got to know Don. I met him again later on that spring, and he just said, "Hey, why don't you come up to Berkeley and teach for a year?" I hadn't really thought about that but things were pretty tough and I was beginning to feel like I wanted to try something a little different because it was kind of rugged in the semiconductor industry at that time. We had a brand new little young son Matt, born that spring. I walked in one day and said, "Judy, I think I want to go up to Berkeley and teach for a year." And she thought I was completely nuts, but she stepped up and agreed to it. So we came up here and ended up getting an apartment out in Walnut Creek and coming here for a year. I never intended to stay. It was going to be a temporary respite. I continued to consult down there and through that year and I saw it as a temporary hiatus to try and just learn something new. And so that's how I came to be up here, really more by accident than anything else. It's incredible how so many things happen through serendipity.

02-00:27:18
Burnett: I don't know how much you know about the history of SPICE. The story that I read was that this CANCER program was proprietary and it was written by a gentleman named—

02-00:27:47
Gray: Larry Nagel.

02-00:27:49
Burnett: There was a Rohrer—

02-00:27:52
Gray: Ron Rohrer. Ron Rohrer was the faculty member.

02-00:27:53
Burnett: Ron Rorher and Lawrence Nagel, right. And that was proprietary and it was rewritten by Lawrence Nagel—

02-00:27:59
Gray: Yes, that's right.

02-00:28:01
Burnett: —with enough differences to be basically open source? Was it open source?

02-00:28:04
Gray: I'll get to that because that's a critically important point about what was happening in Berkeley at the time. So anyway, I arrived up here; we had our apartment. My first assignment in that fall was to teach EECS 105, which is a junior-level electronics course that fall. I found I really liked the environment. I had thought of universities as sort of an ivory tower — this was anything but an ivory tower. The faculty here were extraordinarily engaged with industry. But more importantly than that, I realized that the basic value system, the search for truth as the highest value, educating the next generation of engineers and young people, resonated with me. In industry the highest value is creating value for the shareholders, and that's fine but I resonated better with the value system here. And I also started some research projects and I came to realize that in a university environment like Berkeley, faculty members are really almost like entrepreneurs. You don't really have a boss. Its closest analogy I think of is a big law firm. Berkeley has 1500-faculty members. It's sort of like a 1500-member law firm where every lawyer is out there finding their own cases and building their own career. In the case of the university, it's finding your own research funding, setting your research agenda, trying to figure out how to make a difference and have an impact and teaching, as well. Recruiting your own graduate students, you're really much more of an independent person than I had imagined. So, long story short, a faculty position opened up and I applied for it and I got it and so after that I was a regular faculty member. Let me talk about Don and the department as I found it. It ties to this CAD [computer-aided design] question. In 1971 the department had just merged computer science into electrical engineering. That was an extraordinarily fortuitous thing. Universities around the country are struggling with that to this day. At Stanford, EE [electrical engineering] and CS [computer science] are separate departments but both in the College of Engineering. Here and at MIT they're together in a single Engineering department. At lots of other places they're separate, often with CS in a

separate college, usually a college of science. The organizational chart isn't quite so important as making sure there's this continuum between computing theory, software, software applications, operating systems, databases, computer engineering and hardware. There's a continuum there. It's very hard to really separate it. The key is to have faculty be able to collaborate across that boundary without any impediment at all. I think having the two disciplines combined here in this department has been a huge plus. It's allowed that kind of collaboration with minimum impediment, which has really had a lot of impact.

The leading figures in the department when I joined were Paul Morton, a computer engineer, Ernie Kuh, a circuit theorist, and Don Pederson, who was the integrated circuit computer-aided-design person. Tom Everhart, who went on to be CalTech president, was a technologist at that time here. Important leadership came from Lotfi Zadeh, who was an eminent computer scientist and John Whinnery, who had been an earlier dean of the College of Engineering. That group of people had really shaped the department and it was very, very prominent at the time. The combination really made it one of the strongest departments on campus and for that matter in the country.

Turning to Don Pederson, he had done two phenomenal things here. Let me start with the computer-aided design. Somewhere in the early sixties, Don had recognized this need for computer simulation. To go back to that power amplifier example, back in those days you could still try out your design by building what they called a breadboard and you plugged discrete devices in and it mimicked the chip, how the chip was going to behave. That was pretty ineffective anyway. But once you got bigger than a hundred transistors or so it became completely impossible to do that. Don recognized very early, the way things were going, it was going to be essential. And it was one of those early interdisciplinary things. To build an effective simulator of electronic circuits you have to have someone that knows devices and models the behavior of the transistors electrically. You have to have somebody that understands computer numerical analysis and how you actually solve differential equations on a computer on a large scale. And you have to have circuit people who understand what's needed.

02-00:34:04
Burnett: Right. The relationships. Right.

02-00:34:04
Gray: You have to have a broad spectrum of people. Don was able to assemble that by collaborating with people around the campus, a brilliant stroke. Don was a highly forceful visionary person who really liked to get things done. He assembled a series of remarkable graduate students; Don was phenomenal at recruiting great people. Two of his grad students, Dave Hodges and Rich Newton, went on to become engineering deans here. I don't think anybody else can claim that, at least not at Berkeley. Ron Rohrer was one of the early

faculty members that worked with Don and CANCER was a result of Ron's effort. Another key insight that Don had was that putting this software in the public domain as opposed to trying to license it would, number one, make it widely disseminated and, number two, allow people to build on it. People could invest in it. And that has become part of the software landscape, multiple people iterate on multiple later versions of the software. And long story short, within ten or fifteen years of that point in time, every circuit design engineer in the world was using some flavor of a derivative of SPICE. It became an industry standard. The industry wouldn't really exist without that kind of simulation capability. Once you get [the scale] to the thousands and tens of thousands and hundreds of thousands of transistors, it's the only way you can do design. In fact, many tools at much higher level than the circuit level evolved after that that weren't actually simulating the circuit, but were simulating blocks at a higher level. But underlying it all is an ability to simulate at the circuit level, which that provided. So it was a huge innovation and had an incredible impact and also pioneered a great software dissemination model for universities. Many others emulated that public domain model of dissemination. It calls for a lot of careful management in who you gave it to and what they could do with it, and what they had to do if they wanted to commercialize it. You wanted it commercialized but you also wanted free dissemination of the core program. Don and his successors, like Rich Newton, did a brilliant job of managing that. It had a huge impact and was a great contribution. To this day there's a group of people working on computer tools of that type and the successor types here at Berkeley. It has been a big part of the landscape here at Berkeley for many years.

02-00:37:04
Burnett: It was open source but it was copyrighted by the regents, or something like that? So it was kind of copylefted in the sense that it was restricted legally in order to maintain it in the public domain.

02-00:37:20
Gray: In order to get it you had to sign an agreement. I'm not sure about the copyright. I don't think it was copyrighted. It might have been. But more importantly, to get a distribution of this open source software you had to sign an agreement. And the agreement had a lot of restrictions on who you could give it to, what you could do to it, and if you commercialized it, what you could say about it and what features you could include. I think there was a small fee to support the distribution operation. I might not have that right but I believe that if you commercialized it and started generating income off it, we got a free copy and we got some revenue off it. I believe that's right. I'll make sure when we do the final version.

02-00:38:11
Burnett: Do you feel that the role — not that this is a plug for Cal at all, but that the role of Berkeley is understated in the history of Silicon Valley?

02-00:38:25
Gray: There's plenty of documentation of the role. It's on the EECS departmental website. But if you asked the random citizen on the street anywhere in the Bay Area they would probably say that Stanford was way more important than Berkeley. I think "way more important" is not correct. As described on the website, judging by the number of companies started by faculty or former students, or by the numbers of alumni employed in the Valley, one could argue that Berkeley and Stanford are comparable contributors. In terms of innovations that have mattered, there are many. Examples are RISC [reduced instruction set computer] processor architecture, RAID [redundant arrays of inexpensive disks], MEMS [micro-electromechanical systems] technology, FINFETS [fin field effect transistor], a device structure used now in all leading edge silicon technologies, mixed signal analog interface circuits, circuit simulation and synthesis, relational databases, and so forth. It goes on and on. So I think the perception is probably not quite on point in terms of what the reality is. But Stanford had a big impact, too. I don't know how you would compare those two. You'd have to find some comprehensive, nuanced metric. But Fred Terman set up the industrial park. There are many things that got done by the Stanford faculty and by leaders down there that had a big impact in shaping Silicon Valley.

02-00:39:34
Burnett: There are enough 'without-which-nots' to go around.

02-00:39:37
Gray: Yeah. There's plenty of credit to go around. But I do think you're right that most people don't perceive our contribution as being as great as it actually was.

02-00:39:51
Burnett: So you had the wrong fear about academia. You thought it was going to be stuffy and detached and somehow behind. But you have a different experience immediately. This is generative. It's integrated; it's part of a larger landscape.

02-00:40:07
Gray: That's right. That's exactly right. That's right. You've said it. I can't say it better. But I want to move on to—

02-00:40:16
Burnett: Sure. Let's do that.

02-00:40:18
Gray: Don made one other pioneering contribution, which also had a big impact on me and my colleagues in many ways. Dave Hodges' oral history talks a lot about this. Don and Tom Everhart, in about 1960 — this is really early on — when integrated circuits first got invented, decided, that the campus needed to be able to build experimental integrated circuits, ie., we needed a lab to build chips. I can just imagine the number of people that must have told him he was crazy in thinking they could do that. But they did. They got some money

together. They got space down on the fourth floor of this building. Dave Hodges was an early grad student that helped put that lab together. By the late sixties, maybe ’67, ’68, they had a lab that was functioning, and that could actually build an integrated circuit chip of with few transistors. Not very complicated, but the first in the world in a university. And I think I mentioned earlier that at Arizona my advisor Doug Hamilton had come over here about that time, seen this, and gone back and created such a lab at Arizona. It was an even bigger surprise that they could succeed in doing that given that Arizona was not one of the big research universities near Silicon Valley. So the lab prospered. When I came here my students began working on chips, on chip design projects, and were able to build prototypes in that lab. It had a huge impact because in the conferences where integrated circuits were being talked about you really needed some experimental results. You couldn’t just show a simulation, and for a good reason. You needed to show these things actually worked. This lab gave the capability to do that. So it empowered the faculty here to be major contributors in the integrated circuit design community, and it was tremendously important. I’ll just finish the story of the lab. In the seventies the lab was a place to build prototype chips for people working on circuits, integrated circuit design. That was myself and some folks I’ll mention in a bit. And then toward the early eighties, the chips got too complicated to make in a university lab. The capability evolved to fabricate those chips elsewhere commercially. So our students doing circuit design prototypes built their prototypes using foundry services somewhere. The lab evolved from there-there have been two successive incarnations, the second one here on the fourth floor and then one right there, that building right there [pointing to Sutardja-Dai Hall]. The lab has evolved to be more of a technology development vehicle as opposed to trying out circuit ideas. MEMS technology, you know when you turn your iPhone sideways and the display—

02-00:43:47
Burnett: Right. The gyroscopic—

02-00:43:48
Gray: The gyroscopic chips in there, those are derived from MEMS, which Dick Muller and Roger Howe and their colleagues developed here at Berkeley. Even later than that, the technology that’s used in the latest Intel microprocessor technology, the twenty-two nanometers, is a particular form of transistor structure called a FINFET that Chenming Hu and Tsu-Jae King [Liu] developed in the laboratories here and it’s sort of a 3D-transistor structure. Now it’s become a standard technology for below twenty-two nanometer scale technologies around the world. So a lot of things have come out of that lab.

02-00:44:39
Burnett: When you came here from Fairchild, did you import questions or problems from there or did you develop a whole new set of questions based on your interactions here or something in between?

02-00:44:57

Gray: I started out by doing some projects that were extensions of what I was doing at Fairchild. One of my students, Kiyoshi Fukahori, wrote a program that was an extension of SPICE that incorporated the thermal interactions on a chip. So you could simulate electrically an audio amplifier, dissipating power, and also get the thermal interactions included in the simulation. And that actually was used at Fairchild because I imported it down there and then some other places, as well. And then I also did some work with Bob Meyer on operational amplifiers and other kinds of circuits, circuit architectures and designs here. Before I get into that I just want to mention the people that were my mentors when I first came here were obviously Dave Hodges and Don Pederson. They were terrific. I got to work with Bob Meyer, who had just come from Australia, and later on we coauthored a book, which we'll talk about. But Bob was a terrific colleague. And Ernie Kuh, who was the department chairman at the time I came in, I still remember my first interview in Ernie's office as a candidate for this faculty position that had opened up. He was an iconic person, a famous circuit theorist and known all over the world. I was quaking in my boots, in awe of this fellow. But he was incredibly supportive. He became a big mentor of mine over the years and just was a wonderful colleague. Those were people that really, really helped me out.

I'd been here a couple of years and Dave Hodges and I had worked on some projects together. You remember that when Gordon and Bob Noyce left Fairchild to found Intel, they weren't using bipolar technology. They did a little bit initially but they transitioned to a different kind of technology called MOS, metal oxide semiconductor. And it's just another way to make a transistor, but it's much better suited to scaling the transistor, meaning all else being equal it's a denser technology. It's easier to take advantage of finer feature sizes and you can put more transistors on a chip. When they started Intel to make memory chips, which was the first product, they settled on MOS technology very quickly. Then as time went on they realized they could make logic chips and they began to make logic chips of various types with perhaps thousand transistors, a pretty high levels of integration. And now we're up to maybe 1971 or '72. Dave, Bob Meyer and I consulted with industry a lot, and most of us spent one day a week in Silicon Valley. And one day I remember a conversation, Dave said, "You know, Paul, this MOS technology, I think it's going to take over and we really ought to start looking at whether we can do some of these analog things." Up to that point it had been purely a digital technology for memory and for gates and logic. MOS in that era was poorly suited for analog functions — bipolar was much better for various reasons. It was a sort of crazy idea but, why not? It's a good research project for a university to do, so we did. I had an early student, Bob Blauschild, who looked at building an operational amplifier in MOS. We found out it's really hard; the technology really was poorly suited to analog. The transistor doesn't have very good characteristics. But we kept plugging away, and that evolved over time and pretty soon we started looking at other functions, like A-to-D converters, and I had a series of grad students, Jim McCreary and Ricardo

Suarez-Gartner and Yannis Tsividis, who figured out ways to build analog to digital converters in this MOS technology. And that became an important thing. Back in those days the argument was usually whether it was better to do a particular function using analog circuits or digital processing. It was sort of an either/or. You could do this digitally or you could do this in the analog domain. It changed later, which I'll get to, but that was the issue then. And we were having a little trouble because most of the time if it was a pure analog function, the MOS technology wasn't very well-suited to it. But we kept plugging away.

There was one particular application that Dave was very familiar with, which was the telephone central office. A telephone system in those days consisted of a big building with thousands of mechanical relays in it and a pair of wires from each telephone down to the central office. When you picked up your phone a relay closed in the central office and through a whole chain of events connected you electrically to somebody else. The telephone central office was in the process of being digitized at that time, so they wanted to replace this building full of relays with a big digital computer — much more reliable. But in order to do that you had to have an analog/digital converter and a digital/analog converter for every one of those telephone lines that go into the central office. Dave had a close familiarity with that, being from Bell Labs. Fortunately, we were able to figure out a type of A-to-D converter that we could build in MOS that matched that application really well. Yannis Tsividis was the lead graduate student and both developed the required operational amplifier to make it work and built a successful prototype. It was very successful and got a lot of industry attention.

Over time it became obvious that MOS was going to win the digital battle, that bipolar technology wasn't going to be a factor in digital integrated circuits. Today, of course, it's 99.9 percent MOS, a particular type called CMOS. And as integration levels kept increasing, essentially the debate about whether to do things analog versus digital went away and everything went digital that could possibly go digital. But that meant electronic systems began to look kind of like an egg in an eggshell, where the electronic system is digital egg but the real world is analog. The real physical world presents a bunch of analog variables, light, sound, pressure, electromagnetic fields, etc., and you need interfaces to connect the analog real world to the digital system. And not only that, if you want to build this entire ecosystem in one technology on one chip, since the digital is MOS, that means the analog has to be MOS. That's how mixed signal MOS integrated circuits came about. Mixed signal means it's a digital intensive chip with some analog peripheral functionality. The analog peripherals include things like the power supplies, A-to-D and D-to-A converters, pre and post filters, signal conditioners, sensor interfaces, and so forth, all kinds of peripheral analog and mixed signal stuff. If you look at your cellphone today, you've probably got a dozen or more A-to-D converters and D-to-A converters, all kinds of radios, sensors, and accelerometers that form the analog-digital "shell." There's a lot of analog stuff in that cellphone but it's all converting the information to digital and then subsequently processed digitally. The telephone central office was maybe the first really good example of that, where you needed an analog interface function but you're really interfacing it to a digital system.

02-00:53:43
Burnett: That's interesting. And this is happening in the early seventies. Does that then result in the mid-seventies papers?

02-00:53:50
Gray: Yes.

02-00:53:50
Burnett: The '75—

02-00:53:51
Gray: Yes, that's right. That also is how I ended up spending a year at Intel. Ted Hoff is usually attributed the invention of the microprocessor. Around 1970 or so he was doing some custom chips at Intel for Sharp, and they wanted a set of custom chips that they could use to build a calculator. They were planning to design the chip set using customized versions of the standard blocks they were already making. Ted realized that instead he could actually implement the functions by building a chip that looks like a programmable general purpose CPU [central processing unit] and a peripheral chip resulting in an integrated microprocessor. That then was subsequently adapted to become the 4004. That led to the 8008. That led to the 8080 and all the rest. So Ted was central to that and he deserves the credit for that chain of reasoning and that invention. He'd finished that by about 1975 or so and he was looking for the next big thing to do. If you're a chip manufacturer, you look for applications where the manufacturing volume is extremely high, and he came across this same telephone central office application. For the interface at the end of the telephone line that connects to the central office computer, the number required is very large — there is one of those for every telephone in the world. So that's a big market. Ted decided to launch a program at Intel to build what's called the telephone line interface circuitry, the analog-digital, digital-analog, and the associated filtering and so on and so forth. They were looking around for somebody to help them. Ron Whittier, who I'd met earlier on at Fairchild, called, I went down and had dinner with him. The upshot was they asked me to spend a year at Intel helping them, which I did.

There had been another parallel development at Berkeley, Bob Broderson, Dave Hodges and I had a group of students working on realization of integrated analog filters. Dave Allstot and Ian Young, were the lead students, although Bob Blaushcild and Yannis Tsividis had demonstrated the required operational amplifiers. Ian and Dave had helped us develop a filtering technology called switched-capacitor filters. Bob Broderson was a faculty member here. He arrived in '75, I believe, came from TI [Texas Instruments, Inc.] with a background in signal processing. Bob's an incredibly innovative, visionary guy. Together we were able to develop this switched-capacitor filter technology. Bob, by the way, went on to do many things. He started the Wireless Research Center here at Berkeley, and prior to that he and his students developed something called the InfoPad, which looked a lot like an iPad, but he did it here in this university environment ten years earlier than the iPad. Bob is a really visionary person. Anyway, it turned out that — again, one of those serendipitous things — the switched capacitor technology really matched well to this telephone line card application. Anytime you have an analog digital conversion of a real time signal you need to limit the frequency range of that incoming signal with a filter. It's called an anti-aliasing filter. And the switched cap technology matched that really well. It was a way to build an integrated anti-alias filter and another filter going in the other direction. So I went down and one thing led to another and we ended up designing and building, along with the help of one of Dave's students, Dan Senderowicz, who came down with me, a brilliant guy, we managed to develop, design, and build this switched capacitor filter, which went into production for Intel. Harlan Ohara, an Intel engineer, was a key part of that team. Then their A-to-D and D-to-A converter chip also went into production and the products became a very successful for them and got them into the telephone central office business. Dave Allstott a bit later went to National Semiconductor and did a similar project. The switched capacitor filter technology got used for a lot of other things, too. Voice band, data modems, lots of other applications.

One impact of the Intel project was that when the industry sees a real product solving a real problem in a real application with a lot of volume, they really gear up fast to compete. Up to that point we were a bunch of university guys playing around with some ideas about MOS analog circuits, but that made it real pretty quick; those technologies made their way into widespread use fairly quickly.

Over the years since then, the technologies have evolved a lot. The switched capacitor filter is still used in some applications but other techniques have come along to replace it. A lot of the things that switched cap filters used to do are now done digitally. The MOS A-to-D technologies are still used a lot at much higher frequencies. I'll put in one technical detail that'll help explain all this. In bipolar integrated circuits, if you needed to do some sort of precision ratioing of signals, of voltages of currents, you usually used resistors as the precision elements that you use to define the ratios accurately. In MOS [metal-oxide semiconductor] technology, at least back in that day, you didn't get very good resistors. But it turned out you got really, really good capacitors. Very well matched, very good characteristics. And it also turned out that one of the properties of MOS transistors is they have an insulated gate input terminal, so they can sense continuously and non-destructively the charge held on a capacitor. Those things together enabled the use of capacitors as precision elements in filters and A-to-D converters. So that was essentially the difference. They used capacitors instead of resistors as the precision passive components in those functions. That's, in a nutshell, the difference between these techniques and the older techniques. So, anyway, that's how that all evolved. Dave Hodges, Bob Broderson, and I had a long series of graduate students later on in the seventies and over the next 20 years or so that figured out how to implement various analog interface circuits using variations on those techniques; including high frequency filters, later on some RF [radio frequency] circuitry, voltage references, power amplifiers, and so forth. In essence, we spent two decades trying to figure out how to do in MOS technology the analog digital interfaces you used to do in bipolar technology.

02-01:01:32
Burnett: Is this a world center for that? Who else was doing this?

02-01:01:36
Gray: Well, in the 1970s and the 1980s I think most people would have agreed we were the leaders in that. There were a lot of other universities doing a lot of other really strong things. For example, at the University of Waterloo, Miles Copeland made some tremendously creative contributions, and a lot of other people at various other places. So I don't mean to suggest we were the only people doing this. There were a lot of other people who did a lot of great work. But I think we probably would have been looked at as the people who were doing most of the work in the early days.

02-01:02:23
Burnett: A center of gravity in any case. And so the first thing I think I ever read about digital-to-analog conversion is the history of the compact disc. So that's four years later. Nineteen seventy-nine, Philips and Sony get together and develop the protocols and the standards. And that standard is sixteen-bit, forty-four kilohertz. And the prototype DAC that you build for the mid-seventies paper is an eight-bit prototype. So that's the scale of transformation. Or is that a completely different set of technologies?

02-01:03:01
Gray: It's interesting you should mention that. Rudy van der Plassche of Philips, who developed those early digital-to-analog converters for those CD players was using bipolar technology. The later versions went to the all-MOS integrated solution. But in those days the resolution of those technologies hadn't gotten anywhere near good enough. That changed because — here's a great example — one of Dave Hodges graduate students, Harry Lee, who's now a professor at MIT, figured out a way to auto-calibrate in a high-speed D/A converter the accuracy that you're talking about and the available resolution is limited by the matching accuracy and the ratio accuracy between the passive components, capacitors in this case, that make up the D/A converter. In the as-fabricated state they really can't be much better than about 0.2 or 0.3%, equivalent to 9 bits or so. To get to sixteen bits, Harry figured out a way to auto-calibrate out the errors, to use the A/D converter to essentially calibrate out its own errors. And that self-calibration technique and various derivatives of it became standard in the industry. And that's how they were

able to ultimately use MOS techniques to realize high-resolution A/D conversion at high speed.

02-01:04:38
Burnett: So some kind of over-sampling or is that a different sort of thing?

02-01:04:41
Gray: There are lots of different ways to do this and it's probably going to bore the reader to try to enumerate them. Oversampling, also called sigma-delta modulation, is a technique of A-to-D conversion that requires essentially no precision components but it requires sampling rates that are many multiples, many tens or hundreds of times higher than the bandwidth of the signal you're quantizing. It trades speed and the technology for precision in the components, and has totally taken over in the low-speed end of A/D conversion. The audio CD player would be an example – today those D/A converters all use oversampling techniques. If you looked in a central office at the voice interfaces being designed today you would see all sigma delta modulation A-to-Ds. However, for the domain of A-to-Ds that sample, fast-changing signals, video, data, and RF signals, sigma-deltas burn too much power and is not very practical. And in those these techniques that I've talked about are used a lot.

02-01:06:02
Burnett: Right, I didn't want to take you too far afield. You're describing a research program that you established with colleagues and graduate students that becomes part of a multi-decade project, really, from the seventies into the eighties. And one thing we haven't touched on directly is education. And so you transition from working in industry directly to — I don't know. Were you a teaching assistant in Arizona?

02-01:06:36
Gray: Yes.

02-01:06:36
Burnett: Okay. So you had some exposure to teaching. Can you talk a little bit about engineering education? You spoke about the engineering education you had and you weren't so satisfied with it, at least at the undergraduate level. Does anything change or is Berkeley a different beast when it comes to education?

02-01:06:54
Gray: In the first ten years I was here we followed the standard model with the professor standing in front of the classroom on a blackboard looking at a set of notes and articulating the content and writing it on the blackboard. But I'd like to think — and I learned this as much from Doug Hamilton, my original PhD advisor, probably is where I got this bug, but giving the students an intuitive understanding of how things are working as opposed to only an ability to solve the equations, to describe how it's working, is really critical. I tried to embody that. That's an individual thing. If you had to generalize as to what was happening in the department at that time, I think the means of teaching and the experiences we were giving the students in the seventies and maybe

on through the eighties was still pretty much what had been done for a long time. I just don't remember any big changes in that era. In the 1990s things began to change in engineering education generally and on the Berkeley campus.

Karl Pister, one of our former deans, chaired a landmark national study on engineering education in 1995. It made this point that we're not being innovative enough. We're not giving the students enough breadth, we're not giving them enough sensitivity to the outcomes, the impact of their work. They spend too much time learning abstract things in their early years in engineering and not enough time understanding why they're doing this, why am I studying all this. Not enough motivation, not enough breadth, not enough context. All of the above. That and other studies like it were pretty influential. Not so much here at Berkeley but at many if not most engineering schools in the country retention rates were terrible — far less than 50%. We weren't quite so bad off. But as a general problem in engineering education, retention was a huge issue across the country. Unfortunately that's still the case to dome degree.

Since about 1990 important changes have happened here and nationally. For example, we have freshmen seminars which are motivational really. They're things that are designed to help incoming freshmen understand why they need to study physics and math. Just fun, motivational kinds of things. We have a lot more project work, and a capstone project in the senior year. We have a lot of entrepreneurship training, which has a lot of socialization associated with it. The students learn about business models, about company formation, and about teams and working as teams. These changes have happened in the last twenty-five years. There's still a lot of room for improvement both here and nationally, but things are getting much better.

By the way, another driver for this was ABET, the Accreditation Board for Engineering Training. They began to incorporate some of these goals in their standards. The capstone course is a good example. Unfortunately, we still don't do as well as we might on breadth outside of engineering. To this day the curriculum is so full of engineering technical courses that the amount of time our students spend in their undergraduate years in courses in non-technical areas is still pretty limited. I think we could do better in that. But it is the way it is. I think everybody recognizes it would be nice to have more non-engineering breadth, but in order to do that you have to give up something — some depth in engineering. There's room for only so many courses in a four-year undergraduate curriculum. When push comes to shove you want your graduates to be competitive with the graduates that are coming from other institutions. You don't want them to be less prepared. If you look at the people who come to campus and interview students for jobs in industry, most of them tend to be first-line managers who are only five years out of school themselves. And when asked they will often say, "I want somebody who can hit the ground running. I need that person to design chips, write software, etc.

right away. But if you go to that company and you ask the vice-president or the CEO who's thirty years out of school, "What do you really want?" a lot of them will say, "These students are going to be doing something totally different in ten years anyway. They're probably going to be managing somebody. Just give me a broad student who can learn new things, who has a broad appreciation of values and working with people and who has basic engineering skills and knows something about the area he's going to be working on." They would put a higher emphasis on breadth, and particularly non-engineering breadth. But the reality being what it is, there really hasn't been that much shift in that direction. Typical engineering bachelor's degree curriculum here is very heavy on the technical side of things.

02-01:13:37
Burnett: I think it's a struggle in K-12, in the STEM fields. The refrain is exactly that. Young people are taught to learn something technical, it's boring, you just got to get through it and get your marks and then go on to something better, instead of exploring why or when and how. What's the larger context in which this knowledge was produced? It's inherently interesting. We haven't answered that question. We haven't figured out how to do that. But it's systemic throughout the whole education system. But you're trying to get there. You're trying to develop new ways. I think it might be a good time to talk about the year at Intel. You did describe some of that already in the description of the research program. But you talked about consulting one day a week and how important that was and this was at Signetics and Fairchild in the early seventies, and that informed the work. And then a full year. Is it described as a research sabbatical?

02-01:14:54
Gray: No, I took a leave of absence. It wasn't a sabbatical. I took a leave and went down there and I was paid by them. This is a model that I've tried to promote for faculty doing start-ups. But we'll get to that in a future interview. We have a number of faculty, especially in engineering, who are involved in one way or another, either as a founder or perhaps as the lead technical person, in start-up enterprises. Taking a year's leave is a nice way to do that. It means you can commit 100 percent of your energy and commitment to that. The other model is to do it while you're still in residence here and timeshare. That's harder but a lot of faculty are doing that.

Anyway, getting back to Intel. It was a great year down there. I got to know Gordon [Moore]. Intel at that point, it was in one building with a fab [fabrication plant] next door. All the engineers sat in the office part of that building. Gordon and Bob Noyce and Andy Grove were just down the hall and I got to interact with them. It was a pretty exciting place. The microprocessor was evolving. They were in the process of deciding what to do with the memory business but they were totally a digitally focused company. That's what they did. And here I was, this person from Berkeley, doing analog circuits, trying to build an analog filter and part of a group also building an A-to-D converter. Most people there didn't have any idea what we were doing. Every now and then Gordon would stop by and ask how we were doing. And then when this thing came out and it actually worked, he came by and he was very effusive about that. That was really a great experience, a lot of fun, a high-risk undertaking that turned out to be successful. There were a zillion ways we could have messed that up somehow but we didn't.

02-01:17:46
Burnett: And this was at the beginning of something extraordinary. There's a *Popular Mechanics* article advertising the first personal computer that uses the 8080 chip. That's 1975. And you're there in '76, '77.

02-01:18:06
Gray: Yeah. And I met a lot of interesting people. Craig Barrett, who later was CEO of Intel, had just come from Stanford and his very first assignment was to lead the telecommunications group, which was this set of people. So I worked for Craig for part of that year and then consulted there a lot later on. There was a lot happening.

02-01:18:35
Burnett: How did intellectual property work in the 1970s?

02-01:18:47
Gray: Good question. Patents have been an interesting challenge in the university environment in general. Back in that the 70s, my perception was that there wasn't a lot of focus on patents at the university campus level at Berkeley. There was a lot of patenting going on in individual departments, especially in the biological sciences, biomedical, and so forth. In the circuits and software part of our department people I interacted with weren't that conscious of patents. The Don Pederson model of putting things in the public domain was something Don just did because he thought it was a good idea. I think that had there been focus by the university administration on that at the time, they probably would have had a little bit of heartburn with that. Another factor was that electronic circuits are very hard to protect with patents and derive revenue from. They're too easy to modify thereby circumventing patents. They're often buried inside of a chip so you never even realize that infringement is happening at all. Another factor for us would have been that to collect royalties on them you have to go after the very companies who were supporting your research. We had one important instance in the circuits group of patenting something that yielded a lot of revenue – the [telephone system] central office A-to-D converter that I mentioned. We did apply for a patent because it was so obvious that that solution was going to be widely used – it just was almost like a perfect match. There wasn't any other solution that could solve that as well. So we patented that circuit configuration. That ended up yielding quite a bit of revenue over a long period of time for the campus and for the inventors, which were Jim McCreary, Dave Hodges, and myself. But that was an exception; the vast majority of the other circuit work we did here we did not patent simply because we made a judgment that the

probability of the university ever actually collecting any royalty on it was just too low. In the case of the switched capacitor filtering, you could probably debate the issue but in the end we just didn't do it. There were a lot of other circuit things. We just figured it's better to put it in the public domain, let it get widely disseminated, let it have impact, and get our support by getting those companies to support us with research dollars, which a lot of them did. A lot of our research support in those years came through various industrial grants and gifts to various consortia that we set up along the way.

This is a great topic because if you fast forward twenty years to the 1990s and 2000s when university finances began to get very difficult and state support of higher ed in California and everywhere continued its long-term decline, a lot of people in campus administration and UC administration started asking the question, "Why don't we derive more money from these? We should be patenting more." And so there ensued a period of debate on campus. Should we be patenting these things that have marginal promise? Who should decide what should be patented or not patented? This became a big issue which we can talk about later on. After a lot of debate the resolution was, in effect, that the individual faculty member pretty much has the prerogative to make the decision about whether or not to pursue a patent on something. And I think that's the right call because do have incentives. We have a very generous allocation of patent royalties to the inventor. If this is a patent that's really going to yield revenue for the university in a significant way, the faculty member is incentivized to patent that.

02-01:24:32
Burnett: Well, we will talk about that more later. In the seventies, do you have an administrative role or an experience with that? What happens at that point?

02-01:24:48
Gray: The only administrative responsibility I remember having in the 70s was that Tom Everhart, who was the department chairman in the late seventies, asked me to help organize an industrial liaison program. We had a couple of annual meetings. At the time was kind of a marginal success in that we did get some participation. But it planted a seed. Over the next thirty to forty years, that gradually evolved and developed through various incarnations to become quite a big thing, with a big annual meeting, hundreds of people coming from industry, from all over the country. That led to the establishment of consortia of varying kinds between groups of companies and groups of faculty centered around a particular technical problem or a particular technology. And there are lots of those. Somewhere on the order of a dozen just in EECS.

02-01:26:09
Burnett: And what year was that roughly? The Industrial Liaison Program?

02-01:26:11
Gray: I think that might have been '79. I'll have to check that in the notes. I don't remember what year that was.

02-01:26:21
Burnett: While we’re still talking about the 1970s, so around the time that you joined the faculty, say 1970 at [University of Wisconsin] Madison, in the mathematics building there’s an explosion. A bomb goes off, right?

02-01:26:40
Gray: Oh, yes.

02-01:26:41
Burnett: And the idea behind that was that [the department] was doing contracts with the United States Army and so scientific research was a political phenomenon at the time that you were — it always is, but there was violence on research campuses across the United States. There were protests. What was it like coming to UC Berkeley in 1971? What was the campus climate like? You had a lot of responsibility. You had a lot on your plate. But is there a little 360 you could do about 1971 in Berkeley or the 1970s in Berkeley in that respect?

02-01:27:35
Gray: Well, when you mentioned an explosion I thought you were talking about Ted Kaczynski, the Unabomber, because we had two explosions in this building by Ted Kaczynski.

02-01:27:51
Burnett: He was a Berkeley alum, wasn’t he?

02-01:27:52
Gray: Yes. Getting back to your question about campus climate, I sat at lunch many days in those early seventies and heard the war stories. In the sixties during the Free Speech Movement, the engineers weren’t affected very much. We’re pretty far from the center of things. But some of our faculty, like John Whinnery and several others, played major roles in the negotiations with the student groups. I heard a lot of those stories and that was fascinating. But for the engineers and for people like me, you captured it perfectly. I was a young faculty member totally focused on doing my thing, just like any young faculty member is pretty much. And other than hear the stories it didn’t really affect me very much at all day-to-day. The Ted Kaczynski matter in the 1980s did because one of his first bombs was set literally in a room one floor below us, right there [pointing to the fourth floor of Cory Hall]. A fellow named Diogenes Angelakos, who at that time was director of the electronics research lab that had an office there, picked up this briefcase, which had an explosive starter in it and it was filled with gasoline. The gasoline didn’t go off but the little explosive starter did and it hurt him, fortunately not that seriously. That was the first Kaczynski attempt. Then, I think it was a year or so later, he left another bomb in a room down on the second floor which did go off and severely injured a graduate student who picked that one up. And so we had a very high awareness in this building of that. Now, when you say violence that’s the violence I think of. But on the 1960s and early 1970s campus protests in general engineering was pretty far out of that loop so I don’t have a strong memory except for the war stories.

02-01:30:02
Burnett: Right. I know you didn't have any direct connection to this. But when I think of engineering needs, I think of other folks that I've interviewed who were at Lawrence Berkeley Laboratory up the hill. Were engineering faculty involved in research up there? Were they involved in satisfying some of the problem solving, tasks that needed to be done?

02-01:30:29
Gray: In Engineering, there were quite a few examples of that in the 70s and 80s. In one case of personal experience, one of their engineers needed to design a detector that goes into a particle accelerator. In a particle accelerator you accelerate high-energy particles, create collisions, and generate various kinds of particles that are thrown off. The machine requires a gigantic number of detectors to detect all those. I helped him design those and to contact a silicon foundry to build the detectors.

There are quite a few other examples of LBL people getting engaged here in the department, especially in computation, where there was and still are close relationships between the computation people at LBL and our computer science faculty. For the campus more broadly the strongest coupling has been in the physical sciences, mathematics, and the biological sciences. A number of faculty there have LBL appointments and vice-versa. Chuck Shank and Paul Alivisatos, two of the recent LBL directors, had faculty positions on campus. So there's a lot of collaboration. LBL is a fantastic asset. The science and engineering part of the campus would be much weaker without it.

02-01:32:00
Burnett: And in 1975 you have your second child?

02-01:32:04
Gray: Yes. Judy, poor Judy, my wife, I drag her up here. We live in an apartment for a year out in Walnut Creek. Then we bought a house in Orinda and our second child was born in '75. That was the first of many cases where she had to put up with burdens of the career that I've had but she always stepped right up. She's the best thing that ever happened to me. Ryan and Matt, my two sons, have their own careers now and they're doing fine.

02-01:32:38
Burnett: And so the decision to locate in Orinda and initially in Walnut Creek, was this a very pricey area? Did that affect the decisions? Or were you thinking about lifestyle? And the commute was alright at that time, I imagine.

02-01:32:57
Gray: It's pure serendipity. We had some friends that were family friends of Judy in her high schools years in Chicago, in Evanston. They lived in Orinda. When we found out that we were going to be staying at Cal they invited us over for dinner and showed us around the local schools. It was just pure accident. We liked the town, and they did have a great school system. I had grown up in my teenage years in Tucson and I was used to kind of a spread-out suburban

environment. Berkeley felt awfully urban. I think we just felt a little more comfortable out there. But it was really the connections with her lifelong friends that just sort of tilted the tables. The house we bought a year later was only two blocks away from those lifelong friends.

02-01:34:01
Burnett: Great. Well, perhaps we should pause there and continue next time.

02-01:34;04
Gray: Okay. Good. Excellent.

[End of Interview]

Interview 3: December 1, 2017

03-00:00:19

Burnett: This is Paul Burnett interviewing Dr. Paul R. Gray for the University History Series. And this is our third session and it's December 1, 2017 here on the bustling Hearst Avenue. I think we're at the moment in the mid-seventies when you're contemplating a textbook in electrical engineering. Can you talk about the evolution of that project?

03-00:00:53

Gray: Sure. Thank you, Paul. Pleasure to be doing this again. This textbook ultimately was published in 1977, a collaboration with Bob Meyer. We were fortunate to have good timing on its publication and subsequently it was fairly widely adopted around the country and elsewhere. It's been a wonderful thing because when you have a widely adopted textbook like that, people know who you are before you even meet them, so it's been a real pleasure to meet people who have used the book. Bob Meyer came in 1970 and I came in '71. Remember the timing here. The integrated circuit was only invented ten years earlier than that, roughly 1960, and analog integrated circuit chips that had any usable functionality were only began appearing commercially and in military applications about 1965 or so. So we're only a few years after these devices even became real. Both Bob and I were teaching courses, undergraduate and graduate courses in integrated circuit design, mostly analog, and we were both consulting. I was consulting at that time at Intel and later Signetics, and Bob was consulting at Hewlett-Packard, working on these things. We brought these into our courses, the undergraduate and graduate courses we were teaching, including the introductory course for juniors. And over the period of three or four years we developed an extensive set of course notes that had a lot of this design information in them for this relatively new problem of designing analog integrated circuits in a monolithic implementation. There weren't really any other books there. Alan Grebene, who I'm going to get back to a little later because he was a Micro Linear founder, had a book that he had published some years earlier. These didn't really embody the kind of content we were trying to convey. So Bob and I decided about 1974 to take these course notes and assemble them into a book. We did that over the course of a couple of years, from about '74 to '76. Bob was a wonderful collaborator. We divided up the chapters, each took about half the chapters and we were each other's proofreaders and critics. We just worked really, really well as a team, as we have ever since. So we got the book completed about 1976. We had a publisher, Wiley, and they got the book out, the first edition, in 1977.

The timing was just right. For analog integrated circuits, the people who taught electronic circuits in the academic were then realizing the importance of monolithic integration, and were beginning to translate their courses from teaching discrete component design into the specialized approaches you need to design things in monolithic form. So it was at a good time and the book got pretty widely adopted. It went on to a series of editions. The second edition came few years later, then the third. And then starting with the fourth edition, which was into the 1980s, we enlisted a former graduate student of mine, Steve Lewis, who had subsequently gone to UC Davis to be a faculty member, and Paul Hearst who was a graduate student of Bob Broderson who also went to UC Davis. They became coauthors starting with the fourth edition. There was a fourth and a fifth edition and there may well be a sixth edition coming up. But they took the lead in developing that and did virtually all the work in doing the revisions.

The need for subsequent editions came because the technology was evolving. The biggest change was the transition from bipolar to MOS [metal-oxide semiconductor] technology. So in the later editions, Steve and Paul were able to insert a lot of the MOS circuit design aspects of analog ICs, with more the mixed-signal flavor where you're building chips that have analog and digital together in MOS technology. That made the book more relevant as time went on. It got translated into a number of foreign languages, and was used internationally. All in all, it was one of the most satisfying things Bob and I ever did. That was really, really a lot of fun. But, again, I think we owe it to mainly just doing it at the right time. And there have been some great books subsequently. And today the book is still used but it's been overtaken. There have been several books that have come out more recently that have been more up-to-date with the technology. But it had a good long run. I'm very happy about that.

03-00:06:26
Burnett: How many books were out there on integrated circuits? How many textbooks were there in 1977 apart from Alan Grebene's?

03-00:06:40
Gray: My recollection is that there were several books on semiconductor electronics in which they had produced a revised edition where there was one or two chapters at the end on how you do the integrated circuit part. But it wasn't a complete integrated treatment. Alan's book may have been a little bit more than that, but it was produced three or four years earlier and didn't have the latest developments in technology. I think it was the soup-to-nuts integration. The very first chapter is about devices and then it moves quickly to the monolithic technology and the particular constraints and degrees of freedom that that technology gives you in designing integrated circuits. Having that in the discussion from the very beginning was really a key differentiator.

03-00:07:56
Burnett: So you wanted to explain to the student what was important about this, what this made possible?

03-00:08:03
Gray: That's right. As I think I probably mentioned in the last session, when you build a circuit out of discrete components, if you need a high-precision

resistor in one part of the circuit and you need a certain kind of transistor in another place, you can just go to a parts catalogue and order them all and you can mix and match the different kinds of devices that make up the electronic circuit that you're trying to implement. It's not necessarily easier but it's different because you have a lot of degrees of freedom in choosing device types and component types. The early bipolar integrated circuits evolved from a technology used to just build an NPN transistor [bipolar transistors come in two types – NPN and PNP), and Noyce and Kilby adapted it to build monolithic circuits. The other components, the resistors and the capacitors, as well as the complementary PNP transistors needed for high performance analog circuits, were realized by adapting structures and elements of the process that were not optimized at all for that purpose. The PNP transistor in those early technologies was terrible, very poor characteristics. The resistors have large variation in value, with tolerance is no better than about plus or minus 20 percent. That set of constraints. makes it difficult to realize certain kinds of high-performance analog circuits and analog-digital converters and digital-to-analog converters. But the flip side of that is that in a monolithic circuit, when you build two transistors or two resistors side by side, they match really well. They're almost identical. Just take resistors, for example, they might have an absolute tolerance of plus or minus 20 percent, but they might match each other to better than 1 percent because they're made at exactly the same time. That's a degree of freedom that you have to utilize to really build high-performance circuits.

One of the key aspects about integrated circuits is their economics. ICs are fabricated in a sequence of lithographic steps interspersed with sequences of various kinds of chemical depositions and other processing. It's a batch fabrication process where the unit of manufacture is what's called a wafer, which today is a twelve inch silicon disk. In those days, it was six-inch disk. One wafer might contain several hundred to several thousand integrated circuit chips arrayed in a mosaic on the surface. Batches of these wafers are processed simultaneously, so that you're simultaneously fabricating all these hundreds to thousands of integrated circuits at the same time. The economics of that and the ability to batch-fabricate chips in very large quantities is really the key to the whole technology because it means that the cost of manufacture per transistor keeps dropping as the number of transistor per unit chip area goes up. Today we're building in the most advanced cases on the order of a hundred billion transistors on one chip and the chip might cost a few tens of dollars to make for that advanced scaled technology. But that's a very, very low cost per transistor and that's the real impact of Moore's Law. It's the form factor and power dissipation, but much more important than that is the cost per function. Introducing that concept was a really important thing in the book. Choices have to be made by the designer on things like chip size and complexity, and economics play into that in a big way, due to defect density factors and other things that limit yields and affect costs at large chip sizes. Those are examples of the kinds of considerations that you have to think about when you're designing a monolithic circuit versus designing a circuit made out of discrete components. The book has a lot of that kind of information in it.

03-00:12:43
Burnett: So you can see the importance of understanding the fabrication process. There's the theoretical side, there's the circuit simulation side from the design element perspective. But knowing what happens when you try to scale up practically, the challenges in terms of the physics and chemistry, that's all laid out for folks in the book. So in a sense you're involved in the mass production of electrical engineering students who can do integrated circuit work?

03-00:13:22
Gray: That's an accurate statement, but I'm not sure I'd call it mass production of students. The electronics classes that are taught in a university like this are applied — if you take a spectrum of basic theory all the way to something that is a skill that a student would use rather quickly when they got out into actually producing products, the electronic circuits courses are applied. They teach students how to actually take some objective electronics function and realize it out of components. And so in that sense you're right. It's an applied set of skills.

03-00:14:20
Burnett: And that's on the output side. And on the input side for Electrical Engineering and Computer Science at Berkeley, there's a lot happening in this period from the seventies into the eighties. State support is important. Let's talk about the — I don't know how we would say it, is it a hand-off between federal government support in terms of defense contracts or interest in that to private sector picking up the slack, as it were, if there is slack?

03-00:14:56
Gray: That's a great question. Now we're moving back to the research side of things. It really gets into what's the mechanism of translating innovations, inventions, intellectual property and things that have impact in society from the university environment into the real world. That's a wonderful topic. Let me do one thing quickly because I'd like to talk about that. There's been an immense evolution of how that's done from the 1970s till today. It's just phenomenal the evolution of the university in accomplishing what in oversimplified term would be called technology transfer. More broadly, it's making sure that the impact of the innovations that are happening within the university have a societal impact as quickly as possible. Things have changed dramatically there. So let me come back to that.

I thought I would say a few more words, just because I don't want to let it slip by, about this research that we were doing, and particularly some of the students who were contributors to that.

03-00:16:17
Gray: I think I mentioned in the last session the switched-capacitor filter technology, the A/D converters and some of the early grad students that worked on that. I had a total of about forty PhD students and I'd love to be able to talk about each one of them individually but that's not practical in the amount of time. One of the great things about a campus like this is the quality of the people that come into the graduate program. There's a huge capacity there for innovation embodied in those people. I mentioned the early students, Jim McCreary, Ricardo Suárez, Bob Blauschild, my first master's student, and Yannis Tsividis. They were followed by a twenty-five-year long chain MS and PhD students. Working with my colleagues and these students, we were able to find ways to implement functions and improve on functions at this analog-digital interface, the eggshell part of the egg and the eggshell analogy. That was really the essence of the research program all the way through. I just wanted to mention those students because they really were the heart of what was going on. And the same was pretty much true of Bob Broderson, Dave Hodges, and Bob Meyer. We really were able to keep innovating because of the technology evolution that was happening driven by Moore's Law.

03-00:19:23
Burnett: Can I ask you what the mechanisms of transmission are for that knowledge?

03-00:19:26
Gray: That's a great question.

03-00:19:28
Burnett: So you could have engineering journals, which might be kind of after the fact. It's already too late if it's written up in a journal. How does the knowledge filter in that you know there's an innovatory step that needs to be taken, and how you would undertake that step?

03-00:19:42
Gray: Yes, back to the technology transfer question. Let's start in the 1970s, at the time I arrived in the department. At least in EECS, the transmission of this information was happening through several different mechanisms. Faculty members were consulting in the more applied parts of electrical engineering as well as across the campus, particularly in other branches of engineering..A typical engineering faculty member on the more applied side of things consulted then, as now, typically a day a week or so, usually with a company. That's not so much true in the more theoretical parts of engineering. And as you get to other parts of campus that are further away from applied things, consulting becomes rare. Consulting is an underappreciated and important mode of transferring technology. Another mode was and still is industrial visits like the one I did at Intel. That was happening occasionally. A third and very important mode happens when a graduating master's or PhD student goes to a company. That shouldn't be underestimated. Publications are certainly important with conferences were probably more important than journals in the

microelectronics field. The journals provided, as they do today, an archival record. But the really timely transmittal happens in conferences.

The basic concepts of what was going on do get transmitted via publications, but there's often another level of detail to actually take the concepts and make them work that gets transmitted in these other ways. Actual interactions with people using some of these other mechanisms are best for that.

03-00:21:59
Burnett: Right. Tacit knowledge.

03-00:22:00
Gray: Tacit knowledge. Regarding other transfer modes, in the seventies there was some patent licensing, but in the case of electrical engineering both the patenting and the licensing revenue activity was small compare to some other parts of campus, like biological sciences and agriculture. There was some and some of it was important, but most of the work here was not of a type that was easy to protect using patents.

With regards to technology transfer generally, I think Stanford was ahead of us in that era, doing a better job, as an organizational matter, of making these transfers happen. At Berkeley, we were just beginning to realize the importance of this. I think Ernie Kuh, who was department chairman when I came in and became dean of engineering shortly thereafter, and Dave Hodges and Tom Everhart, saw that we needed to do more to systematize how we're going to do these technology transfers. As I mentioned earlier, early on the 1970s, Tom Everhart asked me to organize some of the early Industrial Liaison Program meetings. For a couple of years, maybe around 1974-75, we had a meeting on campus where we invited a whole host of industry people to come. That caught on. Ernie, when he became dean, pushed that for the college as a whole. It became an annual event fairly quickly in electrical engineering. Took a little longer in some of the other departments. But by the late 1980s we had a fairly robust comprehensive industrial liaison program which involved a two day meeting in Sibley Auditorium full of industrial visitors every year. That then led, over time, later on in the 1980s and 90s, to a number of different mechanisms. We formed a number of what came to be called industrial consortia, groups of companies that have a particular interest in what you're doing. They pay some dues, an annual fee. They don't get an automatic license to the IP, but they often get a right of first refusal to a license, to negotiate for a license for patents. There were consortia for semiconductor manufacturing that Dave Hodges had, and several consortia in the RISC/ RAID [Reduced Instruction Set Computer/ Redundant Array of Independent Disks] area. And then that eventually resulted in some even more ambitious undertakings like the Wireless Research Center and several other research centers like that, a full-blown organization with similar kinds of arrangements about intellectual property but larger amounts of money. The Wireless Center, for example, is an organization that focuses on the design of things like smartphones, the next generation of those, the optimum design of the RF [radio frequency] components of those and different system aspects of wireless systems. It’s been very successful. Bob Broderson founded that and for a long time was the leader of it. This consortium model evolved and became an important part of the life in this department. It propagated, to some degree, to other parts of engineering. There was a major consortium on disk-drive design for example led by Dave Bogy in mechanical engineering.

Later on, in the 1990s when financial pressures became acute due to the long history of the state providing less and less of our operating budget, people in campus and university administration began looking for more revenue. One obvious candidate was doing better on patent licensing. One seeming anomaly was that in the biotechnology areas and particularly some of the agricultural research areas, there was a history of relatively small number of relatively large patent revenue streams coming from products related to agriculture and some drug discovery kinds of innovations. In electrical engineering and the college in general, the flow of patent income was very low by comparison. People wondered why that was. So later on in the 1990s there was an effort to figure out how to do this better. How do we either get more revenue from patents or how do we get the companies to support us more effectively in other ways. That's another whole story for when we get into the nineties and two thousands.

Another sharp contrast between the 1970s and today is the immensely larger role for entrepreneurship that evolved throughout the nineties and early two thousands. There has been a much higher level of activity of founding companies by both faculty members and graduate students. There is a significantly higher level of industry funding of research at the university campuswide, although it still hovers around only 10-12% of the total. Most of that growth's come in areas other than Electrical Engineering and Computer Sciences because we've had a pretty high level all along, since the 1980s.

But getting back to the starting point, in the period we're talking about, the 1970s, it was pretty anecdotal. As we've talked about before, there wasn't much patenting activity going on in most areas of electrical engineering, partly because a lot of the work that we do on the EE [electrical engineering] side of things, and in the CS [computer science] side of things, produced innovations that are hard to protect and even when they are protected, when they're embodied in an integrated circuit they're hard to collect royalties for. For circuit innovations, it's easy to do a slightly different flavor of that innovation and circumvent the patent. And history shows there are a few fundamental circuit patents that you can protect effectively but for every one of those there are dozens that are important innovations that have an impact, but they're just really hard to protect. The switched capacitor one is one that I think we talked about last time. That was one we decided not to protect with patents. For a long time, we worried about whether that was a good decision but it turned out that some years later, one of my graduate students, Yannis

Tsividis, who is a professor at Columbia now, was doing some work on the origins of switched capacitors and he discovered that James Clerk Maxwell, one of the early pioneers in the theory of electricity and electromagnetic fields, had actually proposed something that looked like a switched-capacitor filter. He never built anything, didn't have the technology to implement it, but in some of his writings, he'd actually drawn circuits that looked a little bit like what we were doing.

03-00:31:28
Burnett: This is the nineteenth-century Maxwell?

03-00:31:29
Gray: Yeah. Any clever patent attorney would have found that, and we would probably never have been able to collect anything. That's an isolated anecdote, but in general, what's evolved is, even today, after a lot of discussion about these policies, is that in the end it's probably best to just let the faculty member decide, since we incentivize faculty members with a portion of the proceeds. Today, in effect, the practice is to let the faculty member make a decision based on everything that is in play, whether or not it makes sense to go to the effort to file a patent disclosure. There's a lot of patent activity campuswide. In fact, the number of patent disclosures taken as a whole on the campus has steadily risen over the years and is at a pretty high number today. Not very many of those are in the circuits area though.

03-00:32:31
Burnett: I wanted to ask you, and I'm not sure if you know this. I might have to speak with David Hodges about this. But the systemization of technology transfer that Ernie Kuh and Tom Everhart were involved in, do you know if they were looking at Stanford as a model for how to do it? It sounds to me like they did something different and maybe they felt they had to because it was already existing elsewhere.

03-00:33:01
Gray: I don't know that. They may have been looking at Stanford, but more importantly, I think they were just seeing the semiconductor industry and then everything that's come from that was going to be a tremendous growth engine for the Bay Area, and that we needed to be more tightly coupled to that. Ernie himself was a computer-aided design person in his later research years, and he was pretty tightly coupled to companies in the Valley. I think he came to realize that we really needed to do more to get a connection so that our work could have impact in Silicon Valley. And I think it really has. We had this discussion I think in the last session about comparing us to Stanford. I think we were behind, ten years behind maybe. But if you look at some of the relevant the metrics today, examples like the total number of start-ups founded by graduates of Berkeley and total number of startups founded by faculty, as of this writing PitchBook, a publication that periodically compiles such data, ranks Stanford number one in the country and we're number two and very,

very close to them, and ranks all the others below that. So I think we've come a long way.

03-00:34:32
Burnett: Right. I also wonder about this. And, again, you might have a perspective on this. In the life sciences, of course, patenting of organisms becomes possible in 1980 but there's already a tremendous degree of anxiety and discourse about whether this is a good thing. And I think part of that discussion was about the influence of industry on science: that it's going to distort research, it's going to change research priorities. It seems clear that a lot of the scholars in the humanities at the time, and even subsequently, were not aware of the degree of industry/university cooperation that was happening in engineering. When there was a concern about patenting in the life sciences, was there any conversation with engineering, with the folks in the College about what this represented and what would happen as a result?

03-00:35:51
Gray: I don't remember specific conversations like that in engineering. The two episodes that most exemplify what you're talking about are the Novartis contract and then later the BP contract, British Petroleum contract. The one that would have been closest in time to the era we're talking about is Novartis. I'm trying to think. That was like nine—

03-00:36:26
Burnett: Because 2000 I think was when the—

03-00:36:28
Gray: Right around 2000 and I was just transitioning from being dean of engineering, so during most of that I was in the dean's office so I would have known about conversations like that. I don't recall that. There was a lot of concern generally on campus; I certainly remember the controversy, and we'll probably talk some more about that when we get to that era. So let me put that one aside. More generally, my recollection is that the concern was not just the emphasis on patents but the issue of industry support in general and the influence of industry through all the different mechanisms that I mentioned: faculty consulting, supporting research financially, licensing patents, all of the things that result in the ability of industry to influence the research direction of faculty members. Is it going to drive faculty in the sciences for example to more applied topics, that is, things that are not fundamental anymore but are just solving industry’s problems? Is industry going to be able to subvert our faculty to become sort of a development lab for their products? That's one concern. Another concern is that a lot of faculty in the physical sciences and life sciences, as well as in some parts of engineering, also participate in public policy formation in various ways. They serve on National Research Council committees and advise local government bodies on important decisions. This certainly happens in civil engineering, for example, where we advise on public infrastructure projects, bridges and so on and so forth. Is industry

support going to influence that in some way, creating a conflict of interest? And a lot of other concerns like that. I think that's a legitimate concern.

On the Berkeley campus, these concerns are mitigated, but not totally eliminated, by two factors. On the issue about influencing faculty to be too applied, here at Berkeley I think our faculty have resources available through all kinds of different venues. I just don't see that as an issue for us. We're too strong for that. We have the ability to get support from a variety of different sources and one result of that is that industry is still only about 10 percent of the campus's total research support currently. It's not big enough, I don't believe, to actually materially have that effect except in isolated cases. The faculty here get evaluated, advanced and recognized based on their contributions to research in their field, their impact. They're not about to be subverted to some less impactful role by this influence, in my opinion.

I do worry about universities that have less ability to do things independently, the tier of institutions which don't have the level of research support that we have, and that are very dependent on finding new sources of revenue. I could imagine at institutions like that this kind of influence could be a much more serious problem. But I just don't believe that's an issue here.

The other part of it is the potential influence on individuals who serve as advisors in public policy arenas, I think the key there is disclosure. One of the things that's happened on campus over the years that is really important is the setting up of protocols about disclosure of all these kinds of involvements. Things like Novartis, those are public, everybody knows about that; but there are a lot of other kinds of faculty engagements which are less visible: when a faculty member consults with a company, when the faculty member takes a research grant from a company, when a faculty member goes out and is a chief technology officer of a start-up part-time while still a faculty member here. There's a systematic, required disclosure process in place now. It didn't exist back in the seventies, but it exists now. And I feel that's pretty effective. And anytime you're involved in any kind of public policy refereeing or service like that you have to disclose those engagements. So disclosure is the key thing.

03-00:41:47

Burnett: And it's not as if the state goes away in this period. And if we're talking about late seventies, early eighties, it's quite premature to talk about that. So the government can set up norms or make a call for an innovatory direction, both through direct funding and through just announcements. And this is an example way further on in our timeline. But I understand that the FinFET innovations emerge out of a 1996 call by the Defense Advanced Research Projects Agency for a twenty-five-nanometer scale operation. And so that's another signal. I'm interested in the signals coming into EECS that push the faculty and the graduate students in new directions. And so I think NSF is in the mix. Can you talk a little bit about government funding and government agencies that work with the college to move innovation forward?

03-00:43:05
Gray: Yes, I need to think about that a little bit.

03-00:43:17
Burnett: We could also come back to it if you want.

03-00:43:18
Gray: Well, no, this is very relevant because I was going to talk a little bit about how we got funded over the years. In our case, in the integrated-circuit-design area that I've been talking about, we had some NSF funding, DARPA funding, industry funding. We've had the whole spectrum. Sending signals, I think probably the example you gave of DARPA, there have been a number of exercises over the years to develop what's called a technology road map. It's really a plan based on the extension of Moore's Law. It became an accepted likelihood—

03-00:44:21
Burnett: A norm, yeah.

03-00:44:21
Gray: —that feature sizes were just going to keep going down. And so then the question is, well, how are we actually going to do that, what are those technologies going to look like and how are we going to develop the lithography, process technology, and devices needed to get there? Those roadmaps were developed by different organizations at different times. The SIA, Semiconductor Industry Association, had a roadmap program. DARPA at various points has, in effect, talked about the roadmap they'd like to see, and other organizations. What you're talking about, I think, is one example of that.

I believe that over the year the groups formulating the roadmaps were a mix of industry technologists and technology leaders from the academic world. So it gets a little fuzzy as to who the thought leaders were in sending the signals for future directions. Taking the FinFET as an example, Chenming Hu, who along with Tsu-Jae King [Liu] here, was the developers of that technology, spent I think a year or two as chief technology officer at TSMC [Taiwan Semiconductor Manufacturing Company, Ltd.] in Taiwan, Chenming had extensive industry contracts and experience over the years, both at TSMC and a lot of other places. Chenming or someone like him probably was part of the group that helped the DARPA committee put the roadmap together.

What I'm saying is the importance of faculty members like Chenming being out in industry and seeing what's happening with the technology, and then coming back here and thinking, "What do we need to go the next five years and the next?", being able to see what the industry needs five or ten years down the road, is critically important. I think it's almost the reverse of what you said. It isn't a bunch of people at DARPA saying, "Oh, we need this," it's people like Chenming being able to be closely involved in industry and then extrapolating what's going to be needed down the road and then helping DARPA put together that roadmap. Now, I don't know if Chenming actually did that but somebody like Chenming probably helped with that at DARPA.

03-00:46:57
Gray: The ability of engineering faculty in universities like this to be engaged with industry adds huge value. If you trace out a lot of the things I've been talking about and a lot of things that have happened here at Berkeley that have affected Silicon Valley, that pattern recurs often. Dave Patterson's RISC, for example. He was very engaged in industry in various ways and I'm sure thought, "Hey, if we did things differently down the road we might be able to greatly simplify and make the processors more power-efficient."

03-00:47:57
Burnett: And this is the Reduced Instruction Set Computer.

03-00:47:58
Gray: Yeah.

03-00:48:01
Burnett: Is this basically the beginning of the Internet of Things, where you're sort of building—

03-00:48:04
Gray: It's a little different from that. I'm no expert on RISC. Dave's retired now; I'm sure he'll do an oral history. He certainly should because he's been an incredibly innovative person. The Intel instruction set really was the outgrowth of Ted Hoff's 4004/8008, the processor to implement that kind of grew by add-ons and it got to be very messy and complicated. The Intel chips at one point had 700 instructions or something like that. Dave realized that if you start from scratch you only really need about one-tenth of that and the other 90 percent of the instructions can be implemented using software or a multistep process. The result is a vastly simpler chip, way simpler, lower power, et cetera. The ARM [Advanced RISC Machine] architecture is a computing processor architecture that is used in virtually all cellphones, tablets and other portable devices. It doesn't use the RISC machine architecture exactly, but it uses the same basic concept.

03-00:49:41
Gray: That technology is used in almost every portable device now, and one of the reasons, not the only reason, but one of the reasons Intel has had trouble penetrating that market.

03-00:50:33
Burnett: Let's talk about some of the innovations. Perhaps that's a way of doing it. This is the architecture of chips, this is what's being undertaken here. Can you talk a little bit about the innovations? Is it best to talk about them through the

innovators? These are special projects that get undertaken so that they become kind of innovation segments?

03-00:51:10
Gray: Let me go at that this way, using the evolution of analog and mixed-signal ASICs as an example. In the early seventies, both analog and digital electronic systems were made out of discrete components and simple integrated circuits with low complexity, perhaps 100 transistors or so, typically mounted on circuit boards. As time went on, with the transition to MOS technology, the integration level of the digital integrated circuit parts increased steadily. Complex standardized digital components like memory chips, microprocessors, and other widely used standard functions evolved over time. Many electronic systems needed digital functionality different from or to supplement the available standard functions, so several technologies evolved to build custom digital circuits, which came to be called Application Specific Integrated Circuits, or ASICS. So the integration level on the digital side was climbing. But the integration level on the analog side was stuck at the hundred-transistor level. That's where we came in in the late seventies. The transition to MOS technology for the analog functions allowed integration of them, together with the digital functionality, at much higher integration levels as time went on through the 80s and 90s. However, the missing piece was an ASIC capability for the peripheral mixed signal functions – the ones in the "eggshell". That was difficult to achieve because analog circuits are much more sensitive to the nuances of the technology and device characteristics than digital circuits, making analog circuit design much less amenable to computerized synthesis techniques. By the early 1980s, for many electronic systems the digital part was implemented either using a processor or using some kind of custom digital ASIC chips, or a combination of both, while the analog part was still implemented using low-integration blocks like operational amplifiers, separate A/D and D/A converters, and things like that.

For custom chips that were to be manufactured in very high volume, like those in telephone central offices for example back then, or in smartphones today, the economics can support the cost of a "full custom" approach where a team of engineers creates the complete integrated solution. However, for lower volume applications, a low cost ASIC capability that could accommodate the mixed signal parts was really needed. There are a very large number of these low volume applications, so taken collectively, they represent a very big chunk of the world of electronics in terms of volume of manufacturing.

03-00:54:37
Burnett: Batch production.

03-00:54:38
Gray: Getting back to the Microlinear story, in the mid-1980s, this same gentleman, Alan Grebene, who wrote the book that we talked about, by that time he had founded Exar, an analog chip company. He left there and decided he wanted to start a company to figure out how to build low-cost ASIC realizations of

these analog-interface functions. I was looking for something interesting to do so I took a year's unpaid leave from Berkeley and got involved in that company. Jim McCreary, one of my first PhD students, became head of engineering there and a bunch of other people I had worked with at Intel also came along. The concept was to figure out how to do these ASIC tools and do custom analog-peripheral-interface functions using these new kinds of ASIC tools. It didn't work. It turned out that the modeling, simulation, and synthesis capability at that point in time weren't good enough. The nuances of the variations in the underlying technology that affect the performance of analog chips was not understood and modeled well enough. We just weren't able to get reliable results out of those tools. Things have gotten much better today, thirty years later, and several viable approaches to mixed-signal ASIC realizations have evolved to be widely used. However even to this day the implementation of many of the custom low-volume instances of the "eggshell" functions is done with low and moderate complexity analog-interface chips, and the provision of those kinds of chips is still a large business for companies like Analog Devices.

Getting back to Micro Linear, after about six months it became clear that this was not going to be a viable thing for us so we transitioned to build various kinds of A/D and D/A components as standard products at the relatively low integration level typical for that era. The company was successful and ultimately went public, but the products it was making were not greatly differentiated from the products that a lot of other companies were making at the time. It's a great example of what happens in start-ups. You get out there, get six months in and then realize that your business plan, that seemed so brilliant at one point, had something wrong with it. Either the market wasn't what you thought it was, the technology didn't work the way it was supposed to, and you have to be very creative in a very short period of time to figure out what you are going to do to make the enterprise successful. And so anyway, that evolved, and I continued to consult there and serve on the board for I think five or six years as I mentioned the company went public and then ultimately got bought out by another company in the Valley. It turned out fine, but it didn't achieve the original goal.

03-01:01:24
Burnett: At what level were you involved at the beginning?

03-01:01:26
Gray: When I started I went down there for a year. I managed the CMOS design group. We were to design the elements that would be taken by this computer program and assembled into custom implementations of different kinds of analog functions. Let me give you an example. Suppose you had a controller for some piece of production equipment and there were eight or ten analog inputs that needed to be digitized, went into some sort of custom digital functionality that controlled a piece of production machinery. That would be a perfect example of a custom ASIC mixed-signal chip. And you can do the

digital part pretty easily in lots of different ways and get a low-cost implementation of a custom digital function of which you might only manufacture ten thousand. But we didn't succeed in figuring out how to get the analog part of that done. So today what you would do is you would just buy some discrete components from Analog Devices or somebody like that and implement that in discrete form. It’s still that way pretty much. It was a fabulous learning experience. These experiences teach you a lot about how the real world really works, Alan Grebene moved on and a National Semiconductor VP, Art Stabenow came over as CEO. Art and I worked together on a number of things over the years. I learned a lot from all those people, so it was really a great experience.

03-01:03:13
Burnett: So that was your first experience with a start-up?

03-01:03:17
Gray: Yes, it was.

03-01:03:18
Burnett: And this is in the 1980s. And I guess the elephant in the room in the 1980s is the dawn of the personal computing era. I imagine that comes to occupy more and more of an interest among the faculty. Can you talk a little bit about that, the impact of that on the engineering program here? Did that reorient people very quickly towards that area or is it possible perhaps to overstate the importance of the personal computing era at that time in the 1980s?

03-01:03:58
Gray: The PC was in a sense one instance of a larger development in the 1980s — distributed computing using networks of smart machines like workstations and later PCs. It was hugely important for a number of reasons. In engineering the use of networked workstations, and for the rest of the campus networked PCs, rapidly improved faculty productivity, as it did in virtually every other sector of the economy. With regards to the research agenda, certainly the computer science faculty saw the trend developing early, and it factored into their efforts in both hardware and software. Sun microsystems, an important pioneer in commercializing the networked workstation concept, was founded by a group with strong Berkeley connections.

I think its impact in driving the research agenda in electrical engineering, in the 1980s, at least, was more narrow. It did drive a strong focus on data communications, both the theoretical communications aspects and the hardware aspects. That started in the early days with voiceband data modems, which was one of the early important applications of switched-capacitor filters, and progressed through ISDN transceivers using twisted pair telephone cable, coaxial cable based data communications, and all the flavors of high speed RF data communications as now embodied in smartphones and home networks. So in that sense you could say it drove a lot of different dimensions of the work we did here at Berkeley.

And, by the way, let me go back a second. I should have mentioned one other aspect of the Micro Linear experience. Micro Linear was a "fabless" semiconductor company, one of the early ones.

03-01:06:31
Burnett: Can you talk about what that means?

03-01:06:34
Gray: Yes. The big three semiconductor companies of the late sixties and the 70s, Motorola, Fairchild, and TI were vertically integrated companies. They provided the manufacturing technology, as their ability to make integrated circuits in high volume at low cost evolved in the late sixties, and also had in the same organization groups of design engineers and product specialists who and defined the end product that ultimately got manufactured and shipped to customers. Through the seventies, for Intel, National [Semiconductor], and other companies, the follow-ons that came out of Fairchild, that was pretty much the model. As chips became more and more complex, they came to embody more and more of the architecture of the system being implemented, and system architectural innovation became really, really important. The staffs of engineers dedicated to that grew both in size and sophistication. It was an increasingly uncomfortable marriage between the manufacturing people, who were people running factories, and the design people. So the fabless model evolved in the eighties, in which the design engineers could create their own company. All they did was architect and design the product, and then they ship the database of the integrated circuit chip to another company who did the manufacturing. Generally the packaged integrated circuits are returned to the fabless company for final testing and shipment to the customer. Carver Mead at CalTech was a thought leader in helping bring about that transition, and was a visionary in many dimensions. One of his visions was what he called "silicon publishing." In which a silicon foundry could make the chips and the broad community of engineers could be empowered to do their own design by giving the right computer tools and by structuring the design properly. That was a very controversial idea at the time, but it was, now thirty years later, a brilliant innovation. Of course success has many fathers and some would argue the process was already underway, but that concept is really at the heart of the fabless semiconductor company. The company adds value by innovating in architecture and design, being able to translate the needs of the system customer to an integrated circuit realization but not being burdened with the need to make the capital investment in a factory and to sustain and operate one.

Another key contributor to that transition was Morris Chang, who, in about the same era, set up TSMC (Taiwan Semiconductor Manufacturing Corporation) in Taiwan, a tremendously impactful and innovative step. He had come to the US, had worked at TI and become an executive there,, went back to Taiwan to found TSMC. I don't know if it was the first silicon foundry, but it certainly became, rather shortly, the largest and most successful standalone independent foundry. That enabled a lot of fabless companies, like Micro Linear — and there were other foundries also by that time — but that enabled the flowering of the fabless semiconductor industry, which separated the design function from manufacturing. Intel is still by far the largest vertically integrated chip company. As of this writing, the second largest semiconductor company in the world today in terms of revenues will be a fabless semiconductor company assuming the currently envisioned mergers go forward with Broadcom buying Qualcomm and Qualcomm absorbing NXP. NXP has some factories [fabs] but they're smaller specialty fabs. Nobody would have believed that would happen if you'd asked them in 1975. Everybody thought then that the designers had to have the ability to tweak the manufacturing process to make the circuits work right. With good design and good tools that proved to not actually be true. That enabled a lot of innovation and was a big development in the semiconductor industry.

03-01:12:48
Burnett: And it makes possible globalization in the semiconductor industry.

03-01:12:54
Gray: Yes.

03-01:12:55
Burnett: That's the TSMC story in a nutshell but that then leads to the rest of the story, up to the present day, where lower-cost, labor-wise, manufacturing happens in another country. So there's kind of a twofold disaggregation of the industry. On the one side, this is beginning to happen in the eighties, so the Bell system is broken up. That's one example. Let me say just generally that industries are spinning off their research labs and they are beginning to invest more in universities. So universities become the research hubs in the United States in terms of science and technology, and the industrial labs are becoming less important. And then the other sense is this separation between the design operations and the actual manufacturing. And it makes possible all of these arguably more flexible combinations. People can be hired and leave. That fluidity, which was such a problem earlier, it was a problem for Fairchild, right, that now becomes something that is kind of an expected norm. Let me pose that as a question. In those design companies, the problem of retaining people ceases to be a problem. Is that a way of understanding it?

03-01:14:51
Gray: Well, it's a very competitive marketplace out there, so retaining people is always an issue. I think the success of the fabless model is driven by a number of factors. One is economics. You can found a fabless semiconductor company with a lease on a building and a bunch of workstations, and small enterprises can flourish, with the participant being financially rewarded for their innovations and ideas. They can create a lot of value without a huge upfront capital investment. Another factor is sociological. It allows formation of a self-directed organization that has values of innovation and creativity at the forefront. Retention is always an issue but it's a lot easier to retain

engineers when they're with a community of their peers that value innovation and creativity. If you fast forward to today, it would be hard to contemplate creating a new vertically integrated semiconductor company simply because of the billions of dollars it takes to build a fab today. Things have come a long way from the landscape that was evolving in the seventies and eighties. Today, a fab costs billions of dollars. The mask sets that re used to make the chips cost millions of dollars and the most advanced technologies.

03-01:18:24
Burnett: And the mask set is like the master of the wafer, right?

03-01:18:28
Gray: Yeah, exactly.

03-01:18:31
Burnett: Let's dive into a couple of these projects and maybe along the way talk about the leadership of Electrical Engineering and Computer Science here.

03-01:18:43
Gray: I did want to touch on that, just the evolution of the department. Now we're shifting back to a Berkeley campus focus and not so much on IC technology but on the growth of the department. Now that I've had a chance to see in the jobs I've had the rest of the campus, and also a lot of other campuses and how they work, this department has benefited tremendously from the ability to get the best people to serve as department chair and dean of the college. This isn't true in academia always. There are a lot of parts of this campus and a lot of other campuses where it's hard to get anybody to be a department chairman because it's an onerous job. Most faculty just want to do their research and teaching and not be burdened with these administrative roles. If I think about the leadership we had, when I came we had Ernie Kuh, who went on to be dean of the college and initiated our industrial liaison programs and did a fabulous job. He was a real leader. Then we had Tom Everhart, who really helped get the industrial liaison stuff going and went on to be president of CalTech and was a really, really, great leader. We had a fellow named Dave Sakrison who was a wonderful leader and a great person, but he unfortunately became ill and wasn't in there very long. Next was George Turin, a communications theory specialist who later went on to serve as Dean of Engineering at UCLA. Next were Don Pederson who I've already talked about Gene Wong came next in 1985, a founder of INGRESS, the first or one of the first relational database companies, ultimately bought by Oracle. Gene and Don oversaw construction of the fifth floor built on Cory Hall. He later had some important jobs in Washington, first as associate director of the Office of Science & Technology Policy and later assistant director. We then had Dave Hodges, my colleague, who shares this office. Who went on to be dean of the college. Dave maybe more than anybody else helped drive all these models for different ways of interacting with industry. He was a colleague of mine on all this research, but he also was Don Pederson's student in helping get the micro lab going, just had tremendous impact on the campus.

He helped get Soda Hall funded. He helped get Hearst Mining [Building] funded. I'll talk about Rich Newton, who was another key figure for the department and college, a bit later. I should say, by the way, Dave Patterson was my associate chair when I was chairman here and he did a fabulous job, too. The long series of department chairs and associate chairs that followed on from this group have been equally effective and impactful.

I mention this remarkable list of people because of the pattern of strong leadership the department has benefitted from. The chairs of the academic departments are the most important single individuals in determining the academic future of the campus. They make the final hiring decisions and deal firsthand with many difficult management decisions. We 've really been fortunate to benefit from the leadership we've had.

03-01:22:31
Burnett: Well, in the Joe Cerny interview I think he talks about he did these sunset-to-dawn reviews and went around—

03-01:22:36
Gray: Yes, oh, yes. I remember. [laughter]

03-01:22:37
Burnett: [laughter] And he noticed a difference as he went around. The science departments often, and I think he meant and included engineering in that, the chairmanship of the department or the deanship of a college is considered to be such an important role. It is thankless. Leadership of a department is very important and in the humanities and social sciences it tends to be more like herding cats. It's more of an undesirable burden than anything else.

03-01:23:23
Gray: I think that's accurate. Yeah, that's been my observation. We've had some absolutely fabulous people as chairs of those departments and I've been able to work with them. They have to have their arm twisted. They have to be coerced to do it.

03-01:23:38
Burnett: It's perhaps worth talking about the Cory Hall project a little bit. [Governor of California] Jerry Brown set up a commission at the end of the seventies on ways to develop and foster cooperation among high-tech industries, the university, and the state government. There was this awareness that this needed to happen, not just on campus here. And there was fundraising by the College of Engineering to add two floors to Cory Hall with state matching funds. And Jerry Brown vetoed the addition. So can you talk about that story and how that—

03-01:24:32
Gray: I think that happened while I was at Micro Linear, so I don't have a blow-by-blow on that. I saw it from afar. I think the micro program came in during one of Governor Brown's first terms. The micro [microelectronics laboratory]

program had a big impact. It matched dollar-for-dollar industry contributions to support research in microelectronics. It had a big impact not only here but at the other UC campuses, helping get those people involved in contacts with industry, which they desperately needed to do. It sort of faded away later on but I think other things took its place, but it was something that started a lot of things that flowered after that.

03-01:26:25
Burnett: I think in the Heyman oral history there's a description of that to some degree. And I did want to ask about the Heyman era. This is what we're talking about. He's known for really making fundraising and development a major priority of the university. And he centralized development operations to a great degree. And getting private funding was one of his key cornerstone goals. Engineering was an important fundraiser all on its own and had been for a very long time. So how did Heyman's orientation to development impact engineering? What was the interface there?

03-01:27:13
Gray: Well, the most important thing that Mike did that helped us much, much later was the biology reorganization. That’s a little different from what you're asking, about, but at least from my perspective that was the most important single thing the campus did in his ten years, We were stuck in the old outdated biological sciences model, and we were not prospering. The reason I mention that is what's happened in the biological sciences in the last twenty years and what will happen in the next twenty or thirty years are going to be so profound in their impact. The biologists are gradually figuring out how life works and for every layer of understanding that gets uncovered, more new layers are found. But eventually they'll figure it all out. We're in a leading position in the biological sciences today, particularly in the molecular and cell behavior aspects, the genetic signaling pathways and all that. We probably wouldn't be there had we not done that reorganization. Mike, with Dan Koshland's help and that of the other people in California Hall at the time, really made that happen. He was really focused on that and the Valley Life Sciences Building renovation, which was part of that, and Koshland Hall and the other pieces of that initiative. Mike initially wasn't a huge fan of the Soda Hall project. I think he probably saw it as competitive — his main priority was biology and I think he was right to focus on that. But he did come around and he did get Soda Hall on the agenda for the campaign. As you well know, there were some big gifts that came in during Karl's reign as dean that resulted in Soda Hall being completed. I don't think I was close enough to it in those years to know how much interaction there was between Mike Heyman's fundraising activities and the college's fundraising activities. I think Mike had a really transformative effect on the campus in many ways. Getting the fundraising going, especially for biological sciences, was really an important contribution.

03-01:30:19
Burnett: Well, perhaps we can drill back down into the Electrical Engineering and Computer Science department and talk a little bit about some of the incredible

projects that have come out during these years. Can you talk about RAID? Anyone who's bought a disk drive in the last twenty years knows about this kind of stuff. It's a redundant array of independent disks.

03-01:30:44
Gray: Inexpensive disks.

03-01:30:49
Burnett: Inexpensive disks.

03-01:30:51
Gray: This is a project that Randy Katz and his colleagues initiated in the late 1980s. Disk drive reliability was a serious problem in computer systems of all types, as anyone who had a PC in that earlier era will attest to. The idea that Randy came up with for this was put redundant data distributed across a group of disks so that if any one of them failed the data was still preserved. So you had some redundancy. Brilliant idea. Now they had to build the software and the operating concepts and how do you hook it together? How do you transition it when one fails and how do you make it practical? But that's the essence of it. It was hugely successful. Many companies were founded that built these things. It became a big part of large computer installations. I think most large computer facilities use these kinds of technologies now in their disk drive storage arrays. It was a huge innovation and Randy and his colleagues deserve a lot of credit for that. He had a lot of collaborators over there in computer science. That's one of the four or five things that you think of as this department contributing over the last 25 years and it had a big impact.

03-01:32:46
Burnett: And we can talk about others later as we get out of this period of the 1980s. I think the first papers are 1988 for RAID. I wanted to see about the other development activities that were important during this time. There's the Cory Hall expansion. Are there other projects that were undertaken?

03-01:33:18
Gray: We redid the micro lab. That happened about that same time, if I remember right. That was an upgrade to the microelectronics lab. The Soda Hall project was the big item on the agenda in that timeframe and getting that done. And Dave Hodges finished that up in the early 1990s and we got that under construction in probably, what was it, '94, '95, something like that. I think we pretty well hit most of the important — I can't think of anything else that was particularly important in that era. I don't know, it wasn't a department thing, it was a campus thing, but maybe we should talk about the Asian admissions.

03-01:34:08
Gray: Oh, we're getting a little short on time. We can defer that until next time if you want.

03-01:34:12
Burnett: We can. One thing I'd like to keep some track of — the IEEE awards you the Centennial Medal in 1984. Can you talk about that? What was that?

03-01:34:38
Gray: The Centennial Medal was given on the hundredth anniversary of the IEEE.

03-01:35:03
Gray: I don't recall what the criteria were, but I believe that people who had been active in IEEE organizational activities in any kind of leadership level got a Centennial Medal. I've been lucky enough to get some awards like that over the years and it's usually because I had friends that took the time to actually nominate me for them.

03-01:35:39
Burnett: Well, can you talk about the IEEE and your work with them? You had a role. Can you talk about that and also more generally about the importance of scholarly associations?

03-01:35:54
Gray: Yes. It's the International Institute of Electrical and Electronics Engineers, is a very large organization with 400,000 members, spanning both academic world and practicing engineers. Among many other things, it operates the array of journals in which most faculty members in electrical engineering and computer engineering publish their work. It's important for both groups. The IEEE is organized into divisions for each of the different subareas of electrical engineering, and there's one for solid state circuits, which is integrated circuit design. Dave Hodges, Don Pederson, Bob Meyer and myself all at various times done some leadership roles in that organization, which sponsors the leading conference in the integrated circuit world, which is called the International Solid State Circuits Conference, [ISSCC] held once a year in San Francisco and the leading journal in that field, the *Journal of Solid State Circuits*. And they're very important. And it's not just academics. Those conferences and that journal are very widely read in the industry. They're not just academic journals. Attendance at the ISSCC is probably three-quarters industry people and the papers are probably two-thirds authored by industry. So it's not just an academic thing. But from pure self-interest, if you are a faculty member at a place like this doing what we do, you want to be involved. I'm thankful that we had that tradition. The International Solid State Circuits conference actually got started at Philadelphia, of all places, in the 1950s. And then as the semiconductor industry grew, the conference became three to four thousand attendees every year. The industry was out here and the conference was in Philadelphia, so Dave, when he took over, decided he was going to make his mission to move it to the West Coast, which he did, a complex undertaking because of the internal politics involved. Made that happen. Now it's in San Francisco all the time, all thanks to Dave Hodges, who's a real innovator in these things.

03-01:30:44
Burnett: I think that was really important to touch on that. Associations are so crucial. Another thing, so now your sons in the eighties are beginning to enter the teenage years and that is the era of the PC revolution. So what was that like? Did you have a computer in the home and were you interested in ushering them towards that world or—

03-01:40:20
Gray: Well, remember, it's astounding how recent the PC revolution really is. Let's see. I'm trying to think when. It's in the eighties and my kids were in the era where you would expect them to be involved. I had a PC at home and I used it a lot and I was online all the time. But my kids didn't gravitate to that. My older son ended up becoming a poli-sci major at UCLA, going to law school, and now he's an attorney at a big law firm in San Francisco. So he never really gravitated. My younger son is more mechanically oriented. He's a car guy; tore cars apart, rebuilt cars in the garage. He did end up studying engineering, but never really got into the software. Ironically, he now is managing partner of an engineering consulting company in Boise Idaho, where a significant part of their workload is developing software and firmware for high technology systems. But it was evolving in that time; it took a while. The PC revolution was really happening in the eighties, but it took a while before it became totally — it really took the internet before the PC became mainstream for many people.

03-01:41:39
Burnett: Yeah, it did.

03-01:41:41
Gray: In those early days you had to get a dial-up modem and you had to log on at perhaps 1200 bits per second – very cumbersome. It was the old “you’ve got mail” days. My sense was the thing that really changed the landscape was networking and communication, the internet, and everything that went with that.

03-01:42:14
Burnett: Yeah. That would be the Digital Natives, the people born much later, a generation later, in fact.

03-01:42:19
Gray: Yeah.

03-01:42:20
Burnett: Well, let's pause for now and we'll pick up next time.

03-01:42:22
Gray: Thank you, Paul.

[End of Interview]

Interview 4: January 19, 2018

04-00:00:00

Burnett: This is Paul Burnett interviewing Paul Gray for the University History Series. It's January 19, 2018 and this is our fourth session. We were talking in an earlier session about the kinds of consulting work that you were doing and I was wondering if we could dive back in to talk about your work with Micro Linear. In session three you described Micro Linear and what they were working on. How did you become more involved with them?

04-00:00:53

Gray: Thank you, Paul. Good to be doing this again. Well, as I mentioned, I had gone down there for the 1984-85 academic year full-time to help them get started in the business they were trying to build and it was a great experience for me. Then I continued to consult there one day a week for a couple years after that and then in '88 I joined their board. The company was in the process of going public. It tried to go public in '87 but the black Monday '87 event happened and that put everybody on hold for a while. A couple of years later they did go public and needed a more broadly representative board, so I joined the board as kind of the technical person on that board of directors. I was there for three years. I was going to talk a little bit about some of the other boards I was on over the years both because those experiences really shaped both the people I was able to get to know but also because the experiences really helped me in some of the responsibilities I had around here.

Back in the eighties, corporate boards of the US, at least in the smaller non-public high-tech companies, were in many cases pretty low profile. Often it was mostly advisory and there wasn't a tremendous amount of accountability and expectation about helping with the details of management of the enterprise. This board was very much like that. I learned a lot. I learned a lot about how the company was working, how an IPO works. I got to know Art Stabenow, who previously was a vice-president of National Semiconductor, and who came to Micro Linear as CEO when — I guess that was in 1986, when Alan Grebene stepped down. And he was the CEO subsequently through the whole history of the company. Art was a semiconductor veteran of the first order. He'd been in the semiconductor industry since the very beginning, and I learned a lot from him about management and about the corporate world.

Then in 1991 I got a call from Bob Pepper. This is the same Bob Pepper I met when I interviewed at Sprague Electric back twenty years earlier. Bob had a Berkeley PhD and had spent some time here after his PhD in this building. Bob had left Sprague and gone on to be the head of RCA's semiconductor division. After he'd done that for a number of years he came out west and founded a fabless semiconductor company called Level One. That must have been in the late eighties sometime. The term Level One, just to explain a little bit, is used in networking. Level One is the physical level of the wires and chips that physically connect things. The higher levels are the link level and then software and applications levels that run across a network. It's a networking term, and that's where the word level one comes from. The internet had been born in the late 70s and early 80s with the ARPANET. It was evolving. The Ethernet technology that underlay that was being deployed in businesses and then gradually in consumer applications, and the electronics that go along with that, the devices that connect to the Ethernet media were becoming a big business. Level One was a fabless semiconductor company that built the chips that do that, that do the physical connection and get the data off the wires and into electronic form, which is called a transceiver. I was on that board until '99, when they got acquired by Intel for $2.2 billion. It was a big transaction. Level One was sort of a prototype of a successful fabless semiconductor startup of the 1990s. The company was located in Folsom, up near Sacramento, so it was a quarterly trip to Sacramento. Board serviced at that time was not very burdensome in terms of time. It was another great learning experience.

04-00:05:47
Burnett: Can I pause there for a moment and ask you about the expertise around the scaling of companies? It's something I've always wondered about. There's a story about Silicon Valley, the regional advantage. There's all of these people here, and there are these social networks of people who just know things. So you can call Bob Pepper and he knows how to do X. So can you talk a little bit about where that expertise resides? Has it become formalized or can it become formalized? Can you go and get an MBA in the scaling of start-ups today?

04-00:06:30
Gray: That's a great question. There's several dimensions to that question you've asked. One dimension that comes to mind immediately is the ability of leaders to scale. A start-up might start off with twenty people and if they're successful, might evolve in a few years to have thousands of people in many locations, a huge organization. Marvell's an even better example. For a CEO, and the other leaders of an organization like that, to be able to scale-up is a challenge; the jobs are totally different from a small 20-person startup. Not very many people have the ability to do that. Bob did perhaps because he had run RCA Semiconductor, a huge organization. I'll get to the Marvell experience in just a minute.

Another dimension of that question you asked that is also important is the Silicon Valley ecosystem. You need an incredible variety of kinds of people and skills. Just to cite a few examples, you need venture capitalists, law firms and bankers who know how to do an IPO, people who know how to get exotic materials and services from vendors, and an infinite array of other things. It's all there. If you don't know who it is, you can ask the person in the next cubicle or call somebody you know and get access. I think the value of that infrastructure and that ecosystem is underappreciated. I don't think there's any question that one of the things that is hard to replicate is the ecosystem that has all the elements. If any one major element's missing, then it's a big impediment. It's different depending on segment. For the biotech people, it's a totally different world with different skill sets and infrastructure needed. Different pieces of the semiconductor world are different. And so, it varies a lot. So, I'm not sure it's become formalized but it's a very important part of the evolution of the Valley.

04-00:09:29
Burnett: Just to ask you a follow-up on that. As the technical point person for a board, they meet quarterly, but there's literature that you keep abreast of in the interim and there's an agenda set. To what degree were you on tap throughout the year basically?

04-00:09:5
Gray: There was always some of that. I also did some technical consulting for a Level One independent of the board service. The board service itself did not take much time since I did not have a role like chair of the audit committee or compensation committee.

04-00:10:48
Burnett: So the com committee and the other one was?

04-00:10:51
Gray: Audit committee. And there's often a governance committee. These are some roles that take more time. But the real point of mentioning that is that things have really changed today. Things are radically different today than they were thirty years ago. So, let me talk about—

04-00:11:08
Burnett: Sure.

04-00:11:10
Gray: By the way, this is all happening in parallel with things going on here on campus and these are one-day-a-week and less engagements. The reason I thought it would be good to talk about was, first, we can get it out of the way and not keep going back. But, secondly, these were important relationships from a learning perspective and just understanding the Valley and how it works. Level One got acquired in '99 and I got a call from Sehat Sutardja, Sutardja-Dai Hall [gesturing to the building next door]. Sehat is a PhD student of mine from the early eighties. Sehat left Berkeley, went to Micro Linear, and worked there for a while. He then went to a couple of other companies and in the mid-eighties he and his wife, Weili, founded Marvell, along with his brother Pantas. All three are EECS grads. Marvell's first business was making electronics for hard disk drives, realizing more integration, less cost, and higher performance. They were quite successful at that through hard work, good marketing, and a lot of innovation. They captured a pretty significant chunk of that market, and by about 1990 they'd become a major factor in the disk drive world. And they had started another business in the Ethernet

transceiver business, just like Level One had, and they were trying to get involved with some other businesses, as well. By about 2000 they were ready to go public. They needed broader representation on the board, and I joined their board about 2000. The company did go public about that time. The lead venture firm was a called Tallwood Capital, of which Dado Banatao was the chairman. They had funded the company in the startup phase and Dado continued the board. By 2008 they had a revenue of two billion dollars a year and about five thousand employees and locations all around the world. It was a very successful enterprise as a start-up. Rich Newton was able to get Sehat, Weili, Pantas and his wife Ting, along with Dado, to make the gifts that enabled us to build this building here. The construction of the CITRIS and QB3 centers was partially funded by the State of California. Half of the building costs were awarded by the state, but they had to be matched. Those gifts gave us the match to get CITRIS, which is a whole other story well get to later. We wouldn't have it without those gifts. They were critical for the campus.

But let's back up. By this time some other changes were happening. We'd had the Enron crisis scandal. We had the Tyco scandal in the late eighties. Corporate boards were being asked and demanded to take more accountability for corporate governance. That was needed. Those scandals really energized the congress to mandate that the justice department and the SEC demand more from corporate boards. There were a lot of changes in accounting rules, like the GAAP standard, generally accepted accounting principles, a lot of other changes that required boards to spend a lot more time and take a lot more responsibility, and so board service changed. Marvell was also evolving during that time. The most impactful experience for me during that time, and in some ways the most impactful experience for the company and for the industry, was the stock option backdating episode that happened in the 2006, '07, and '08 timeframe. I'll just give you a small capsule summary of that so that you get a sense of that. I think I learned more about the public corporate world in those two years than at any other time in my whole career.

Stock options were a basic part of the Silicon Valley compensation scene. Almost every high-tech company in the country, but especially in Silicon Valley, used options as a big chunk of the compensation for engineers primarily but in a lot of companies options were a part of every employee’s compensation. An employee stock option allows an employee to purchase shares in the company over a period at a purchase price which was usually set at the share price on the day the option's granted. It's very, very useful as an incentive because if the company's successful, the share price goes up, the employee realizes a lot of gain over that four-year period. Unfortunately, in 2006 a lot of high-technology companies in the Valley had fallen into the pattern of granting these options but with an exercise price that was set by the stock price not at the grant date but at some earlier time when it was lower. That's called backdating. Now, there's nothing illegal about that. You can give an option at any price you want to. But if you award an option at an exercise price that's below the market price on the day you give the option, that's a benefit to the employee that from an accounting perspective has to be taxed. It's taxable. From the standpoint of the company it's an expense that should appear as an expense on the books of the company at that point in time. That was not happening. It wasn't being treated either taxable to the employee or as an expense to the company and it was widespread. People had just started doing this over time.

An enterprising academic, in the fall of '06, discovered this and wrote a couple of papers about it. It got the eye of the press and it became a cause célèbre. It was characterized anywhere from gross negligence to outright fraud.

04-00:18:02
Burnett: Right. Criminal, yeah.

04-00:18:03
Gray: Criminal behavior. It was an incredible black eye for the industry and it really was a huge issue for people like me who were on the boards of companies where this was in fact happening. I think the reality of it was that the executives involved in doing this just weren’t well informed in most cases. Everybody else was doing it. There was a breakdown in knowledge and the advice they were getting. But, irrespective of that, it was a huge problem. I'm going to skip all the intervening two years of drama and move to the outcomes in 2008. There were some executives who lost their jobs, but at Marvell, at least, the shareholder value recovered. The practice was stopped, guardrails were put in place. The founders stayed in place. The company survived and continued to grow. So other than some reputational damage on some people’s part, the industry survived. And now most of the companies use fewer options and a different mechanism called a restricted stock unit, which is a different way of achieving the same thing. It takes away this issue of when you date the option. But I think everybody's put guardrails in place now so that these things don't really happen. But this was another contributor to making board service much, much more accountable and a lot more work. And so, your earlier question about time commitment between board meetings, well, now there are a lot of them because you're often certifying things and you're paying attention to a lot of things that many boards didn't pay attention to before. So, board service has really changed.

I tell that story because when young faculty ask me my advice today, and people on campus, "Should I join corporate boards?" I'm always a little bit more cautious because it's a very significant commitment of responsibility and if things go wrong you have to be there to fulfill the responsibility to the shareholders. You have to think very hard about how much of that you really want to be doing. I think some is tremendous but too much of that can be not a good idea.

04-00:20:48
Burnett: Has compensation increased as a consequence of the increased accountability? If you're on the hook for these decisions, you need to be more invested.

04-00:20:59
Gray: That's a great question. Let's put aside start-ups pre-IPO because there the compensation is usually mainly equity which can be either very good or very bad depending on how the company does. But if you consider established public companies, there has been some moderate growth over the past decade in real terms for a company of a given size, reflecting the increasing burdens I mentioned. The companies that rate the effectiveness of their corporate governance look very hard at board compensation. If it's excessive relative to their peer companies, nationally, they get dinged for that.

To finish up Marvell, it was great learning experience. I learned a tremendous amount there. The company still exists, and it's now an even larger company today than it was then. We owe the founders a lot because they helped us build this building. They've moved on to do something else but the company's still going. I got involved in some other boards later. Applied Micro Circuits, which is another public company board. Some start-up boards, Telegent and Sentons, which were founded by former students, Weijie Yun and Sam Sheng. And those were great fun and I'm still on one of those.

The reason I thought it was worth talking about these boards is the insight it provides, and serving on a long series of these, about just what an incredible place Silicon Valley really is. It just keeps rolling. The culture of innovation, the culture of risk-taking, the commitment of the people that get involved in these start-ups. The ecosystem that you're talking about that's kind of hard to define but it's there. I haven't gotten the latest numbers but as of two or three years ago it was still the case that one-third of the venture capital investment in the entire United States happens in the nine Bay area counties.

04-00:23:57
Burnett: Yeah, amazing.

04-00:23:59
Gray: And so, it just keeps going. A lot of people worry if we are losing our edge, is something happening where other region are catching up? There's some of that but by and large the Valley keeps rolling. And if you think about Berkeley and Stanford and why we're resilient and we keep staying as highly ranked and impactful universities, a big part of it is being connected to that ecosystem. So, I just thought that was worth talking about.

04-00:24:33
Burnett: Absolutely. And we can talk about this in our open session. There are concerns about technological bottlenecks or hard walls. And I think one of them was reaching a certain quantum scale, that you run into some basic problems of subatomic physics. But lately there's talk of this quantum

computing, of learning to take advantage at that level. And I'm way out of my depth there. But just as an example, there is a spirit of continuous innovation, risk-taking, improvement, but always the threat of Moore's Law being confounded, for example. So having been involved for decades, do you feel that there's just a certain level of comfort with that? We're always going to have a specter of a hard wall and that you have to trust in this ecosystem to carry it through?

04-00:25:44
Gray: There are two answers to that. One is the fact that a significant fraction of the innovation that all of this venture investment is funding moved further down the food chain from the core microelectronic chip world, closer to the user experience. Apple, Google, Facebook, exemplify these innovations that have been enabled by the underlying technologies. And that's going to keep going. On the fundamental Moore's Law side, the rate of reduction in cost per function has indeed slowed as we approach fundamental limits to scaling in the technology itself. While it has slowed down a bit, I'm an optimist and believe that progress will continue in one form or another. I think there is good reason to believe that breakthroughs and progress will continue. Say you had a hard one-dimensional device scaling limit at four nanometers, a four-atoms-long transistor. It may be possible to move to 3-dimensional structures and retain some but probably not all of the economic cost reduction impact of scaling. That may continue Moore's Law for a time in another dimension, or some totally new technology for computing, like quantum computing, may prove viable. I think there's so much innovation happening in atomic-level manipulation of electronic structures that I'm not too worried.

04-00:27:41
Burnett: Well, I think some of the values and targets can change as society changes. We were obsessed with speed, with, say, personal computing. And once we got to streaming video, the basic processing power isn't such a problem anymore. But people had hot computers. And so now they're basically fan less devices because it's gotten so much more energy efficient. So energy efficiency becomes this major, major target, making them cooler. As I'm sure you can discuss, the thermal consequences are important for the operation of the devices.

04-00:28:28
Gray: Absolutely, absolutely.

04-00:28:30
Burnett: So we continue to see this innovation as we go on. So you did some of the small consulting? Sentons is multi-touch force sensors?

04-00:28:39
Gray: Yeah, that's right.

04-00:28:39
Burnett: And you're still on that board?

04-00:28:43
Gray: Yes.

04-00:28:44
Burnett: And Applied Micro Circuits, it's an old company, right? Seventy-nine?

04-00:28:50
Gray: AMCC has been around for many years. It's gone through several iterations and transformations and evolutions. It was acquired recently by a company called MACOM, so it doesn't exist anymore as an independent company. Maybe it's most significant recent activity that's maybe worth mentioning is they made a strong run at taking the ARM architecture, which is used in virtually all mobile devices, as opposed to the Intel X86 and adapting the ARM architecture to server applications. That is, cloud server farms, the processors for which are now virtually 100 percent supplied by Intel. The argument is that ARM is a simpler computer architecture, being closer to a RISC type architecture, and should be amenable to lower power dissipation, which is a big deal on server farms.

04-00:29:50
Burnett: Yeah. Absolutely.

04-00:29:54
Gray: It's very, very difficult for a small company to drive a change like that. And they had a nice run at it. And we'll see if the larger company that's acquired them will continue to make a run at that. AMCC has been acquired so it's off the radar screen now as an independent company.

04-00:30:17
Burnett: There are a couple directions we can go right now before we get back to Berkeley. And one is this context in the eighties, going back in time. There was a moral panic in the early eighties around the semiconductor industry in Japan and this foreign competition. So, I'm wondering if you can talk a little bit about the history of the industry response to foreign competition at the very moment when the industry in the United States goes global. There's kind of a parallel track there. Can you talk a little bit about that, that story, as you encountered it?

04-00:31:08
Gray: By the way, Dave Hodges, who shares this office, is a fundamental contributor in manufacturing technology, which I'll talk about a little bit. I guess it was in the early eighties, the development was that the Japanese semiconductor companies, the Hitachi’s, Fujitsus, NECs, began to really be factors globally, mostly early on in the memory business, which was a very big chunk of the semiconductor business at that time. Intel was just getting out of the memory business but we had a lot of other people in the memory business. Not only were the Japanese chips cheaper but they were better. They had better reliability; they performed better. Memory at that time was thought of as sort of like the canary in the mineshaft. They were the most difficult to

manufacture, the most demanding.. However that went, the rest of the semiconductor components would go. And they were beating us in memory chips in terms of price and performance and quality. In '85, the semiconductor industry sales globally were about $35 billion. About 40 percent of that was from Japanese companies. The rest was split between — the US was maybe half and the rest was the rest of the world. The Japanese share was growing and this was creating a lot of consternation. There was a lot of press coverage. Congress was upset.

04-00:33:17
Burnett: Yes, that's right.

04-00:33:18
Gray: The semiconductor industry was worried. If you fast forward now today, thirty-some odd years later, and look at semiconductor manufacturing in the world, it's about 20 percent Taiwan, about 20 percent South Korea, about 17 percent in Japan and about 13 percent in the United States and the rest is Europe. If you look at semiconductor companies, there's only one Japanese semiconductor company, that's Toshiba, in the top ten semiconductor companies by revenues and they're number eight. The Japanese threat faded away. They're great companies and they do a lot of great things, but they haven't taken over the semiconductor industry. By the way, semiconductors today are a 350 billion [industry], ten times what they were in 1985. What happened? A bunch of different things contributed to that. There was some government intervention. Bob Noyce went to Washington and advocated and ultimately the Sematech consortium was established. Sematech was focused mostly on manufacturing. It was a government-industry consortium funded by the federal government. One of the important things they did was gather together the makers of semiconductor equipment and standardized a lot of the interfaces in semiconductor manufacturing. That helped a lot to make US semiconductor manufacturing more competitive, better quality, lower cost, et cetera, et cetera. Sematech was important. And Bob Noyce continued that for a while. Then he went back to Intel and then Bill Spencer, who's somebody you may know, took that over. There were some other government initiatives.

Another thing that got everybody's attention was the fifth-generation computer initiative in Japan. Along about the same time, 1982-83, they launched this very public, very high-profile fifth-generation computer initiative. They wanted to make Japan a leader in computing. It was built around some concepts of parallel computing and AI [artificial intelligence]. Both of those words appeared. The US government wasn't making those sort of government initiatives like that at that time in semiconductors. That did spur some things. Later on, there was the HPCC, which was a US government initiative some years later. The MITI initiative on computing was a big factor.

04-00:36:11
Burnett: If I recall some of the congressional testimony, that's what they were saying, is that we don't have the MITI, we don't have the [Japanese Ministry of

International Trade and Industry] a state-sponsored technology hub and they would sponsor innovation and coordinate among the industries, which seemed to be antithetical to the kind of Wild-West private-enterprise system in the United States. And so Sematech was a kind of answer to that, effectively?

04-00:36:45
Gray: Sematech was important. No question. The subsequent papers that had been written on it showed that, but some other things were probably even maybe more important. The US semiconductor people focused away from memory and focused on places where innovation really mattered. Not that innovation isn't important in memory but they focused on microprocessors and a wide array of other kinds of functionalities and integrated circuits where application and architectural innovation are important. They were able to do a lot more innovating in those domains. We only have one memory manufacturer, Micron remaining in the US. The innovation engine that was enabled by focusing in other areas is important. The fabless world emerged. Currently, only 13 percent of semiconductor manufacturing is done in the US, but a very large fraction of the revenue is from US companies. The fabless sector is a very important sector. That change allowed the low-cost manufacturing to be done in Asia but a lot of the application and architectural innovation to be done here. That was a huge, huge factor.

I and many others attribute a lot of the manufacturing progress to Intel and to Craig Barrett. Craig was a materials scientist at Stanford, a faculty member. He went to Intel in the late seventies and I worked with him there for a while. He really worked hard to get Intel to be a world leader in semiconductor manufacturing. He and his colleagues focused on making Intel the best semiconductor manufacturer in the world and they pretty much succeeded at that. Of course, he went on to be CEO and chairman and watched over a lot of that. He deserves a lot of credit for personally leading the charge.

I want to mention Dave Hodges. Dave, in about the same era, maybe a little later, decided he would make semiconductor manufacturing an academic discipline, which it wasn't at that point. Nobody was paying any attention to this in the academic world. He hired Costas Spanos here, and committed his personal effort and reputation to developing this as an academic discipline. He started a journal, the *IEEE Journal* in semiconductor manufacturing [*IEEE Transactions on Semiconductor Manufacturing*], devoted to that. That helped create an environment where academic people can work on these kinds of topics and that can be valued as an academic discipline. It's hard to measure the impact. I've never seen a study of what the real impact of that's been, but it must have had some significant impact in improving US semiconductor manufacturing, helping worldwide manufacturing.

04-00:40:01
Burnett: Right. To be clear, all the companies that you've talked about consulting for, acting as a board member on, they're all fabless.

04-00:40:11
Gray: They're all fabless.

04-00:40:13
Burnett: Yeah. So that tells you the change in the landscape.

04-00:40:13
Gray: By the way, another interesting thing is that the fifth-generation computer project had the right words in there. They were doing parallel computing and AI, but it was twenty years too soon. The parallel computing is a crucial factor today and our guys here in computer science have led a lot of that, Dave Patterson, for example. But it took a long time for there to be enough power in the technology before it got to the point where parallelism was critical to enable the technology to keep progressing. In that era, they got a lot more mileage out of just doing a better job of improving the processor architectures they already had. And we weren't to the point where AI could be implemented the way it is today, where you have many orders of magnitude more computing power available to drive that. So that fifth-generation initiative sort of faded away and didn't end up having very much impact. With all of that angst and all that publicity, the ecosystem adapted and it turned out okay. The Japanese, although they're huge factors in the global ecosystem of microelectronics, don't totally dominate it the way some people were afraid they might.

04-00:41:51
Burnett: Coming back to Berkeley now. In doing all of this external consulting and board service, I imagine that that really helps you pedagogically, that this is another dimension, even for, not just graduate students, but junior faculty, as you mentioned. Is that another added dimension to the Berkeley mix, that you have this external consulting and that it brings it back home to the educational process?

04-00:42:25
Gray: Well, I think the answer is yes, it helped. Just the perspective on how the rest of the world gets things done and how management works at different levels and just the educational value of having those experiences certainly helped me here. I really do believe that if we could get more of our campus managers and leaders to get some more exposure to that, it would be helpful. But yes, it certainly helped, and so I wouldn't trade any of those experiences for anything.

04-00:43:08
Burnett: So in the eighties you're getting tapped to lead units in EECS. And I think to set some of this up, can you talk a little bit about the importance of electrical engineering and computer science vis-à-vis the rest of the College [of Engineering]? It's large, right? It's a huge chunk of engineering proper at Berkeley. So can you talk a little bit about its size, its importance?

04-00:43:37
Gray: Yes. It’s a little bigger now — but in those days, the EECS department was between ninety and a hundred faculty members, about evenly split in those days between EE and CS. The college of engineering was about 220, so EECS was about 40 percent of the college. The campus had about seventeen hundred (check this) faculty members. There was only one other department on campus of comparable size, which was MCB, Molecular and Cell Biology. Those two large departments were a bit unique because the typical department on the Berkeley campus is twenty to thirty faculty members or so and there are a lot of departments that are way smaller than that. It's big and it takes a little bit more management and organization than your typical academic department. And those two departments have a disproportionate impact in the state and nationally because of their size and the number of people in them and the impact of their research and alumni. I'll give you a quick sketch of the different administrative roles I had along the way.

04-00:45:03
Burnett: Sure.

04-00:45:05
Gray: When I came back from the Micro Linear experience I did a stint as the acting director of the Electronics Research Lab [ERL] for a year. The Electronics Research Lab is an organized research unit on the Berkeley campus. I need to give a little context about what that is. For an institution like Berkeley, a research campus, one of the themes that keeps recurring is the adaptation to new and emerging cross-disciplinary opportunities. It's been true for certainly the entire post-war period, post-World War II. Universities have evolved organizationally over centuries to be resistant to external pressures to change. They’re not well suited either organizationally or culturally to rapid adaptation and change. Yet disciplines do emerge and evolve, and the old traditional stove pipes of traditional academic departments get superseded by new domains of knowledge, innovation, inquiry and discovery that are not aligned. The molecular and cell biology transition, the advent of bioengineering, environmental challenges, there are just countless examples, including data science that we're facing right now. Different universities across the country and around the world have differentiated themselves on how they solve the problem of how you adapt. On the Berkeley campus, for many years, one method of evolution was to utilize the organized research units. An organized research unit is an administrative unit that supports research that crosses departmental and college lines. It's not just in one department. If all the activity is in one department you can just have the departmental organization support the research. But these cross departmental lines. ERL was the biggest organized research unit on the campus in the eighties. But there were over a hundred of these units. They ranged in size from one faculty member and one staff person in a little tiny office all the way up to ERL. There were something on the order of fifty or sixty faculty involved and dozens of staff people and a multimillion-dollar budget. ERL included most of electrical engineering and computer sciences, quite a bit of faculty from other departments, and some

faculty from physics and chemistry were involved in that also. These ORUs [Organized Research Units] provide administrative support, contract and grant administration, and some personnel functions for graduate students and faculty working on grants. They provide a lot of programmatic activity. In the case of ERL they operated the microelectronics lab. They often run seminars and provide lots of programmatic functions for this activity that crosses departmental boundaries. These evolved at Berkeley over many years to cross these boundaries. There are a lot of other things that evolved, things like the Energy and Resources Group, which was sort of a giant ORU that evolved in the eighties. There are the science institutes like CITRIS [Center for Information Technology Research in the Interest of Society] that evolved after 2000, much larger, that are just different but have some similarities. And there are lots of others, which we'll talk about later.

This is relevant for many reasons for our later discussions. This matrix organization creates all kind of management challenges. So, to get back to ERL, when I came in to do this job temporarily in 1985, Bill Oldham, who was a long-term faculty member in this department, had been the ERL director for some years at that point. He took a year's sabbatical. I stood in for him. Bill was fighting a tremendous fight at that point with the campus about money. That's a topic which will recur frequently.

04-00:49:41
Burnett: Yes. [laughter]

04-00:49:46
Gray: These organized research units — and this is this era of the eighties — had a fixed allocation of funding from the campus and they all reported to the vice chancellor for research, your friend Joe Cerny that you mentioned. It wasn't Joe Cerny then. This is 1985. The campus had at some point in the distant past, picked a number that was the operating budget for ERL and that was it. The problem was ERL was growing as sponsored research and EECS was growing dramatically in those years, and they kept getting more and more faculty and more and more grants. But they had the same amount of money to support all the staff and everything and Bill was just tearing his hair out trying to deal with this. Now, the vice chancellor of research at that time was Chang-Lin Tien. As you may remember, he served as vice chancellor of research for two years here on the Berkeley campus just before he went to UC Irvine to be the EVC [executive vice chancellor] down there. So, we went to see Chang-Lin. I'll never forget this meeting. Bill was (and is) a very vocal guy. We had this meeting where Bill just pounded on the table. "We got to have more money." And Chang-Lin, as I learned much later, didn't have any money to give. His budget was set by other factors and that's one challenge of that vice chancellorship over the years, is they haven't had enough discretionary funds. These things have changed now. But this was true in that era. Chang-Lin couldn't do anything. So, we were trying to operate this entity. There were challenges with staffing, there were lots of challenges with providing enough

research support. We were in effect relying on grants, asking PIs [principal investigators of funded research projects] to voluntarily donate money to help keep us going. Later, just to fast forward a little bit, when I was in the provost's office and Beth Burnside was the vice chancellor of research, we went to a formulaic method of establishing the budget for the organized research units. This operating expense should be paid out of overhead generated by the unit. That's the reasonable and logical way to do it so you have some allocation of overhead money to these grant administration units to cover grant administration costs. And that's what we ultimately arrived at. That's all changed yet again after those years, and we'll get into that later. So anyway, my main memory of that year was we had the usual set of management challenges retaining good people and dealing with people who weren't performing as well. I did come from that year with the strong sense that on this campus we spent, and rightly so, a great deal of time and energy worrying about faculty retention, faculty recruitment and keeping the faculty effective and motivated. But sometimes the staff gets lost in the shuffle. I tried to pay a lot of attention then and in subsequent years to making sure that staff concerns were addressed because we can't run the place unless we have a good staff. And we do have that, fortunately. But I really learned that in that year, how important that was. And, again, things have evolved since then. ERL doesn't exist anymore as that. It's been through some iterations and is called something else now, but we'll get into all that later.

04-00:53:51
Burnett: I talked with Joe Cerny about this and read some other oral histories. The organizational research units are old in this university. In one sense they go back to the seismic research in the late nineteenth century. They had been supported by the state in the fifties and sixties and a lot of them had been created then. And the state stopped supporting them in 1971. There's no new money for ORUs after 1971. And there's the gap decade. The 1970s are bad. And then the 1980s is the Heyman area, where they're really working on development. And it seems that especially electrical engineering is way out in front, in that they are really, really engaged in the outside world. Ernest Kuh has gotten the Bechtel Center going and there's a lot of energy around that. And yet there was this wall or this budget problem that couldn't be solved and that was what your colleague was frustrated with.

04-00:55:10
Gray: Yeah, that's the crux of the issue. Viewed in a larger context, there's never enough money to go around, so something has to give. We'll get to this later on but a lot of universities have gone to a budgeting system called resource-centered management, which is a way of allocating resources to the unit that generates them. In systems like that, units like ORUs would be automatically allocated on a formulaic basis some fraction of the overhead generated on the grants they manage. Now, there's a lot of difficult and not-so-great things about that system and we don't use that on the Berkeley campus, although it's been talked about. But one thing that does do, is if you have an ORU that's got

either zero or a very small amount of grants, they disappear automatically because no money's coming in to pay anybody, so it has a natural selection effect. When you have a hundred ORUs operating, there's a pretty good chance that a fair number of those have long since outlived their natural impact, usefulness, and maybe they need to be phased out. And Joe, as we'll maybe talk about, tried to do that and I think a lot of that was very well justified.

04-00:56:33
Burnett: Well, he was very complimentary in his oral history. I just have this quote here. He was talking about the reviews that he was trying to undertake and he had this experience across the entire campus. And he says, "We'll see this later in the big sunset-to-dawn review. The humanities faculty have zero experience with a review committee coming and reviewing them. They don't know how to cope with it. The social sciences cannot be very good either. Engineering, they're all set, right. That's what they do for a living."

04-00:57:06
Gray: Yes.

04-00:57:08
Burnett: [laughter] Cost-benefit analysis, trying to — right?

04-00:57:12
Gray: That's true.

04-00:57:14
Burnett: That's kind of built into the operation of engineering. So it's an interesting story.

04-00:57:10
Gray: That's true, that's true. Well, that's maybe a good segue to this next job I had. I was vice chairman for computer resources for EECS from '88 to '90. This was a part-time assignment and my job was to help facilitate the faculty getting the computing resources they need to do their research and teaching. There were one or two staff people and we oversaw an economic recharge system so that faculty got grants charged for computer time and resources they used from the campus and from the department. What's interesting about that gets back to Joe Cerny's quote that you said. Our biggest challenge was dealing with the campus, which was struggling immensely with trying to provide services. Computing and information technology was evolving rapidly, and the campus ranges from people in the humanities who need email and they need word processing

04-00:58:46
Burnett: Yeah, exactly.

04-00:58:46
Gray: They don't quite know how to use a PC yet, and that's about it, all the way to people in this building who had rooms full of VAX computers using UNIX

and needed large amounts of network bandwidth. Trying to craft a campus support service and network operating model that somehow serviced all these people with what they needed was a nightmare. And, of course, along with that there was Central Campus Computing. There was still batch computing going on that had to be accommodated. They were having a lot of trouble. What kind of recharge model do you use for somebody running a VAX computer versus somebody running a PC? It was very tough for them.

04-00:59:44
Burnett: Just quickly, a recharge model is—

04-00:59:47
Gray: Well, it's a lot like your internet service provider today. To have an internet connection coming to your office, somebody has to pay for that infrastructure. Who should pay, how much should they pay, how much of it should be absorbed in the general overhead of the campus versus charged to the individual user? Those kinds of issues. The same argument applies to what was called workstation support services, where if you had a PC sitting in your office and you needed somebody to update it with the latest operating system, who does that? Who should pay for it? The French department didn't have anybody that could do that, so somebody with the central campus needed to do that. It was just providing the support needed to the wide array of different kinds of people was just a really hard thing to do. So I found myself in that job. I was at first sort of — not fighting but I was negotiating with the campus about how things were going to be paid for but I rapidly evolved to trying to help them because they were just really struggling with this. Anyway, that job was interesting, and I learned quite a bit doing that.

04-01:00:59
Burnett: And there must have been security concerns, as there are today, right?

04-01:01:02
Gray: There were, although I don't recall that being an issue in that era to anywhere near the extent it is today. Let's see, that was 1988. Ten years later it was a gigantic issue. But fortunately, at that point in time, it was still early on and somehow the computer security — I don't think the network had developed to the point where the security was the issue it is today. The challenges faced by campus IT people today are orders of magnitude more complex for many reasons. The concerns I describe above seem quaint in today's context.

04-01:01:43
Burnett: There was one case of an East German hacker who got — I think it was '86 — and he got into LBL's system. He confused LBL with Livermore. He was trying to get into the weapons side, and so it was a firewall there. It was a graduate student who caught it because someone had logged on and they traced it back to an address in East Germany. It's one of the first cases of that kind of activity. But you're right, it was not so widespread. But serving that range of needs would have been very difficult to do.

04-01:02:30
Gray: Yes. It was hard.

04-01:02:35
Burnett: And that was three years, right? It was '88?

04-01:02:36
Gray: A couple years, I think.

04-01:02:37
Burnett: Okay. Eighty-eight to ninety.

04-01:02:40
Gray: We're going through learning experiences and administration, and one other I ought to mention was this Asian-American admissions controversy. I served on a campus senate committee to look at the Asian-American admissions problem and issue in 1988 and '89. We actually started in late 1987. Let me start by giving a little background about this. Through the 1980s we were in an era where really the driving force for this was the increasingly selectivity of the campus. The capacity of UC was growing but very slowly. The number of high school seniors coming out of California high schools that wanted to go to UC and could be eligible was growing more rapidly. As a result, the more visible campuses like Berkeley and UCLA were getting more and more selective. That led to admissions going from being just a sort of administrative exercise to something that people paid a lot of attention to. Prop 209 [Proposition 209 – a California ballot proposition on affirmative action programs that passed in November 1996] was later. Prop 209 and SP-1 and 2 were in the nineties [These were admissions and employment policies for the UC system passed by the Regents of the University of California in the summer of 1995]. And so, we were still in an affirmative action era. Admissions is an unbelievably complicated beast and so I'm going to kind of oversimplify things a little bit. A simplified view is that in the 1980s, to a first approximation, we were taking all the underrepresented applicants to Berkeley that were UC-eligible. They were admitted. And in the remaining slots the admission was done — starting in about 1983-84 — on a two-tier system. Tier one was based purely on grades and test scores and tier two had some supplemental criteria added to that. And the percentage of tier one and tier two varied over time. And that system only came in about '83 or so, so it wasn't true throughout the eighties. But to a first approximation that was the status at that time. Progressively through the whole time the campus got more and more and more selective. Of course, that all changed multiple times after SP-1.

Around 1984 both at this university and at a couple of East-Coast universities, some of the Asian-American advocacy groups noticed that it looked like acceptance rates for Asian-American applicants were lower than for Caucasian applicants in some years at some of these universities. And accept rate just meant the percentage that applied that got in. They raised a red flag publicly and there was a lot of press about this. And if you looked at the numbers, something did look a little bit odd. So, starting in about 1984, going up maybe through 1986, there was a long period of back-and-forth press coverage. The campus didn't really address the issue with a full-blown investigation. I think they were just trying to address the problem by communicating, but I think it would be safe to say they didn't do a full-blown investigation on the campus. This was also going on at other campuses, as well. Our local advocacy group was called the Asian-American Admissions Taskforce. This continued and finally it got to the point where, in late 1987, the senate and the chancellor agreed to appoint a taskforce, which I served on. The committee included Chang-Lin Tien and Herma Kay from the law school, and several other prominent faculty members.

04-01:06:52
Burnett: Was Ling-chi Wang on the—

04-01:06:55
Gray: Ling-chi Wang was not on the committee. He was the chairman of the advocacy group, the Asian American Admissions Task Force. He was a faculty member here. The committee began to do its work. The basic charge was what's really going on here? What's the data show? We worked for three or four months and we're into early '87. The chairman of the committee for some reason decided he would give an advance copy, draft of the committee report to — I think he gave it to one of the vice chancellors on the campus. I'm not sure. He gave it to somebody. And this became known. He didn't talk to the committee about this. And this caused a furor. Chang-Lin resigned in very public and dramatic fashion from the committee and then several other committee members resigned. The committee fell apart. And it was just a mistake, an ill-advised thing that the chair did.

04-01:07:58
Burnett: What was your attitude? Did you think it did compromise the investigation?

04-01:08:04
Gray: It didn't compromise the investigation. None of us even knew about it until we got this email that Chang-Lin Tien had resigned. It may have compromised the credibility of the investigation. I think it probably would have done that. At the time I thought this reaction was overly dramatic. Thirty years later, having a little bit more understanding of the importance of public perception and public confidence in these kinds of things, I think I might have a different view of that. I think it was good that we went back and started over with a new chair. We didn't do anything for a couple of months and then the chancellor and the senate appointed a whole new committee. Some of us carried over and a bunch of new members came in and the new committee was chaired by a fellow named Bill Shack, who was dean of the grad division, a very, very capable, solid person. Anyway, we worked along. All of this was happening while there was a lot of publicity — this was in the newspaper all the time.

04-01:08:33
Burnett: Right at that time Ling-chi Wang was writing articles in the *New York Times* stating that this was similar to Jewish racial quotas at Ivies.

04-01:09:34
Gray: Yeah. It was not pretty. Getting back to the committees work, sometimes you do something that you look back on and you think, "Wow, that was pretty good," more by accident than anything else. Somehow one of us came up with the idea of getting at the problem in a different way. Remember, for most of those years the admission was being done in tier one and tier two. Tier one was pure test scores and grades. Tier two had the supplemental criteria. The suspicion was that something in the supplemental criteria was being adjusted to the disadvantage of Asian American applicants in some years. We went back and took the applicant pool and we redid the whole admissions process from 1981 to 1987 using only objective criteria, tier one criteria. In other words, we redid the whole thing using only tier one, pure grades and test scores, and then said, "How would the outcome have been different?" One of my grad students, Steve Lewis and I, did this work.

04-01:11:08
Burnett: Very scientific.

04-01:11:11
Gray: We stumbled by accident on to it. So, it turned out that in all the years except for two, there wasn't any difference at all. Almost the same result in terms of numbers of Asian Americans versus number of Caucasian students. There were two years, 1984 and 1987, where there was a clear significant difference and when we went back, turns out they'd made some subtle changes. One year they changed the floor on the SAT verbal.

04-01:11:50
Gray: One year there was another change. And these, at least to the best we could determine, were not made to exclude Asian-American students. They were made for other seemingly reasonable reasons. But they had the effect of disadvantaging the Asian American pool. That report came out six months later or so, and all the same political squabbling was still going on. Nothing much changed publicly. But in private, with the Asian-American Taskforce and all the other people who were involved in this, they looked at that data I think developed a bit more confidence that they knew what was going on.

04-01:12:31
Gray: And so Mike Heyman apologized in front of a legislative committee in the legislature in Sacramento for these years where these things were done which inadvertently affected, in a bad way, the Asian-American student admission rate. He apologized for the way the whole thing had been handled, and indeed it could have been handled better. Those practices were stopped that were resulting in the relative disadvantage of Asian-American applicants. And that piece of the admissions process faded away after that. I think that was early

'89 when he apologized. I learned an incredible amount about how admissions worked.

But I think what's relevant about this is that it was just the beginning of the admissions controversy at UC. Maybe in parallel with, or perhaps even triggered a little bit by that — I can't remember when Pete Wilson was elected. For whatever reason, the conservative forces in the state who were worried about these things began to look at affirmative action in UC with a lot of energy. Then if you go on forward for another five or six years, you get into the era, which we'll talk about, of SP-1 and SP-2 and Prop 209, which, of course, the practices in the 1980s would have been totally illegal under 209. You can't admit any minority group preferentially the way we were doing. I don't know whether that was sort of enabled or triggered or enhanced by the Asian American admissions controversy, but it certainly was the start of a long controversy. —Admissions became a big part of what every campus administrator was worried about from that point forward.

I should mention one other relevant thing in the history of that. The discussion about affirmative action in general was starting to pick up by the time this finished in 1989.

04-01:15:11
Gray: There was a follow-on study, a group led by Jerry Karabel, who was a well-known sociology faculty member, to look at that issue and the result of that was the so-called Karabel report, which I think was '92 or so. And that did away with this practice of admitting all historically underrepresented minorities who were UC eligible and implemented instead a process of more comprehensive review of those applicants and something that looks a lot more like the comprehensive review that ultimately ended up being implemented following SP-1, SP-2, and [Proposition] 209. So the campus was kind of out ahead of this in trying to adapt what it was doing to the realities of what ultimately became Prop 209. I think that you can look at that as some good thinking and the senate really did a good job of foreseeing some of those issues and trying to deal with those issues.

04-01:16:42
Burnett: It was a baptism for you, for sure.

04-01:16:44
Gray: Yes.

04-01:16:45
Burnett: And an encounter with the effort to balance diversity efforts with access in terms of formal merit. And those issues come out. People were arguing, "Oh, the Asians are overrepresented compared to their high school leaving population." And so this question of balancing those interests just grows and continues to this day. And it was a national conversation, as well, as you

mentioned. It was very good for you as an administrator to have that encounter. So that's in 1988. And how long did it last really?

04-01:17:32
Gray: I've got it right over there. I think the report is early '89 and my recollection is it kind of wrapped up in the spring of '89, along in the 1989 year sometime.

04-01:17:48
Burnett: And we can talk about this later, as well. There are persistent questions around diversity in engineering or in the STEM fields generally, trying to get the numbers up in terms of gender, and sometimes it is diverse in terms of the Asian population. South Asians and Asians are well represented in engineering but there's a struggle and that's something that you've had to deal with, or you as in the college, has had to deal with.

04-01:18:24
Gray: Yeah, absolutely. We'll talk some more about that.

04-01:18:27
Burnett: So we're getting into the 1990s, into the Peltason years, and those are tough years. Nationally there's a recession that is fairly brief but has quite a bite in that it hits white-collar employees for the first time since World War II. We were used to recessions but if you were in a professional domain, if you were in a white-collar domain, you were usually pretty safe. And this was the first time where it hit— middle-management folks were tossed out. And I'm wondering if you can talk a little bit about that larger context as it impacts the department and your new role in the department.

04-01:19:22
Gray: Yes. That's a great way to approach it. I should say, Dave Hodges, who was chairman of this department up till 1990 and he then was asked to be dean of engineering in June of 1990. Karl Pister was dean before that. Somewhere along the line, one of them asked me, after going through the process, to be chairman of this department. I cannot remember the process. I don’t remember that conversation of being asked. I don't remember if I considered saying no.

04-01:20:14
Burnett: Wow. That's interesting.

04-01:20:14
Gray: Kind of a puzzle to me why I don't remember that, but I don't. And anyway, I agreed to do it and so I started that job in July of 1990.

04-01:20:26
Burnett: Well, you're close to Dave Hodges.

04-01:20:28
Gray: Yes, we worked together, my closest working partner all these years.

04-01:20:33
Burnett: And so, he was head of the engineering department, EECs, so perhaps just by dint of being kind of in the loop in that sense you had some familiarity with it?

04-01:20:46
Gray: I don't know how that all came to pass. This campus uses department chairs, not heads. There's a difference. The department chair is a person who, importantly, has the support of the faculty and the department itself. In fact, there's a poll. It's not a vote but it's an advisory poll, as a part of the selection process. This is opposed to the department head model used at a number of other universities, where the department head is often appointed from outside, is viewed as an administrative extension of the dean and is a more viewed as an administrator as opposed to a partner and representative of the faculty. It's a subtle difference but it's significant. It’s the right model for Berkeley, but in some ways makes the job almost harder. I've often said over the years that the department chair is the most important single job on this campus because, first of all, you have one foot in both camps. The faculty has to support you if you're going to get appointed but at the same time you have to have the support of the dean and the campus administration. But you're the person that guides the process that selects and hires the new faculty, the most important single thing you do in one of these places. You're the person that may have to sit there and tell some poor, young assistant professor they're not going to get tenure, not an easy thing. You have to deal with the staff, support them, make them effective, feel appreciated, deal with the problems there. You have to make the budget balance. You have to deal with the faculty that complain about almost everything at one point or another. You're really on the front lines. I really do believe it's the most important job, in some ways the hardest. By far the most overriding issue of those three years was the budgetary situation.

California's tax system, which has this huge reliance on income tax, really works to the detriment of UC. There was the 1990 recession we're talking about. It was bad, but it was made much worse by the collapse of the aerospace industry in California. The Cold War had just ended; defense expenditures are dropping. Not only did you have this recession, but the state's revenues dropped like a rock. But the same thing happened after the dot.com bust in 2000. The same thing happened in 2008. If you take the national recessions as measured by GDP fluctuation and then you superimpose on that a picture of California's tax revenues as a state, they're dramatically accentuated. Dramatically accentuated. And this really affects us a lot.

In the 1990 recession, between 1990 and 1994, we had the voluntary early retirement program [VERIP]. The campus went from about 1580 incumbent FTE ladder rank faculty members to about 1300. That's about a 20 percent drop. This department’s faculty shrunk correspondingly. We had about ninety- and we ended up with about seventy. We went down about twenty. If you ask any random faculty member at a university today, if you cut your faculty headcount by 20 percent in a short time like that, what would that do? They'd say, "Oh, well, it would be devastating. Devastating." To me it's an incredible indicator of the resilience and power of this institution that we went through that and none of the indicators changed significantly at all. National rankings didn't change significantly. We survived that. Now, it was a huge help that we had this retirement system that enabled us to make those reductions. A subset of those twenty-some odd faculty in this department that retired came back on recall as professors in the graduate school. They didn't teach a full load, but they taught some. They maybe didn't keep all their graduate students, but they kept some, so it helped. But still, having lived through it as a department chair, it was really a wrenching experience because all the teaching loads had to be adjusted, the grad student allocations, and so on and so forth. It was really the dominant issue of the time. Over the course of those three years there were all the other issues. We did a fair amount of recruiting because even though we had a lot of retirements, those were senior faculty with high salaries and part of the formula of adjusting the budget was you could replace those with new junior people who made half as much. So, we did do some recruiting. I don't remember how many we hired in those three years, but we did some. The process of convincing a person to come here when they're looking at what was going on here with reducing the headcount, it's a hard sell. Jeff Bokor who's the current department associate chairman downstairs, was recruited during that period. It's interesting to talk to him about his perceptions of that. There was a lot of doom and gloom. A lot of people were very, very worried about the impact of all of that.

Chang-Lin Tien deserves tremendous credit for leadership during that period. He really was a cheerleader and an advocate and just a tireless leader of the campus during that time. The voluntary early retirement program had three phases in between '90 and '94. They were incentives where if you retired you could add a certain number of years of service to calculate your retirement benefit. The retirement benefit, as I recall, involved how old you were, and your years of service and you could add an increment on those numbers. And the first two phases went through and operated as they were designed. And then the third phase had an even more aggressive—they hadn't gotten enough retirement. This was UC-wide. And, by the way, this was faculty and staff. We lost a lot of senior staff, too. In the third phase the formula was even more aggressive.

04-01:28:34
Gray: Chang-Lin looked at this third round, did the math and looked at some of the senior faculty that were going to be affected by this and just decided that this was—

04-01:28:54
Burnett: A bridge too far.

04-01:28:55
Gray: We were going to be hurt too badly by this. So, he went to the wall. You've read his oral history. He basically told them he was going to resign unless they made some special change for the campus. And it went to the point where he thought he had resigned and then some regents heard about it and the regents put the pressure on the president and the president came back and said, "Well, okay." They ultimately made an adjustment. He deserves a lot of credit for that. But that's a little bit of a nuance. The bigger picture is it was an incredible hit to the Berkeley campus in terms of the number of faculty. We have never gotten back to that size faculty. I think today we're in the 1500 range, up somewhere in that, approximately. We got down to that low ebb, then we gradually grew back over the next ten years. Another important indicator is the student-faculty ratio. That's a parameter that a lot of people look at to compare institutions. The elite privates have student faculty ratios in the single digits. Our student-faculty ratio after that jumped. We'll fill in the exact numbers. I'll make up some numbers. I think before that the student-faculty ratio was probably in the vicinity of fourteen and after VERIP it was probably up around eighteen, something like that.

04-01:30:45
Burnett: Yeah. I think seventeen comes to mind but I may be pulling that—

04-01:30:47
Gray: But today, by the way, I think it's about twenty-four because we've grown so much. We've grown the number of students here by a very significant factor.

04-01:30:58
Burnett: But maintained the excellence. I think that's the key thing. And the VERIP design was great in that you could retain the human capital. Because people wanted to be involved because of what was happening here.

04-01:31:12
Gray: I often wonder. We have some budget challenges on the campus currently and they're being addressed and that'll all work out. I did have some conversations with some of the leaders about whether we could do another VERIP. We can't do that anymore because the retirement system is not as healthy as it was back in those days.

04-01:31:37
Burnett: That's the other piece of it, isn't it?

04-01:31:38
Gray: The leaders I spoke with thought that those responsible for operating the retirement system today would never agree to something like that because of the impact on the funding level of the retirement system. I'm not sure that option exists for us today.

04-01:31:55
Burnett: Well, there are consequences to that because there is a generation of professors here.

04-01:32:04
Gray: Yes. So if I look at the people who actually took that early retirement, they're some of the ones I've already talk about. Don Pederson retired.

04-01:32:12
Burnett: Don Pederson.

04-01:32:13
Gray: John Whinnery retired. Ernie Kuh retired. People who built the department. But, as you said, they didn't just go and play golf; they stayed here. They contributed after that time. It really was the best of both worlds. It worked out fine. I think it shows the resilience of the place.

The department, as I mentioned several times, consists of the EE part and the computer science part that was established in the sixties as computer science was brought over. Not only at this campus but nationally, there is a tension that exists between them. What's the best way to marry those two together? In this department at that time we had a chair and an associate chair. In those years the chair was an EE person and the associate chair was CS. That changed shortly afterwards to be alternate and today it's alternating. But my associate chair was Dave Patterson. We had a great working relationship. Dave's a really straight-ahead, highly capable problem solving guy and we worked really well together. We were trying to complete funding and planning of Soda Hall.

04-01:33:49
Gray: Soda Hall construction started in about '93, along in there somewhere. Dave Hodges, as the dean, was trying to finish the funding of that. Karl Pister had finished most of it but not all of it. So Dave Patterson, Dave Hodges and I, I think we were meeting once a week, going through the donors and going through the process of identifying the rest of the private funding to build that building. But construction was either started or just about to start. But they were great partners.

There was a sea change in teaching going on. In the eighties there was a Carnegie report that Karl Pister chaired that called attention to the fact that teaching and undergraduate education in engineering were neglected terribly, that, writ large, the country was not doing a good job. Karl also chaired an internal UC study on faculty rewards that made the same point. Now I'll go from the national picture down to one department. We had some teaching going on in this department that was not good at all. In that era, as long as the students weren't rioting out in front of the building, mediocre teaching was sort of excused. There were teaching ratings, but nobody paid too much attention to them. Teaching was beginning to be considered in advancement cases, but it still wasn't as heavily weighted as it should be. That all has changed in the intervening twenty-five, thirty years. There's a much stronger focus on teaching quality. The campus teaching award was implemented not long after that. But the way it manifested itself to me was we had a few faculty members who were prominent researchers but terrible teachers. And counseling them and motivating them to improve was a challenge. And I remember those challenges well. It was just very hard to get that problem fixed. Now, those people retired over time. Now I think there are many, many fewer instances where students have a poor learning experience because of a poor teacher. It still happens but there are ways now in the incentive system and in the evaluation system. That gets weighed heavily. I would think it's a fair statement that you cannot get tenure at this institution today with poor teaching. In my era you couldn't really make that statement. It's a good change that's happened over the years.

I'll just finish up by saying, since our time's getting short here, I finished up as chair, I had a great experience. I still think of that as a highlight of my time here. It was really, really fun. Again, paying attention to the staff, trying to make sure they get appreciated, recognized, valued. That's something I got to think of as a more and more important problem as time went on because there's a tendency to not do it in this kind of an organization.

04-01:37:39
Burnett: Was it a generational shift? Last night, for another project, I had a conversation with a gentleman who attended engineering. He didn't finish. He attended engineering in the fifties. So this is way, way before this time. He talked about these “elitist SOBs” who didn't care about teaching at all. Some of them were European and they probably come from a very hierarchical model. "Come, come, gentlemen, you must just move along with this stuff." And there were numerous instances of that. And I wonder if that was part of engineering culture.

04-01:38:22
Gray: Yeah. Oh, I think so. Yeah. I think it was part of the culture. That was the way of the time.

04-01:33:28
Burnett: Yeah. “Man up.” Man up and just get through it.

04-01:38:30
Gray: Yeah. That's right. The teaching part has really changed. The part about honoring and valuing staff has gotten better. I still think it falls short in some ways, but it's gotten better. Let me just mention one last thing, which is after I got done as chair, I served on the budget committee for a year. The campus budget committee, this is another topic we'll get into a lot later, but I do want to mention it since we're going to move on to the years after this. The budget committee, is a senate committee on the Berkeley campus called the Committee on Budget and Interdepartmental Relations. It has nothing to do with the budget and has no role in interdepartmental relations, so I don't know why it's called that. It is an academic personnel committee and it also has a role in allocation of campus faculty positions. It has a long history. It, I think, got formed in an earlier era when shared governance on this campus got

valued much more highly. In effect, in the period of my service the provost used the budget committee as an advisory, but very closely listened to advisory group on the advancement of every single ladder-rank faculty member and some non-ladder rank professorial titles on this campus: appointment, promotion, advancement within rank, every step. The case had to go all the way up through faculty departmental committee, department chair, dean and be looked at by the budget committee, evaluated, and then the provost makes a final decision. It’s almost unbelievable because there are fifteen hundred faculty. They go up for review on average every two-and-a-half years, some two, some three. So that's about five hundred to seven hundred cases a year. There are something like seven or eight budget committee members. So that means each member looks at a hundred cases a year. It's a huge job. In addition to that, they advise the provost on the allocation of new faculty positions every year. The replacement rate of faculty hiring here is about seventy or eighty a year if you take separations and retirements. So there are seventy or eighty reallocations of new faculty positions a year. Every time a retirement happens that position goes back to the central campus. It can be reallocated to a new department if necessary.

04-01:41:23
Burnett: Really?

04-01:41:24
Gray: Yes. Now, that doesn't happen very often because—

04-01:41:27
Burnett: Okay. Faculty lines are typically—

04-01:41:30
Gray: Faculty lines. The expectation of a dean or a chair is that they're going to come back. But you shouldn't always do that. Some disciplines need to shrink, some disciplines need to grow, so it's an important committee. It's the most trusted committee on the Berkeley campus in my opinion. And if you're a provost it's important. When you describe this role to people from other universities, they think you're crazy. They can't imagine how this could ever work. Well, I should say the committee also makes recommendations on salary levels. There's a formulaic step-based system but the formulaic step-based system was by then becoming obsolete. Now it's totally obsolete. Most of the appointments are not on that anymore. So, there's a salary and a step recommendation that happens. And most people from other universities can't imagine how that could ever work. Now, it's been softened a little bit in recent years. For example, I don't think the BC [budget committee] looks at every step; I think they still only look at major steps. I like the system. I think it's a strength here. What sometimes tends to happen in universities like this is you get a lot of excellence, but you can get pockets where you get a deterioration, sort of a self-perpetuation of not very high standards. And this helps that because you have a central, in-depth review of the quality of the appointments, advancements, and promotions. That helps. If you're a provost, one way you

could look at this is it's something being imposed upon you by an academic senate — something you don't want. And there is some of that feeling sometimes. But I always thought that if we're going to have a central review of every case and I've got to do five hundred cases a year, how would I do that? I'd probably go out and find a committee of six or eight of the very best people I could find representing the campus at large and I'd sit them down in a room and ask them to do this. I would do the same exact thing. I wouldn't call it a budget committee. I might call it something else. But I'd do pretty much the same thing. The budget committee gets overruled for various reasons, but not very often. So I got to serve on that and it was immensely helpful to me later on, because just understanding how the committee works and what it does and how it adds value. I worked with some great people during that. And so that experience — again, it's the educational process. I really, really learned a lot there.

04-01:44:21
Burnett: Is it known as kind of the farm team for the upper administration?

04-01:44:28
Gray: No, no, perhaps more the opposite. When you become a dean or a vice chancellor or a provost on this campus, you've kind of gone over to the dark side. You're never to be trusted again. I'm exaggerating a bit of course. If you look at the number of budget committee members who have become deans and vice-chancellors versa, it's not a very big number. There are some but not many. Ernie Kuh was one. John Dwyer was one. I was one. It's hard to find a lot of other examples. There are some. Several former BC members over the years have gone on to serve as Vice Provost for academic affairs.

04-01:45:06
Burnett: Engineers.

04-01:45:07
Gray: It's more intended to be a representation of the faculty itself and their culture and values and doesn't necessarily mean you're going to be an administrator or that you have been.

04-01:45:20
Burnett: I asked Joe Cerny about the representation of engineers in administration and he said, "Well, there's this historian here, there's this psychol—they were all top people." He was very generous in distributing that [credit]. But I think about engineering as a set of interests, and it's about systems. Engineers are interested in systems. Across the types of engineering, it seems to be the case. And maybe that's just too general. Everyone's interested in systems. But I think there's a particular acumen, a particular interest and enthusiasm for systems and the optimization of systems and so much of that kind of thinking has gotten into administration that it seems to be a kind of natural fit. What do you think about that?

04-01:46:10
Gray: As you know, I did a commencement address for a college of engineering recently and in doing the research for that I discovered some interesting data. Of the sixty AAU presidents, the most elite sixty research institutions, sixteen of them, or more than 25% have a degree in either engineering or computer science. Now, remember, only 5.5 percent of the Bachelor of Science degrees in the United States every year are engineering degrees. So that's an incredibly high number relative to the population that they're drawing from. Similar pattern happens in the CEOs of the S&P 500 companies, the corporate world. I think it's just problem solving — engineers tend to be more pragmatic problem solvers and that's an important skill. But there are a lot of other important skills, too. I don't mean to say that's the only important skill. But I think that's part of it. And the systems view, I think you're right about that. I think taking a system view of problems is an important element. I was quite surprised at that number.

04-01:47:40
Burnett: Well, Dr. Kuh called the budget committee the single most important committee on campus. It was such an important role in maintaining and enhancing the quality of the campus.

04-01:47:55
Gray: Well, Ernie Kuh holds one record that I don't think anyone else holds. You asked if it's a proving ground for deans and administrators. Ernie Kuh was a department chair and then dean of engineering here on the campus. And then after that was asked to serve as a member of the budget committee, which he did for three years, and I think he was chair for one year. I think that's right. No one else in history has ever done that, in the history that I know about. It's rare that someone who's served in a high administrative capacity like that sustains the trust of the faculty to the degree Ernie Kuh did, to be asked to go back and serve in that budget committee capacity and represent the whole campus. On the budget committee you're representing the whole campus, not just one college or school. And it's a tribute to Ernie and the esteem that he was held in that the academic senate asked him to do that. I don't think there's any other instance of that happening.

04-01:49:04
Burnett: Well, next time we're going to jump into the boom years of the dot.com revolution and we'll take that up in session five.

04-01:49:12
Gray: Okay, great. Thank you, Paul.

04-01:49:13
Burnett: Thank you.

[End of Interview]

Interview 5: March 7, 2018

05-00:00:18

Burnett: This is Paul Burnett interviewing Paul R. Gray for the University History series. It's March 7, 2018, and this is our fifth session. We're here at UC Berkeley, in Cory Hall. Last time, we were talking about your period at the budget committee. This is a time of change at the University of California. You lose about 25 percent of your faculty in the three VERIPs at the beginning of the nineties, and there's a period of austerity, and entering a period of rebuilding and reconstruction. Can you talk a little bit about what you learned in your exposure to the larger campus about changes and how things were being done, a greater interest in gathering quantitative data about how the university is run, that kind of thing? What's changing on the horizon as you encounter it on the budget committee?

05-00:01:32

Gray: Sure. Thank you, Paul. Happy to do that. Good to be doing this again. Let me just share a few thoughts on the budget committee that occurred to me since we talked last time. As I think I mentioned last time, the increasing emphasis on teaching was really becoming apparent. On the budget committee, we were paying a lot more attention to quality of teaching, metrics on that. There was a lot of debate about the appropriateness of things like student ratings of teaching, with some feeling those were critically important and really useful, others feeling they sometimes aren't. A lot of discussion about that. But the most important point about it is that teaching was becoming weighed more and more heavily as time went on, and I really saw that on the budget committee. I think that was an important change from the sixties and seventies, and transitioning to a time when quality of teaching, both graduate and undergraduate, is much more highly valued.

Another couple of other recollections I'd just throw in. I didn't mention this last time, but a tricky thing that I was glad to have understood after having served on the committee was the balance of authority between recommendations the committee made about all sorts of things — appointments, promotions, faculty FTE [full-time equivalent] allocations — and the decisions of the provost about things like that. The methodology that was in place when I was on the committee for that year, and which I continued later on for six years as provost, was that the committee made its recommendations, and the provost took those under advisement. Ninety percent of the time, that was the decision. But when it wasn't, the provost would go and sit down, sometimes with the chancellor if it was a major issue, with the committee and explain the decision, and why the decision was different from what the committee had recommended. That's pretty powerful. Obviously, the chancellor and provost can disagree with the committee's recommendation, and did, occasionally. I would guess that might have happened a couple times a year, on a case, on an appointment, or on an advancement. More often than not, it was on faculty position allocations. That may not sound like much, but when you have committed that if you're going to not follow their recommendation, you go down there and spend an hour sitting there, having a discussion about it, that's a pretty powerful prerogative of the budget committee to have an opportunity to have that debate. So it had the effect of giving the committee a lot of authority, and their recommendations were really listened to strongly.

The other thing I remember most about that is just the colleagues. It was people who were committing a great deal of time and effort to this, committed to the Berkeley campus, trying to do the right thing. They were people representing different parts of campus. I happened to be the engineering representative, but there was much more of a sense of doing what's right for the campus than doing what might serve your particular organization. It was a really terrific experience. When it became clear I was going to become dean of engineering — I think that must have been about April of that year — I did move off the committee, and Bill Oldham replaced—

05-00:05:31,
Burnett: Of '96?

05-00:05:32
Gray: Ninety-six. Bill Oldham, the same Bill Oldham who I stood in for as ERL director, Bill came in and served out the rest of that year for me on the budget committee.

05-00:05:52
Burnett: It sounds like there's a spirit, as siloed as things can be, that there is a spirit, perhaps a newer spirit, of transparency and accountability. Joe Cerny is going around to the various departments and interviewing them and really getting a sense of what their needs are. And at the same time, in terms of his position, getting a stronger sense of what happens to people when they leave Berkeley. Getting that sense of, is the teaching effective, how do we know it's effective, what are the metrics? That's happening at other universities, other top universities, as well. So really, at the same time that there is clear and relatively transparent conversation between, say, the provost office and the budget committee, there is also a sense that we need to get more and better information about how we're doing. That seems to be a part of the story.

There's also changes happening at the higher levels. Chang-Lin Tien is done the next year, in 1997, and Richard Atkinson was in as president of the UCOP [University of California Office of the President] in 1995. So there's that, that we'll keep in mind as we're going forward to chronicle your return to the engineering college. Can you talk a little bit about that shift, and why it happened and what you were doing there?

05-00:07:36
Gray: Let me do that. Let me just throw in one other thing about the budget committee that might be worth mentioning. One of the most important

functions of that committee was a leveling effect. That is, cases for faculty members who were going to be appointed in art practice, public health, engineering, rhetoric, all were being looked at by the same committee. The way the committee worked was that this large number of cases would come in for, let's say, advancement. In each one of those cases, the committee member — in my case, I did the engineering cases — would read the case, then present it to the whole committee. So we'd have these four-hour-long meetings once a week, where — I think it was actually, during the heavy parts of the year, twice a week — where each committee member would take two or three minutes to summarize the pros and cons of each case, and there would be a discussion. The effect of that was that you really did start thinking about how you compare someone who's working in art practice to someone who's working in engineering. It does go back to metrics, to how you actually compare the quality of a case for advancement of two people in such incredibly disparate disciplines. That, I think, was really healthy. It makes you think back to what your fundamental values are, and really makes you think hard about how you measure performance and impact in these different areas. That was extremely valuable, and I think was very healthy for the campus.

05-00:09:25
Burnett: Can I ask a question about that? Disciplines, as they become professional entities, are very jealous of their own prerogative to define who and what they are and how they do things, at least historically. What do you do when a discipline says, "we are the arbiters of excellence in our field?" How can an engineer tell the art practitioners how to do their jobs?

05-00:10:08
Gray: Your question about metrics is an interesting one, because your first inclination, when you start looking at these academic personnel cases, is to look at a metric like number of publications. But you realize pretty quickly that that metric isn't really very useful, because there are lots of ways to get lots of publications. What's important is the impact of those in the domain you're working in. By far the most important indicator on any of these cases was the external reference letters from the leaders in that field. The reason is just exactly that. The other metrics, they're just not indicative and consistent enough across disciplines.

So, to answer your question, in the end — let's put aside the intermediate steps for a minute, but at the major steps, like getting tenure or going from associate professor to full or something like that — for those major advancements, it's mostly determined by whether there are letters in the case from the three or four or five leaders internationally in that field, saying that this individual has made impact — not necessarily written large numbers of papers, but there are one or two or three papers in that period of time that have really changed the field and really had an impact. That's really the most critical thing. It still leaves the field's essentially self-defining quality. That's true. But you have to take it on faith that if you're looking nationally and internationally, the leaders in the field are going to be able to tell you if this person is at least a leader in that field. That's the most important thing. The quantitative metrics, like numbers of papers, amount of money raised, things like that, they're harder to use, and really those letters are the key thing in most of these cases.

05-00:12:18
Burnett: Right. I guess it's a little bit later that we get into the dominance of impact factor in, say, the social sciences or the sciences.

05-00:12:28
Gray: Right, right. Getting back to the engineering side of things, you may recall Dave Hodges had been chairman of electrical engineering in — let's see. He was dean of engineering from 1990, and decided to step down in 1996. I'm walking in his footsteps, I guess. I succeeded him as chair of EECS [Electrical Engineering and Computer Sciences]. Then when he stepped down as engineering dean, they looked around and did a search for a new dean of engineering. I didn't see myself as a candidate for that at the time. I just didn't think I was particularly on a track to become an academic administrator. I had a lot of interesting research going on, and I didn't necessarily think I would be the best person for that. But anyway, I did talk to the search committee, and they, for some reason, decided they wanted me to do it, and they asked me to do it. So I agreed to.

It's worth saying a little bit about my family, because it had an influence there. My older son, Matthew, at that time, was in Georgetown Law School, and went on to graduate. He's now a partner in a law firm in San Francisco. My younger son was at Oregon State, and went on to graduate, and now he lives in Boise, Idaho and has an engineering consulting company. We were empty-nesters, so to speak. They were off in college and on their way in their successful careers, and now they've become wonderful people and have great life partners. [They were wonderful kids earlier too!] We'll talk more about that later. So Judy and I were empty-nesters. Judy had taken up floral arranging and was working almost full-time as a floral arranger in Orinda. She is a very creative person, and got a lot of satisfaction out of that. But we had some time. I could imagine taking on something more complicated. By sheer chance, we also had moved, just that year, '95, into an old Spanish house in Orinda that we fell in love with, which was a huge maintenance challenge, but it was big and was good for entertaining, which we ended up doing quite a bit of.

It's hard to recreate the thought process, but for whatever reason, I said, okay. I became convinced I could pay something back to the campus by doing this job, so I agreed to do it. I started over there in the dean's office in July of that year, 1996. If you'd like, I can talk a little bit about that situation that I went into.

05-00:15:17
Burnett: Yes, and I think it’s worth reminding listeners about the scope. The College of Engineering is big.

05-00:15:25
Gray: The college is — well, at that time — about 220 faculty, something on the order of 4,500 students. It’s about 15 percent of the Berkeley campus on those measures. Another important measure, as we’ll talk about more later on, is fundraising. A college raises something like 20 or 25 percent of the total amount of money raised on the campus from private sources, philanthropy, and things like that. It’s an important school for the campus because of the connection to Silicon Valley and the Bay Area innovation ecosystem. I can say this now, having seen it from the standpoint of the campus-wide roles, that it is an important college for the campus. I don’t think I had much of an appreciation for that in 1996, but I developed it over time.

Anyway, I started that July. I learned in the subsequent years why that initial team of people that you either start to work with or recruit and put in place in those first few months in a job like that is so critically important. When I arrived there, Dave had established a really strong team. He had a fellow named Dave Brown, who was the college — I think we called him the executive officer, but he was the chief administrative person in the college. When he retired shortly after I came he was succeeded by Marcia Steinfeld, another very strong administrator. Melissa Nidever, who had just started as the chief development officer of the College of Engineering, and is still there. Twenty-three years later, still has that job. Karen Earles was the financial person. Diana Barclay, the academic personnel person, and Marilyn Witbeck, who was my administrative assistant. They were great people. Where I really lucked out was with Bill Webster. Bill Webster was a naval architecture faculty member, distinguished member of the faculty, and he was serving as associate dean, at that time for student affairs. He went on and did a lot of other things, but at that time, he was there. Alice Agogino, who was a professor of mechanical engineering, ran the outreach and diversity office, which we put a lot of effort into. I was able to get Jim Casey, who was a professor of mechanical engineering, and who later was instrumental in getting [the department of] bioengineering established. Jim came in to run the interdisciplinary programs that the college was involved in. That was a really solid team of people.

So as I got started there, now, in retrospect, it’s pretty clear what the big challenges were. The biggest issue was bioengineering and what to do about that, and I’ll talk about that quite a bit. Naval architecture, a small department in the college at the time, was an issue. We were trying to finish the Hearst Memorial Mining Building Project. There were a lot of other things. But let me talk about those three things.

05-00:18:46
Burnett: Just to be clear, you inherited a great staff, and you had full confidence in them, and you knew Dave Hodges and you could talk to him, say, so, is there anything that needs to be done? Did you have that conversation with him?

05-00:19:06
Gray: Yes, I did. The fellow who was running IDS, Ted Lewis, was stepping down, and I needed somebody for that. Jim Casey was able to come in and do that. I think everybody else continued. There were some changes later on. Dave Auslander came on later on and ran student affairs. At that outset time, I think pretty much the team was there. Jim Casey was the only one that I had to bring in.

05-00:19:40
Burnett: And Tom Budinger is—

05-00:19:41
Gray: Well, I'm going to get to Tom.

05-00:19:42
Burnett: Is that chair of EECS?

05-00:19:45
Gray: No. I should mention that. When I moved to the dean's office, Randy Katz, who's now the vice chancellor for research on the Berkeley campus, came in as chair of EECS. He did a wonderful job on that. That was terrific. Let me talk about Tom Budinger. David laid the groundwork on a lot of these things, but by far the biggest challenge was bioengineering, so let me back up and talk about bioengineering a little bit. For the last fifty years or more, engineering has been connected most closely to the physical sciences and mathematics, in many cases doing the translational innovation resulting from fundamental discovery in physics and the mathematical sciences, and also in computational sciences more recently. Most of the science background the undergraduates were getting was been in those disciplines, as opposed to, for example, biological sciences. What was becoming apparent in the 1990s was that the explosion of fundamental discovery in the biological sciences was going to transform everything: health care, agriculture, virtually every discipline.

05-00:21:29
Burnett: It already was.

05-00:21:30
Gray: It was already happening. The whole genetic revolution, molecular and cell biology. Engineering needed to be a part of that. Engineering had an important role to play in the translational role from those discoveries, in an analogous way to the role it played in the translation of the physical sciences innovations that had been happening earlier and of course continues to happen. That had led to several universities across the country launching bioengineering departments. Georgia Tech had one. Johns Hopkins had one, as well as UC

San Diego. Those are maybe the three prominent early ones. Here at Berkeley, we'd had the biology organization, molecular and cell biology, which was really driven by this biological science revolution. At Berkeley, we had had for some time an existing joint bio engineering graduate group with UCSF [University of California San Francisco]. That's a group that offers graduate degrees in a discipline that crosses interdisciplinary boundaries, in this case, campus boundaries. They had UCSF involvement in that as well. That had been going on for some years. Tom Budinger was a key player in that, as was Jim Casey. But it was clear we needed to do something more to capture this opportunity. Tom Budinger is really a fascinating person. Tom is an MD PhD and is a distinguished medical imaging person.

05-00:23:18
Burnett: MRI work, right?

05-00:23:19
Gray: MRI. He has appointments at UCSF, UCB, and Lawrence Berkeley Lab. He's really a Renaissance man in the fields he's worked in. But Tom was a tremendous advocate that we needed to do something more aggressive, and he really thought a department was the right way to go. The issue on the table was, should we do a joint department of bioengineering with UCSF? Dave Hodges had laid some groundwork and I launched a strategic planning committee in the fall of '96. Jim Casey was the chair of it. It had representation from across the campus and UCSF and was to take a year and make a recommendation on what to do. There was another piece of this that needs to be mentioned, and that's the Whitaker Foundation. Uncas Whitaker was a mechanical engineer who founded AMP, the electronic components company. He believed fervently in the importance of engineering getting involved in biomedical science. He created the Whitaker Foundation, the principal aim of which was to launch biomedical engineering academic departments in the United States. That was their reason for being. The foundation was to spend down its asset and cease to exist. It actually, I think, went from '75 to 1990, if I remember right.

05-00:25:01
Burnett: I think a bit later.

05-00:25:02
Gray: Maybe later.

05-00:25:02
Burnett: In the 1990s, they gave away $700 million to get thirteen bioengineering facilities at campuses.

05-00:25:13
Gray: They essentially gave away all their assets. We were one of them. This was a huge motivator. When you have something like that out there, it really motivates people to move in the direction that they're pushing. So the Whitaker was a big part of our thinking. We established contact with them

early on. Tom had a good contact with their board. The strategic planning committee came back with its report. There was a lot of debate about whether starting a department was the right thing to do. This was a cross-disciplinary area. There are a lot of areas like that. Data science might be a good example today. Starting a department was not the only option; there are lots of ways to address that. Build an ORU. Build an institute. Do something like ERG, like the Energy and Resources Group. There are lots of ways to address research in cross-cutting disciplines that span across boundaries. The thing that made this different was, number one: we needed a curriculum, so it needed to be in an academic unit, at least partially. But more importantly, it was really, really important, and we already had a graduate group. I think most of us who were involved felt more was needed than just another institute or ORU. Another factor was that the Whitakers wanted to see departments. All this kind of played together. So it became apparent fairly quickly that forming a department was an important objective.

I got to know, during this process, a number of people at UCSF. Carol Christ. by the way, was a huge supporter of this idea. Very, very important, because she was willing to commit some—not explicitly commit, but offer the opportunity for us to ask for faculty positions to support this overtime, which we did, and which did materialize. The period from 1995 to 2000 were the boom years for UC. We were growing. There were going to be new faculty positions that allowed for things like a new department. So anyway, Carol and I went, at least once, maybe twice, over to UCSF to talk about this joint department. We met with Holly Smith, who played a key leadership role there on special projects. We met with Haile Debas, the dean of the medical school. Mike Bishop got involved in that later on, when he became chancellor [at UCSF]. The UCSF people really wanted this, because they do a lot of translational work, and they saw a connection to engineering as really adding value for them. Cliff Attkisson, who was another one of their vice chancellors, was very supportive of this.

Another set of people that we engaged was the bioscience people here on the Berkeley campus. Dan Koshland, who's—

05-00:28:20
Burnett: Interview we've done.

05-00:28:21
Gray: Oh, you interviewed Dan? Okay.

05-00:28:23
Burnett: I didn't personally, but.

05-00:28:26
Gray: I got to know Dan and Bob Tjian. Occasionally you do a few things right. One of the first things I did was go over and see both of them and talk to them about this, and they both became supporters of this. Dan, of course, is a totally

unique individual nationally, but especially on this campus. He was a very distinguished biochemist, a member of the National Academy of Sciences, a leader on the faculty and in his field, but in addition, he was a member of the Haas family and an extraordinarily wealthy person in his own right. That made him a force on this campus, and he was a key driver for the biology reorganization some years earlier. But Dan was an incredibly thoughtful, nice person, but who could be forceful when he needed to be. I hit it off really well with Dan, and got along really well with him, and he was very supportive. Bob Tjian, another very distinguished biologist, served as chairman, at that time, of something called the chancellor's advisory committee on biology, which was formed during the biosciences reorganization. That group had a lot of influence on faculty hiring in the biosciences. Having those two people support this was essential, to do something like form a new department, because the biosciences already did and still do a lot of translational work. There's not quite the distinct boundary in the biosciences between fundamental discovery and the more applied domain. At that time at least it was more of a continuum in the biosciences, more so than in the physical sciences, at least in my experience. There was a little bit of concern there, but we got through that, and in the end, all those folks supported it, which was essential.

05-00:30:30
Burnett: Can I ask, their apprehension was that on the table was perhaps putting something like bioengineering in integrative biology or molecular and cell biology?

05-00:30:43
Gray: Well, it didn't quite take that form. I think they saw that a lot of their faculty were doing, in effect, what was bioengineering. Look at Jennifer Doudna as a present-day example. She's engineering revolutionary ways for in-vitro gene editing. She's in Stanley Hall. But there are a lot of people who do things that are purpose-driven, that's research that's fundamental discovery, but purpose-driven in the biosciences, and particularly biomedical. They could have seen bioengineering as taking away resources and perhaps faculty positions that might have gone to the biosciences. There were a couple of things that worked there. First, these were times when there was growth. So in times like that, people are less worried about these things. But more importantly, I think they saw that there was an opportunity to bring more resources into the collective Berkeley environment for supporting that kind of work. There was one other extraordinarily fortuitous event that fed into this, which was the QB3 Institute. We'll get, a little bit later, into that. It plays into the bioengineering story, because, at about this time we felt confident that the Whitaker Foundation would support us to the tune of $25 million or so for some sort of a building, or some sort of a home for this department. So we were proceeding on that assumption.

Then, in late 1998, early ’99, the institute idea came up, and Richard Lerner at Scripps got Governor Gray Davis to advance this. It was seemingly preordained, in some sense of that word, that one of these was going to be a joint Berkeley-UCSF translational biosciences-bioengineering institute. The institutes were essentially supported through building gifts. Each one was $100 million to be matched by another $100 million of other funds, all for construction, and in the case of QB3, one building at UCSF, and one building here. That lined up perfectly, because then we could take the Whitaker, use that as matching, along with some other gifts, and put the bioengineering department in this new building, which became Stanley Hall. So that all evolved very nicely and fortuitously.

05-00:33:44
Burnett: Can I interrupt and ask, in the absence of these forces — money for a building, the support for that general direction coming from the life sciences, coming from industry, the writing on the wall, period — can you sell me on the value-add of bioengineering housed in the College of Engineering, with perhaps its associations with electrical engineering and computer science? Can you give me a pitch on why it’s better housed inside the College of Engineering?

05-00:34:34
Gray: There are two parts of that. One would be the educational pathways part, where you would be taking an inflow of students who want to be engineers, and want to be problem-solvers, and want to be on the applied end of the science spectrum, an engineering spectrum, and give them a pathway to make their careers in addressing biological and medical innovation, whatever form that might take. It might be medical, it might be agriculture, it might be any number of things. You’ve got a group of students coming in the pipeline that are really learning to be problem-solvers and innovators, and people who design things. That gets them into the biological domain. I think that’s the biggest argument, that the students who end up in biological sciences may be more interested in basic science and fundamental discovery. That may be why they chose that pathway. So from an educational standpoint, it gets the flow of engineering students having a way to get into the world of biomedical science. I think, from the research end, you can make research collaboration happen many different ways. There’s a lot of collaboration between the UCSF people, the Berkeley bioengineering people. There’s a lot of joint appointments with Berkeley bioengineering and the biological sciences division of L&S [Letters & Science]. That’s a less strong argument, because you could probably have made that happen other ways. I think the strongest argument is the educational pathway at both undergraduate and graduate degrees that are engineering degrees, but focused on biomedical science.

05-00:36:29
Burnett: Wow. I was wondering about computing, too, and if there’s a specific – I don’t want to make a pun on hard wiring – but the dedication to thinking creatively about harnessing processing power in new ways, and the importance, the increasing importance, of modeling in the life sciences.

Would there be special expertise that could be deployed that you wouldn't necessarily find in structural biology or something?

05-00:37:03
Gray: Absolutely. Two of the most visible, early faculty members illustrate that. One was a fellow named Adam Arkin, whose project at that time – he's moved on now, but you'll remember the term "SPICE"? [Simulation Program with Integrated Circuit Emphasis] SPICE is the electronic circuit simulator that Don Pederson's students developed. simulator. Adam's goal was to build bio-SPICE, which is essentially a program that simulates the biological systems in the human body. Brilliant.

05-00:37:31
Burnett: The human-on-a-chip.

05-00:37:32
Gray: Yeah, the human on a chip. Now, that's turned out to be way more challenging for many reasons, but I think that was a wonderful example of the synergy you were talking about, and I think that kind of work has blossomed into many other directions. But the point I'm making is, that's a marriage of exactly what you said: computational knowledge and expertise with biological science. Adam was a great example of that. The other person I'd mention is Luke Lee. Luke Lee is a person who marries biology with integrated electronics. He builds lab-on-a-chip systems, where you have a chip with these little channels that can carry different biological materials. You can, these days, by mounting them in instruments that are either inside or attached to the body, do diagnosis and sensing of chemical makeup and things of that sort. He's an example that marries biological science with microelectronics and integrated technology. Those are the kinds of synergies that this kind of department should bring about: computation, information technology at the physical sense of that work, communications. There are people working on building body communication networks, for example. Anyway, there's a whole array of things like that. Certainly, the research connections with different phases of engineering are very important. That's a benefit that's really paid off for that department.

05-00:39:14
Burnett: That's fascinating. So you have the wheels in motion. The money is there.

05-00:39:22
Gray: Let's leave out the intervening years of blocking and tackling, starting a new department. Let me just mention one thing. The original idea was this department was going to be literally a joint department between UC Berkeley and UCSF, where the faculty members would be appointed to some unique hybrid kind of faculty position that would have one foot on both campuses. That proved to be impractical. Everything about a medical school environment — the way they construct their salary and compensation plans, the way they mix grant funds and state funds to pay salaries — a very high

percentage of UCSF faculty are on soft money, either mostly or totally — and a whole bunch of other things about the way medical schools work. After maybe six months of looking at it, we just concluded it's just not worth it. So what we ended up doing was setting up the two departments. There's a department at Berkeley and a department at UCSF, and the faculty voluntarily work together on recruiting, on graduate students, on faculty meetings, and events. They work together as a team, but it's a voluntary collaboration. It's not baked into the actual organizational — they're not tied together formally in any major way. But that worked out fine. I think we got the benefits of the UCSF connection pretty effectively through that. Then QB3 is a joint UCSF-Berkeley institute, so that strengthened the ties that way.

Having said all that, fast forward to, let's say, 2004. Stanley Hall gets built, a whole floor devoted to bioengineering. At that point in time, they're up to maybe twelve faculty members, something like that. A lot of joint appointments. One of the most popular majors in engineering. Very hard to get into, very popular. They're thriving. There were a lot of challenges, but now, even another ten years later, they're doing really well. Starting a new department is a challenge. The last departmental change prior to that was the biosciences reorganization almost twenty-five years earlier. Prior to that, I think you have to go back to criminology or something, in the sixties. It's very, very rare to actually start a new department on this campus. If you go down the road fifty years and look back, my guess is bioengineering and biologically connected parts of engineering will be really critically important. What's happening in the basic biological sciences is just mind-boggling.

05-00:42:39
Burnett: And it happened fast, because the reorganization in the life sciences at Berkeley begins in seventies, late seventies, effectively, and it's not really fully complete until the mid-nineties. That was a twenty-year thing, whereas this is a few years that this comes to being.

05-00:43:02
Gray: The bioscientists are basically figuring out how life works. If you just think of the implications, things like inheritable genetic modifications, life extension through DNA engineering. It's going to transform so many things about society. Anyway, I'm really gratified that engineering now has a stronger role to play in that.

05-00:43:33
Burnett: One of the things that we should leave for our final session is to reflect on these drivers of innovation, because that's really what is in play. I think there's this effort to move beyond what you described in an earlier session, is this university tradition which is about slow change. It is about silos of disciplines that follow tradition as much as they innovate, to something that is about bottling innovation, baking it into, as you say, into structures. I want to ask later about drivers of innovation, such as space, for example, the physical space in which knowledge is produced, the right combinations of institutional

structures that support scientific research. Does it need to be in one place or can it be shared? And perhaps a tension between the benefits of disciplines that are allowed to evolve discrete techniques, discrete practices, and interdisciplinary approaches that can be pursued almost for their own sake, on the assumption that just making things connected to other things are going to produce the happy accidents that we've seen in history. I want to come back to that and allow you to think about that for our future sessions—

05-00:45:09
Gray: Okay, will do.

05-00:45:10
Burnett: —but I want to also keep us to our project here.

05-00:45:15
Gray: By the way, before we leave that, I thought I'd just mention again the two people that were — Tom Budinger was the founding department chair of bioengineering. I think he was in there for five or six years. If bioengineering on this campus has a father, it's Tom Budinger. Then Dan Koshland, who passed away a few years later, just was such a force on this campus, advancing the biological sciences in so many different ways. He was a huge factor in helping get QB3 building built, along with Graham Fleming, who I should mention, and a number of other people.

Another problem we had in engineering at that time was naval architecture. Around the country at that time, there were two or three distinguished departments of naval architecture. These are people that design ships, and other marine structures, like oil platforms. Bill Webster, who I've mentioned and will mention a number of times again, was one of the country's distinguished naval architects. Our department had very good quality, but not a lot of student interest. Over the years, it had just shrunk and shrunk. It was down to something like six or seven faculty members, and a very small number of undergraduate and graduate students. Dave Hodges had proposed and had started some study committees to look at eliminating that department and folding it into civil engineering, as a program in civil engineering. To make a long story short, I finished that job in the first year I was there. If there was ever a no-brainer, that was one, because you just didn't have critical mass. Even though it was seemingly a straightforward thing to do, it turned out, to be a challenge because there are always a few people who don't want to see a department die. I would say Ron Young, who was the department chairman, was a real statesman in seeing that this needed to happen, and he was very supportive of this over time, as was Bill Webster, who was in that department.

05-00:47:41
Burnett: Can I ask about another shift? Because you mentioned that engineering is about translating the achievements of the physical sciences—

05-00:47:53
Gray: Fundamental discovery.

05-00:47:53
Burnett: Fundamental discoveries in the physical sciences into applications. But there were these very application-specific departments in the university system of the United States, such as schools of mines, for example, engineering devoted to a particular industry. Naval architecture sounds like part of that way of organizing things. It's applied to a specific application, and there's a body of knowledge that is important to keep together in order to support a particular industry. Engineering moves away from that to cluster the knowledge around the fundamental physical processes, or chemical processes.

05-00:48:52
Gray: That's a reasonable synopsis. From the end of World War II up to the present, engineering has gotten to be very much more engaged with science, and particularly the physical sciences and mathematics as a core content of the discipline. I don't think mining engineering became a smaller part of engineering necessarily only because it was less analytical, but also just because there was a decreasing demand for mining engineers over time. It's also true that the engineering disciplines have a very much larger content and dependence on and reliance on the in-depth understanding of the physical sciences and mathematics that they're based on than they did back in the time just after World War II. So I think that's right. Naval architecture, I think, maybe could fall into that category. I think that's probably not unreasonable. But it's also true that there just wasn't a demand for those kinds of people. We decided to just get out of that business. Although we didn't really get out. It was really more of an administrative thing. The faculty were still there and still teaching courses, but it just became part of another department.

I should mention the Hearst Mining Building. I inherited this project, and it was almost ready to start construction in 1996. It was principally a seismic project. The campus paid most of the cost of that renovation through seismic funds — retrofit funds. But it was a special project because of the history of the building. Phoebe Hearst had given the money to build it, and had participated in the ground-breaking. We have wonderful pictures of the event in the Bancroft library, in 1902, before the earthquake. It was really interesting to be involved in the decision-making about what to preserve and how to preserve it, and how much money to spend in order to preserve it. It became obvious very, very quickly that it would have been way cheaper just to bulldoze the building and put up a new one. Of course, that wasn't going to happen. I'm really proud of the way that project turned out. If you spend time in the building today, you see that the historical elements are preserved, and it feels a lot like it did back when it was built. It cost some money to do that. We raised some of that money. I remember, vividly, going down to visit Gordon Moore, along with Bob Berdahl, Ron Gronsky, myself, Don and McQuade. This would have been 1999, maybe, and meeting with Gordon at Intel. He ultimately made a big gift to support the Hearst Mining project, and that helped a lot. It was a very satisfying project, but it involved jacking up the entire building and putting earthquake isolators under it, which was phenomenal.

05-00:52:34
Burnett: It's amazing. That in itself is almost a sell. Is there something about the building itself? Is it an early example of modular architecture? It was designed that the exterior walls would bear the load, and inside you could redesign — and that's in fact what happened, and that was a problem. People had put all kinds of catacombs of offices inside, and that was all gutted to return it to its original state. So it has significance in architectural history to some degree?

05-00:53:12
Gray: It was a John Galen Howard design and it was also one of the most important examples of the Beaux-Arts style of architecture, that was being used in a lot of other places at that time. So the architects we were working with were just ecstatic about being involved in this. A fellow the name of Rob Gayle, who was the campus architect at that time, was the thought leader about this preservation project, and he did a wonderful job. He passed away not long ago. Rob, over his career, had a huge impact on the campus and projects like the Hearst Mining Building.

05-00:54:03
Burnett: The Mining project was three years in that retrofit.

05-00:54:08
Gray: That's right. I'm trying to think when that opened. Probably must have been about '99, somewhere in there.

05-00:54:14
Burnett: Right. One of the things that's happening from the outside, in the state of California, is that there's a real interest in institutionalizing interdisciplinary research. Gray Davis takes this up as governor. New campus research institutes are established. I think they're all called California Institutes for Science and Innovation. One is CITRIS, that's established here, the Center for Information Technology Research in the Interest of Society, and what you described earlier, the QB3, the California Institute for Quantitative Biosciences, which has three campuses involved in that: Berkeley, UCSF, and UC Santa Cruz. Then there are two others, but perhaps we could talk about how this impacted the college, and how you were involved in that.

05-00:55:32
Gray: This is a great spot to talk about that, and talk about Rich Newton, who I'll say a little bit about. Remember, this was boom times. Boy, in 1999, the economy was booming. Gray Davis was governor, and the state's budget was flush. Richard Lerner, who at that time was the director of Scripps Institute, got this idea that UC needed these institutes to promote translational research. This is answering the question, how could UC be more impactful in advancing the state's economy? The idea was these institutes would be translational.

They would take fundamental research and marry it to applications. I think this reached some stage of concreteness in ’99, as I mentioned. There had been a lot of early thinking about this, and that early thinking led to the idea there would be three institutes. There would be the QB3 Institute, which I’ve already talked about. It’s Berkeley, UCSF, and Santa Cruz, which we participated in. There would be a nanoscience institute, the CNSI [California NanoSystems Institute], which was going to be joint with UCLA and UC Santa Barbara, and that got built and is an institute. Then there would be the Calit2 [California Institute for Telecommunications and Information Technology], the information technology institute, at UC San Diego.

05-00:57:14
Burnett: With Irvine, I guess, as the other partner.

05-00:57:16
Gray: With Irvine. That was the plan that we learned about in 1999. Well, the QB3 part is fine. You should go over and have a coffee in that building. It’s a wonderful place, and it’s had a big impact here. Let me talk about Rich Newton. Rich, who became dean of engineering after I did, was chair of EECS in ’99; Randy Katz was chair from ’96 to ’99, and then Rich from ’99 to 2000. I first met Rich in 1977. He was a graduate student in a class I was teaching here at Berkeley. He had come from Australia, I think recruited by Don Pederson. Just a brilliant student. He went on, got his PhD. I remember this, about 1980 or ’81. At that time, our policy in EECS was that we didn’t hire PhDs right off their PhD from our own department. They had to go away and do something, then they could come back. There was this big debate about Richard, because he was so good, nobody could imagine having this person go to a competing institution. Somebody made an exception, and we hired him to be a faculty member.

Richard went on to a great career. He was a computer-aided design guy. He didn’t work on the original SPICE, but worked on some of the later versions of SPICE. But he, along with Alberto Sangiovanni-Vincentelli, who sits next door, were co-founders of Synopsys, and were instrumental in the founding of Cadence, which are the two biggest computer-aided design companies in the integrated circuit world. Richard, as a faculty member here, along with his colleagues and along with Alberto, really helped drive computer-aided design in the US semiconductor world for the next twenty years or so. Immense impact. We just wouldn't have a semiconductor industry of the type we have without the SPICE component of it, which evolved to much, much more sophisticated synthesis tools, things that don’t just analyze integrated circuits, but synthesize them to meet certain objectives and specifications. Rich, during that time, took a long period of time off and became a venture partner at Mayfield, a big venture firm down in Palo Alto/Menlo Park. He spent a lot of time down there, and lived down there for a fair period of time. Then he came back to the Berkeley campus in the mid-nineties, late nineties sometime. He then served and chair and succeeded me as dean.

When Rich learned that the only information technology institute was going to be at UC San Diego, when we're Berkeley — we are sitting right next to Silicon Valley — he rightly pointed out to me and many others that we can't have that. The San Diego Information Technology Institute was, at that time, mostly hardware-oriented. It was about computing and communications hardware and software, as might be practiced in an electrical engineering department. Rich saw a broader connection between computation and societal problems across a wide spectrum – medical records, climate change modeling, etc, etc. The vision was a bit of a forerunner of what we're seeing in data science today. He wanted to propose another institute, at Berkeley, that would be on computing in the interest of society, or CITRIS. This was a very controversial thing, because it looked like we were fighting with San Diego. Now we're moving into a little bit later period, but in the period from '98 to the time when those institutes were announced, which was — I remember it well— December of 2000, Rich just did an incredible job of working with the UCOP people, and working with campus people like me and Bob Berdahl. He actually was able to work with the legislature, and to work with the other institute proposers and convince them that things were so good that there was a possibility of a fourth institute. He had a compelling vision.

I remember this vividly when the results were announced. Bob Berdahl and I were at the Faculty Club Christmas dinner, Christmas of 2000. I got a phone call on my cell phone, and it was Rich Newton, who was sitting in Saint Mark's Square in Venice, where it was early morning. Rich had just gotten a text that they had decided to award not three, but four institutes, and CITRIS was going to be one of them. That was one of the highlights. Classic Rich Newton to do that from Venice. That's the kind of guy he was. Then, fast forward. We built the CITRIS building right there; it houses the MicroLab and a lot of other things.

05-01:03:16
Burnett: That's Sutardja Dai Hall.

05-01:03:18
Gray: Yes. I should mention that Rich was also the one who was able to raise the matching funds from the people I already mentioned in our last conversation. The building got built. Rich went on to be a very successful dean of engineering and do many things, and then, as you know, he passed away — he had pancreatic cancer — in early 2007. It was a huge loss for this campus, just a huge loss. That's sort of the institute story I thought I would tell. Rich won't have a chance to do a history, and I really think his contributions here are just really phenomenal. Had he lived, he would have clearly been a provost, maybe chancellor, here at some point.

CITRIS is joint with Davis, UC Santa Cruz, and UC Merced. QB3 is, as you mentioned, joint with UCSF and UCSC, so the Northern California campuses are all involved in those institutes. One argument in our favor I think was that

Davis and Merced would have been left out totally. They wouldn't have been part of any institute if we hadn’t gotten a fourth one. So that was a huge win for the Northern California campuses.

05-01:04:39
Burnett: Can I ask, is there also an effort — because one of the things that’s also happening is that incredible research is being done — it used to be that Cal was it, and then UCLA became important in high-end, new research, and the other schools were kind of also-rans that served particular populations in particular areas of California. But over time, UCSD comes up in the tech world and is breeding its own kind of Silicon Valley industry, and you’re seeing that. Is that part of it, that they wanted to give opportunities to people at Davis, for example, whose own research programs are maturing, an opportunity to collaborate in the big leagues with the established campuses?

05-01:05:33
Gray: I don’t know that, but I’m guessing that was probably a factor. You’re right. What San Diego has done, starting in the fifties, and becoming a campus that’s not only an AAU [Association of American Universities] institution, but with a very large number of programs ranked in the top ten in the country, it’s amazing. Really quite amazing. I don’t remember if it was [Richard] Atkinson or Bob Dynes, but anyway, whoever the president when the institute decision was made, and certainly Larry Hershman, who I did talk with a lot — certainly would have thought, yes, if you can help UC Davis — they’re a very strong campus now, and I think that helped them. These things helped them. So I’m sure that was part of the thinking.

Let me talk about a couple other things, because we jumped a little bit, and one thing that I haven’t mentioned that was a big factor in that four years was campus growth. We had this thing called Tidal Wave II. Carol [Christ] liked to call it Tidal Wave II. There was tremendous pressure on admissions within UC as a whole, and certainly at Berkeley, as we’ve already talked about. There was a strong motive to grow the capacity of the campus. By 1998 or so, Carol and Bob Berdahl had committed to grow the campus by 4,000 students, and indeed we did grow. From 1997 to about 2005, we went from about 29,000 to about 33,000, roughly. We also grew the faculty. Well, we started down a path to grow the faculty. Again, the bioengineering positions were part of that. The growth of the faculty part got derailed, and slowed down dramatically, by the 2000 dot-com bust. We did the student growth, but we didn’t really do all of the corresponding faculty growth. We did some of it, but not all of it. Part of the planning for that was to significantly expand summer session; there wasn’t much of a summer session here before that. That was expanded significantly to give students a pathway to get some of their student credit hours in the summer. But this was something that took a lot of time, and Carol put a tremendous amount of effort in. We were in a hiring mode in engineering. We were growing particularly the bioengineering positions, but also some positions in other departments.

The other thing that I really remember vividly is Prop 209, the admissions issues. SP-1 and SP-2 were ’95, and then I think 209 was late ’96. Chang-Lin Tien was a huge, a very big advocate of diversity and inclusion on the campus, and quite a cheerleader, at the time, This was really devastating to him. He was trying to do things to counteract the impact of SP-1 and SP-2 and Prop 209, at the system and the campus level. A lot of the other oral histories, like Jud King’s, talks about all of that. For a long time, for people on the campuses like the Deans, it wasn’t clear what was okay and what was not okay. As it has shaken out, the impact of particularly 209 is you can’t use ethnicity at all in making decisions on actual admissions or hiring. However, you can expand the pool of candidates, trying to include more minorities to choose from. There’s nothing illegal about recruiting in minority high schools, or things that would help you bring in more candidates of disadvantaged kids to be considered. When you make the decision about who you’re actually going to admit, ethnicity can’t be a consideration. That’s apparent now, but it wasn’t very clear at the time. We all knew that these issues all had to be sorted out and clarified in some court cases and some administrative decision-making and so forth, over a period of time, after 1996. So it had a chilling effect.

In the case of engineering, we had a lot of programs. Alice Agogino ran a large office of outreach. We were participants in a statewide minority engineering program. We did a lot of recruiting at minority institutions, both for undergraduate and graduate students. I made a trip to Howard and a trip to Tuskegee, I remember, at one point, looking for potential grad students that might apply here. We were doing a lot, but the people in those offices were a little bit demoralized by this turn of events that was happening with the regents, and then in the state of California. If you look campus-wide, up until those years, we were at something like 18 percent or so underrepresented minorities being admitted in each freshmen class. Right after 209, that number dropped precipitously to something like 11 or 12 percent. Huge drop. Interestingly enough, over the intervening years, it’s climbed back up to almost 20 percent as of the most recent admit class. All of the things that have been done in admissions on comprehensive review and looking at other factors have helped mitigate some of the impact of that in terms of equity and access. The impact in engineering qualitatively mirrored that. We were already struggling mightily to get a reasonable representation of underrepresented students as freshmen and transfers. It dropped immediately after that, and that was really painful. So we just redoubled our efforts. Fortunately, one of those two regents resolutions had a very strong commitment of the university as a whole to outreach efforts to try to mitigate. So there were some resources available to do things, and we took advantage of those. But still, it was a difficult period.

05-01:13:21
Burnett: SP-1, I think, had the provisions for — there was a $60-million kitty, I guess, across all campuses, for diversity and outreach, and so it at least provided some kind of alternative policy to pursue. Then I guess SP-1 and 2, are they repealed in 2002? So it's a five-year period, but there's a move to overturn them and—

05-01:13:52
Gray: There was that, but once 209 passed, that all became moot. It didn't matter whether you had SP-1 or not, because—

05-01:14:00
Burnett: So it was symbolic, basically.

05-01:14:02
Gray: I do remember, that, actually, and it was pure symbolism. The students wanted the regents to make a statement and repeal SP1 and 2. You can understand why, but was mainly symbolic at that point. It was a tough time. Chang-Lin — I have some great memories working with him. Well, let's see. Is there anything else on admissions? I'm trying to think.

05-01:14:38
Burnett: I imagine that the diversity provision in SP-1 was what allowed engineering to pursue diversity efforts. Alice Agogino, was she hired specifically for that, in the wake of it, or had she already been there?

05-01:14:57
Gray: Alice was already in place when I came in. That's a good question. I don't know how long the college had had an associate dean for outreach and diversity. Alice had that title. She was already there when I went into engineering, and was doing a great job. Very active person, and to this day, she's still active on the faculty. I don't know when that position was first populated. I did come in, and we worked a lot together in trying to advance this. The pressing issue, at that point in time, was minority admission, and we focused mostly on that. We had a huge problem with gender, too, and had for a long time. Most of my recollection of that period was being focused on the impact of those developments on our minority admit issue. We should have been more worried about women, too, but the whole issue of having this precipitous drop in minority enrollments was just a huge problem, and we were trying to deal with that. That was really our first priority at that point. As I mentioned, the campus, in the nineties, went to a system of comprehensive review, and then after 209, that was refined, and refined more, and the system we have today is really kind of an outgrowth of a continuous evolution of that. That, together with a lot of outreach and a lot of efforts, have gotten the numbers back up to at least something approaching what it was earlier.

05-01:16:59
Burnett: Right, right. And so you worked fairly closely with Chang-Lin Tien in developing—

05-01:17:11
Gray: One episode I remember really well was — this would have been ’97 or so — we were trying to get Rockwell Corporation, the aerospace company, to fund an endowed chair in engineering. They had indicated they were willing to do that, but they wanted a visit to sort of nail down the details. So Melissa Nidever, that I mentioned earlier, and I were going to go down to Irvine where they were based at that time. Melissa and I flew down there to meet with their board of directors at Rockwell, and Chang-Lin was the contact person, so he was going to come down with us. I saw him the day before the trip, and he was sick. He had a terrible cold. He could barely talk. I said, “You should skip this trip. You shouldn’t be traveling. You’re not well.” He insisted “I’m going to go. I’m going to go.” I thought he wouldn't go.

Sure enough, we showed up down there in the lobby at Rockwell, and here he was. He showed up. He had done a whole day of visits down there in Irvine that day, and this was in the afternoon. We show up there, and he can’t talk at all. He can’t talk at all. He’s got laryngitis. Couldn’t say a word. We troop up to the board of directors room, and we walk in, and the board is there. I give a little pitch about our endowed chair and why we needed it. Every so often, I’d turn to Chang-Lin, and he’d give a thumbs up, or throw both arms up making a V symbol with each hand, give two victory symbols. He couldn’t say a word. Never said a word the whole time. Full of energy, and enthusiastic. We finished the meeting, and he walked out without ever having said one word the whole time. Sure enough, they gave us the million dollars. That was so much like Chang-Lin. That’s sort of who he was. I learned a real lesson from that. His most important single leadership skill was just total commitment. He would do anything for this campus. If you were around him for more than five minutes, you realized, hey, whatever he asks me to do, I’m going to do it, because—

05-01:19:38
Burnett: It’s infectious.

05-01:19:39
Gray: —he’s committed. That episode was such a perfect example of that. He should have been home in bed, but he came down there because he wanted to get that gift. They sensed that. They got that. If you’re ever going to take on a position like that, you’ve got to be ready to give it a full, 150-percent commitment, and he did that. I think that was a big part of his success, is he just gave off that commitment.

05-01:20:09
Burnett: He was a legend on campus, even. That’s a high-stakes thing for a million dollars. Would you show up if you had a cold? Maybe, if something like that was riding on it. But he was also known for showing up in the middle of the night in the library as students were cramming for exams, to support them. He didn’t have to do that either, right?

05-01:20:33
Gray: No. He was quite a leader. I really admire his commitment. Then I got to work with Carol a lot, Carol who's chancellor now, of course, and also a wonderful leader. She was really committed to this bioengineering thing.

05-01:20:51
Burnett: What was her position at that time?

05-01:20:53
Gray: Provost. She preceded me as provost. Despite the fact that she's a professor of Victorian literature, was then and is now very, very supportive of the sciences and engineering. Really did a wonderful job. We had to do a lot of work to get this done, but she never hesitated to support every step of the way, and that was really valuable. Then I got to work with Bob Berdahl. Bob was just a wonderful guy. He inherited a tough situation with ethnic studies. I'll talk about that a little bit. I got to be great friends with Bob over the years, and still a wonderful friend. I remember the first day he came. He arrived in — is it '97 or '98? I think it was '97, I guess, right? The summer. He had been here a few months, and then he decided to do a visiting tour, where he'd go around and visit each of the deans in their office, which is, by the way, something I learned from him – that was a wonderful idea. He came to see me in engineering, maybe by November or so of that year. We sat down in my office. Just as a way to make conversation, I said to him, "Well, Bob, after being at Texas all those years, and now you've been here at Berkeley for a few months, what's the biggest single difference you find between the two presidencies and the two jobs?" He sat there and he thought for a minute. He said, "Well, the biggest difference is my biggest donor isn't named Jim Bob." I just fell out of my chair laughing. Bob always could bring in his sense of humor, in ways that made situations better. I came to really be a fan of that sense of humor.

He had some real struggles. The biggest one was the ethnic studies one. That affected us significantly, because we happened to have one of our engineering dinners partially derailed by it. We had an engineering advisory board, with very influential and loyal set of major donors and friends of the college. Every year, we'd have a black-tie dinner at University House, hosted by the chancellor. The year we were supposed to do that — I think it was spring of '98 — might have been '97, '98 — anyway, we were supposed to do that there. It was '97. It was that same year. Because of the ethnic studies controversy, the demonstrators had first built a tent camp around California Hall — that lasted like a week — but then they began to picket University House, where we were supposed to be having our dinner. On the night of the dinner, we had to, on very short notice, an hour or two, move the dinner down here to the Bechtel Center. The cooks had to come in, set up something, and serve some food. It was a bit of a disaster although it made for a lot of funny conversation. I still remember that, feeling for Bob. But he did, in the midst of all that, come over later and give his speech and greet our guests. He did a fine job with that. But he faced a lot of challenges.

05-01:24:40
Burnett: What's the context for the ethnic studies controversy?

05-01:24:48
Gray: In the Free Speech Movement, in the sixties, the campus administration finally brought the crisis to an end by, among other things, agreeing to certain things with the students. There were a number of things like that that came back to haunt us, and I'll talk about a couple of others, including DeCal [Democratic Education at Cal] courses, when we talk about the time in the provost's office. One of those agreements had to do with creating a department of ethnic studies. It was sort of a representational thing. The minority students felt they needed to have a role, and their history and culture needed to be recognized and talked about and be part of the curriculum. So the department of ethnic studies was created in the sixties. Now fast forward thirty years, and what had happened is that, for whatever reason, they hadn't been able to find faculty that could be appointed that were, at least in the views of the budget committee, up to Berkeley standards. They had positions, but something like half the positions in the department were vacant. I don't recall exactly. It might have been twelve-member department, and a lot of those positions were vacant. The reason they were vacant is they just couldn't find or couldn't agree on people that could be appointed using our system of pretty rigorous campus review. So the students were getting more and more and more upset about that. They thought that the administration was just trying to eliminate the department, just by starving it to death, never appointing any new faculty. There were also some issues with the student enrollments in the courses. They weren't very high, and there were other challenges with that department. It wasn't thriving; it wasn't doing well.

This happened very shortly after Bob got here. He came in '97, summertime. I think this was the spring of '98. So the students thought that the campus was trying to eliminate ethnic studies. Carol was handling this with the budget committee, but somehow Bob, at least he said at the time, he didn't learn that this was even an issue until there were tents out in front of California Hall. That's described in his oral history. But whatever the sequence of events was, the result was that a large tent city grew outside of California Hall, insisting that those faculty positions be filled immediately. That was the demand — immediately. Of course, you can't do that around here. Even with perfect candidates it's a long process. There was a long, long period of negotiation. Part of that was when our dinner got canceled. There were some key people in the senate, David Hollinger and others, who helped with that — Jack Citrin — and it all worked out over time. But the chancellor made some commitments to fill some positions. I don't know the details of what those commitments were. They were controversial. Part of the campus didn't like that. I think it was probably commitments to not eliminate the positions, and to ultimately fill them. I don't think he committed to a timeline to fill them.

05-01:28:45
Burnett: At any rate, the larger story, I suppose, is Berkeley has this reputation, and a lot of it is fueled by conservative elements across the United States who feel that Berkeley represents this bastion of radicalism. Although there was a progressive left that was part of the campus, part of the student body, part of the faculty, to some degree, it has this outsized reputation. You're part of the Berkeley that is about innovation, about science, about progress. How do you feel about the way that Berkeley gets perceived and framed in the media — and framed in both senses of the word — given everything that you have experienced on this campus?

05-01:29:53
Gray: I think, around here, we've all been living with this for so long that we just accept it. Just speaking for myself, I don't worry about it much anymore. It's so much a part of the woodwork. We have this way that Berkeley is perceived in the higher ed community, in the community of California parents who want to send their kids to a fine university, in the community of people who worry about innovation in science and engineering and technology, Silicon Valley. With that set of people that we have, I think, a high profile with and a very good reputation. Then there's the set of people, many east of the Mississippi, perhaps typified by the *Wall Street Journal* editorial board, a whole other set of people—

05-01:30:44
Burnett: Or *Breitbart*.

05-01:30:46
Gray: —who have a totally different perception of Berkeley. When you say Berkeley to them, they envision a complex that includes a campus and a city. There are some other anecdotes that will come up when we talk about California Hall and being the provost that are wonderful examples of this dichotomy. I don't see that changing anytime soon. [laughter]

05-01:31:20
Burnett: You focus on your constituents, which are the students and the graduate students and the faculty, and the larger connections to science and engineering worldwide. I think that seems to be what you're saying.

05-01:31:33
Gray: Yes. That set of circumstances you're describing now has a whole new context, which is the version of the free speech issue that we're having right now with allowing controversial speakers on campus, and that keeps renewing itself in different ways. But the fundamental perceptions, I don't think, have changed very much.

05-01:32:00
Burnett: We're heading to the end of the millennium now. There were some changes in the works outside of the College of Engineering. There was Joe Cerny's Sunset to Dawn reviews. There was some sunsetting of ORUs [organized

research units]. Because of that, there was an opportunity to create some new ones. There were forty-seven proposals, and they chose eight. So there's some renewal on campus, generally, in terms of new clusters of research approaches and institutions. Joe Cerny steps down in 2000, and Beth Burnside is made vice chancellor of research, and she replaces Linda Fabbri. There are all kinds of changes happening at the executive level of the university. Can you give us a sense of the changes that were in the works, and how the college fit into that, and how you, in your career, fit into that?

05-01:33:26
Gray: I'm trying to think how best to answer that. There were a lot of changes. When I moved to California Hall, we were able to bring in a lot of new people. As you mention Beth started about that time. I was able to recruit a new set of vice provosts. Those first three years of Bob's chancellorship had been difficult ones for him. Ethnic studies was difficult. There were some other kinds of issues that came up that were difficult. I had the sense that, perhaps as a consequence of that, he wanted to have kind of a change of the guard. On the other point, the issues about interdisciplinarity and how to deal with it — well, we were living that already with the institutes and with bioengineering and all that. Later on, we would do this campus strategic plan that would embrace that even further. But in that time, I guess my biggest concern was how I could help the chancellor make his administration be more effective. Maybe that's why he asked me to be his provost. I was really anxious to try to help Bob in any way I could.

05-01:35:33
Burnett: So that was the context in which you take up the position in 2000. Can you describe the hand-off with respect to the College of Engineering?

05-01:35:47
Gray: Sure. Maybe this is a good way, I'll kind of wrap it up. We can set the stage for next time. I really liked being the dean of engineering. It's a wonderful job. I didn't mention this earlier, but the set of alumni and friends that this college is connected to in California and around the country, but especially in Silicon Valley, is really phenomenal. Those people were such great college supporters. People like Bill Floyd, who's been a key person on the engineering advisory board for at least twenty-five years, and John Neerhout, a retired Bechtel vice president. When the Channel Tunnel got in tremendously difficult political difficulty between the French and the Brits, Bechtel loaned him to the tunnel authority to serve as project leader, and he was the person who actually completed the project. Those are only two examples. We had a collection of people — Lou Oppenheim, who was a Kaiser vice president, Steve Bechtel, who was on before my time — a collection of people who were just tremendous. Today, we have an analogous set of people, including people like Eric Schmidt and Paul Jacobs. I just want to make sure I mention the importance of that. The most fun part, by far, I found, of that job, as well as being the provost, was the connection to those outside people. This campus has incredible strength in that community. It's just amazing to me.

Anyway. I had gotten to know Bob Berdahl pretty well because of two other things I hadn't mentioned. At some point in 1999, we made a trip to Saudi Arabia. Bob was invited to visit by a person who was not a member of the royal family, but who was a high official in their government. He asked me and Ed Penhoet to go, along with John Cash, who was the vice chancellor for development. Our goal was to spend three days in Saudi Arabia, meet alumni and some of the members of the royal family, and talk about philanthropy at Berkeley. We have a lot of Saudi alumni. So we flew over there and spent three days, probably the most fascinating three days I ever spent. I got to spend some time with Bob, got to know him a bit better. We learned fairly quickly that the Saudis were less interested in philanthropy, and much more interested in programs we could do, or help them with, to advance their internal higher educational system. They had, then, this bifurcation of their society into a wealthy upper class, dominated by the royal family, and then the rest of the country, which is economically okay because of the oil income, but which educationally and culturally struggled in important ways. You probably are aware, but not long after that, they began the establishment of that major new university just north of Jeddah. It was fascinating. By the way, I should have mentioned when I talked about bioengineering and getting that one of the other people who was a key supporter and enabler was Ed Penhoet, who, at that time, was dean of the School of Public Health. Anyway, he was in Saudi Arabia with us. I worked with Ed a great deal later on at the Moore foundation where he was subsequently president there.

When John Cash subsequently stepped down, or announced he was going to step down, Bob asked me to chair the search committee for his replacement. That was a very broadly constituted search committee with a lot of outside people. Folks like Dwight Barker were on that committee, as was Ed Penhoet. We got Don McQuade to finally agree to be the vice chancellor.

When Carol decided to step down in 2000, Bob appointed a search committee for her replacement. I liked being dean of engineering. I didn't think I was particularly well-suited to be a provost, and so I didn't make myself an applicant. Over time, some people from the search committee talked to me and they led me to believe they thought I could help them. Again, these jobs are all about helping the institution. I had had a wonderful career here, and I felt I owed it to them, and felt honored to be asked, so I agreed to do it. Again, Judy was willing. Oh, by the way, I forgot to mention, one of the things that we tried to do over those four years in engineering was host an annual event at our house for all the department chairs and all the administrative people. That was really important to do, I think. Getting the team together in social settings like that, away from campus, really was useful. Fortunately, we had the house that enabled us to do that. I kept doing that occasionally in California Hall, too.

Bob, after the search committee reported and all was said and done, he asked me to do the job, and I agreed to do it. Carol was great about giving me briefings. I realize now, and I fortunately realized then, that that period of time, those first few months when you're deciding about who your key people will be, whether they're, in that case, vice provosts, or key staff people, it's just so important to take your time and get that right. It's the DNA that forms the creature that the administration is going to become. So I was able to convince Bill Webster to come over and be the vice provost for planning, and he did great things for this campus, which I'll talk about next time. Jan de Vries is a professor of both economics and history and had been interim dean of the social sciences for a period of time. Very distinguished guy. I asked him if he would be the vice provost for academic affairs. This is the person that works closely with the budget committee and handles all of the academic personnel. I had to work on him. He didn't really want to do it. But he was just the perfect match. He was just the right person, and an extremely capable person. Finally, I convinced him. He said no a couple times, but I kept after him, and he said yes.

05-01:44:05
Burnett: How did you know that he would be the perfect — or you found out —

05-01:44:09
Gray: I asked for nominations. I don't remember exactly how I did this, but I asked for nominations for these positions. There was a broadcast call. I don't think I had a search committee. I talked to a whole bunch of people. Of course I consulted a lot with Carol and Bob on these appointments, along with a lot of other people. Carol knew him well, and it just became obvious, he's the perfect person. A little bit later on, we appointed a vice provost for undergraduate affairs, and we got Christina Maslach to agree to do that. Christina is a professor of psychology, and had been chair of the academic senate. She was great. Then Beth Burnside had come into the administration, a wonderful appointment.

I got some wonderful staff people. Jeanne Fong, who'd been an administrator in the library, came to run the office. She was terrific. Then came a couple of administrative people, Rita Gardner and Cathy Beemer, they were just great. So we got the team pulled together, and that was key, to get that done.

Different chancellors work with their provosts in different ways. Bob really asked me to be, I think closest analogy would be a chief operating officer kind of person. The vice chancellor for administration at that point was Horace Mitchell, and the vice chancellor for budget and planning was Jim Hyatt. Bob made it clear to me that he wanted me to be able to go to those two vice chancellors and problem-solve with them. I did a lot of that, and they were great. They were great partners. But that was really important. We had some important issues on the administrative side that needed to be addressed. My personal opinion is that a campus works best when you have a chancellor who's the visionary and thought leader and outward-facing, and a number two person who really has the ability to make changes inside the institution operationally, to make things work better, and has a clear mandate to do that. I was lucky enough that Bob saw that way, too, and I think we were able to help with some of the issues. All chancellors don't like to work like that. Many chancellors want to have their fingers on those issues themselves, and that's okay, but after six years of observation I think a chancellor has so much to do in managing the outside relationships, perceptions, all of those constituencies that matter both on and off campus, politically. It's a very tall order to try to manage all that, and at the same time, worry about the more operational aspects. Bob and I worked together terrifically well. Maybe that's a good point to sort of wind it up, and we can move into that next time.

05-01:48:01
Burnett: Absolutely.

05-01:48:03
Gray: Okay.

[End of Interview]

Interview 6: April 19, 2018

06-00:00:17
Burnett: This is Paul Burnett interviewing Paul Gray for the University History series. It's April 19, 2018, and we're here at the University of California Berkeley. This is our sixth session. We spoke last time about the very beginning of taking up your new position. We were talking about setting up your team. Can you talk a little bit more about those folks that you were getting involved?

06-00:00:53g
Gray: Happy to do that, Paul. Thank you. At the end of the session last time, I was describing putting the team together and making the transition to California Hall. I mentioned the new people that we were able to bring in, I think Bill Webster, and Jan de Vries, and Christina Maslach. But I should have mentioned also a couple of key people who were already there. One of those was Charles Upshaw. Charles was the chief of staff in the EVCP [Executive Vice Chancellor and Provost], the provost's office. He might have started it with Mike Heyman, had been there a number of years, and then continued on several years after I finished my term. He managed the staff and did a whole bunch of other things as well — the term, "chief of staff" is sort of like White House chief of staff. It can involve a lot of activities that you might not anticipate, and Charles did a lot of different kinds of things. But his main job was supervising the office staff there, and he was a tremendous asset.

Another person I should mention is John Cummins. I don't know if you're planning or have done a John Cummins oral history. John was the assistant chancellor. It might not have been called that, but it was, in effect, the same job, with Al Bowker. He served with five chancellors, I believe, all the way through Bob Birgeneau's term. John was also called the assistant chancellor at one time. He also served as chief of staff for the chancellor. I came to think of John as Mr. 911. He was the person who managed day-to-day issues that needed to be dealt with. Along the way, he also, at times, took on special responsibilities. He managed athletics for a period of time, and in fact is in the process of writing a book about that subject. You have a lot of interviews of his at the Oral History office online.

06-00:03:13
Burnett: That's correct.

06-00:03:16
Gray: A great resource if you want to understand the history of athletics at Cal. I worked very closely with John on a lot of different projects. Charles Upshaw and John Cummins were two of those people who have the institutional memory that goes back for decades. I thought I also ought to mention something about that period with my graduate students. I had talked in previous sessions about the research activity in mixed-signal microelectronics and the egg-and-eggshell analogy, where the digital electronics are the egg, and the mixed-signal electronics are the shell that makes the digital circuitry

talk to the real analog world. We continued working in that field, and at the time I made the transition to California Hall, I still had probably eight or nine graduate students. They had transitioned to working on a particular part of that problem, which is the interface between digital electronics and radio signals. If you take a typical smartphones, it has probably five different radio chips in it. There's the cellular radio, the Wi-Fi radio, the bluetooth radio, and nowadays there's a near-field radio. It's a really big part of the microelectronics mixed-signal world today. At that time, we were trying to — along with a lot of other people around the country — figure out how to integrate, on a microchip, the radio functionality, which, up to then, had not really been very integrated at all. I had a number of students working on that, and they made some contributions, although there were a lot of other people in the country that also made big contributions there. Today, all of those radios are implemented on microchips.

As I made the transition to the chancellor's office, California Hall, it just got to be almost impossible to find enough time to supervise eight grad students. I had a PhD student, Chris Rudell, who is now is a faculty member at the University of Washington. Chris became sort of the head grad student, and he really did most of the work at keeping things on track, and helping write research proposals and getting funding, and dealing with all the things he needed to deal with to help the grad students finish their work. So I owe an awful lot to Chris, because he took on way more than a typical grad student's duty. I found, in the EVCP role, there just wasn't enough time to do a proper job of supervising grad students, so I stopped taking new students. The ones that were in the pipeline gradually finished, and that was the end of the twenty-five, thirty years of research. It's interesting that different people in those kinds of jobs take a different approach. Many keep a strong program going. Bob Birgeneau did, for example. They do that, usually, by having senior graduate students and post-docs take on most of the organizational and management role, and they can oversee it with a relatively small time investment. I found I wasn't able to do that effectively, so I kind of got out of the research business. But I wanted to mention Chris, because he was such a key person in that transition.

06-00:06:56
Burnett: Could I ask you, how did you feel about that? Because going in, did you think you were going to continue your research career? Or did you make a decision? Did you just have a conversation with your wife and say, hey, I've got to make a choice here?

06-00:07:12
Gray: No, I had to make a choice. I knew I couldn't do both. I just felt the quality couldn't be there. Can you do it? Of course. You can delegate it all and have an activity and get grants. But can you do it at the level of impact and quality that you really want? Some people obviously can. I found I just felt I couldn't do that, so I had to make a choice. I had made my commitment to help the

campus with an administrative role, and I just said, I'm just going to do that, and someday I might come back to the research. I never really did, but I could have, I guess, if I had wanted to do that. It wasn't because I didn't want to be doing it. It's great fun. It's tremendous excitement. There are other examples. Chang-Lin Tien had a tremendous level of research and impact while in CA hall; there are other examples of people who successfully do that and have impact, and I'm a great admirer of those people. I wish I was one of them.

Let me mention one other thing about the transition. Two things I found to be very useful. Right after starting in California Hall, we took a period of about six weeks, and Jan de Vries and Bill Webster and I went and visited every single dean on the campus, in their office, and toured their facilities. Each visit took probably two hours. We tried to develop an appreciation for what their challenges were, what their activities were, and particularly set an expectation that — by asking the question, "what can we do to help you make your school or college or division stronger and more effective and impactful than it is now?" And setting the expectation that we were trying to enable them to be more impactful, as opposed to being a gatekeeper or serving some other function on resources. That paid huge dividends, just setting that expectation, and also the awareness and understanding of what each of those units and colleges and schools and divisions were facing, and what their issues were.

06-00:09:56
Burnett: Can I ask you where that approach comes from? I think Joe Cerny had the same spirit in the eighties and nineties. Is there a picture of how it was done before?

06-00:10:12
Gray: I think it just came from my previous experience as a dean and department chair. Maybe because I had served in that capacity, I had a sense that the deans of the units are really the most important agents of change here. You can't run everything from California Hall. You can do some great things, and you can make things happen through allocation of resources, but in the end, it's the twenty or twenty-one or twenty-two deans of all those schools and colleges and divisions, and their department chairs and their people, that are going to generate the programmatic ideas, generate the impact, and you've got to make them successful. I can't really say where the idea came from. I know Bob Berdahl did a tour like that when he came in. Not quite the same way, but he did. It was sort of the obvious thing to do. Anyway, for whatever reason, we did that, and that paid big dividends in many different ways. I think, partly, just giving the set of deans in place at that time the feeling that we were trying to support them.

The second thing that really made a difference was I resolved going in that I was going to understand where every dollar was and how every channel of funding worked. That's not a small undertaking around here. I think if you're going to be the role of a provost, as sort of the chief operating person of the campus, you just have to do that. In the end, almost every decision of significance, in one way or another, involves some sort of financial aspect. I found that to be incredibly valuable. I worked with Jim Hyatt, who was, at that time, vice chancellor for budget and planning, and he was very cooperative and helpful in that. By the end of the first year, I really had a good understanding of the finances. I think that's essential. One thing that brings this to mind is all of the successive EVCPs, of which there have been three or four now since then, have at some point asked "What do you think is the most important thing for me to do getting started?" I mentioned those two things as really being critical. They've usually done them, and I think it's helped them. So I just thought I'd mentioned that. Those were things that, viewed from twenty years later, were good things to do.

06-00:12:51
Burnett: One of the other perspectives I have is interviewing Mark Yudof, who came in later, obviously, and was the president of the university system. One of the things that was talked about was the lack of transparency that even the chancellors had about how the money worked. There was this siloed finance division in the universities and at UCOP [University of California Office of the President] had their own kind of way, and a lot of the chancellors were in the dark about how things worked. As executive vice chancellor in that period that he's talking about, how did you shine the light, in other words?

06-00:13:43
Gray: This was Mark's innovation, which was to bring transparency and do what was called the re-benching exercise. What it really did is make the allocation of resources from the Office of the President to the campuses more transparent and more rational. That happened during his time, which was after I was gone. I'll always think of that as the greatest contribution Mark made, because prior to that it was almost impossible to make rational decisions. The Office of the President would receive a large chunk of the resources that flowed into the system. Some of it was overhead, some of it was student fees, there was the state appropriation, and other large flows of money. That went into a black box, and then their budget and planning vice president at that time, Larry Hershman — who's a brilliant guy, but this was his way of working — he would just allocate it out, and there wasn't much apparent correlation between parameters you would think of, like research activity and overhead generation and student credit hours, and the amount of money the campus got. When Mark was talking about lack of transparency, that's what he was talking about. The system had worked that way forever into the past. I don't mean to be critical of Larry, who was a brilliant person and a great servant of the university, but it was time for a change. It's almost impossible to manage a place like this when you have that lack of visibility into what's determining the money flows. So it was a huge problem and a huge challenge, because you never quite knew how much money we were going to get. It was just part of the landscape that made it difficult. But at least once the money came to campus, you could get a good understanding of what happened to it after that.

06-00:15:38
Burnett: So down the stream, you got—

06-00:15:39
Gray: That's right. Mark did a great thing, and he took a lot of heat for it. There were hidden pockets of inequity that nobody knew about, because it wasn't transparent, and once it was, then that got fixed, and there were winners and losers in that. So there was a lot of angst, but it was absolutely the right thing to do.

06-00:16:04
Burnett: At that time, there is the dot-com boom, and there is the sense, still, at that late stage, of needing to recover from the previous [recession]. When I talked to others, they said the mood was "rebuilding." That was the focus. Can you talk about that and what then happened?

06-00:16:31
Gray: The period from ninety-six to 2000 were boom years. In 1998, Carol and Bob Berdahl — Carol was the EVCP at that point — committed the campus to grow the student body by four thousand students, I think from thirty-two to thirty-six thousand. As a part of that, to grow the faculty by two hundred FTE [full-time equivalent], from fourteen hundred to sixteen hundred, which would essentially fix the reductions caused by the VERIPS, replacing all those people that were lost during the VERIP years. That plan envisioned using summer session for a lot of this. In 1998, the summer session was very small. There wasn't much activity, and the idea was we would dramatically increase the number of student credit hours offered in summer session. Every undergraduate that went through here would have a high probability of spending at least one summer here on the Berkeley campus. That was part of the plan. In July of 2000, when I came in, this was in flight. We were going to grow the faculty. We were going to grow the students. We were going to ramp up summer session. It was exciting. It was an exciting time.

So, for the first couple of years, Jan and Bill Webster and I worked on this, but as you well know, in 2001, the bottom fell out of the stock market, and especially fell out of Silicon Valley and the state's income stream, because state is so dependent on income tax. People hadn't realized the extent — in the period from 1996 to 2000, a very significant part of the state's income tax revenues were coming from stock option exercises in high-tech industry. Those give a disproportionate anomalous boost to state income, because it's a one-time large amount of income for individuals. There was a mild recession in that era for the whole country. In most states, it was modest, but in California, it was really accentuated by the state's drop in income tax revenue. We saw a really precipitous drop. There was a time delay. It took a little time for the university's budget to reflect the realities of the state. But starting in about 2002, we began to see cuts. Not just flat budget, but we actually had a couple of years of actual reductions, when we were supposed to be seeing increases. So we went from boom to bust very quickly.

I think one important aspect of that period was when Bill Webster, who at that time was vice provost for facilities and planning, suggested rightly that we needed some sort of strategic plan for the campus. We knew we were going to be growing, but we didn't have any specific strategic idea of how to do that. Where do you put those faculty positions? Is it proportional? Everyone grows proportionally? Where do you put the students? Which programs grow? Which ones don't? And a whole bunch of questions like that. We appointed a strategic planning committee, which was co-chaired by Bill Webster and a fellow named David Dowall, who was the chair of the academic senate at that point in time. This was, I think, in about maybe the summer of 2001. It was a very large committee, twenty-some-odd people. Had a lot of really great people on it. George Breslauer, who ultimately became the EVCP after me, was on it, as was Christina Maslach and Cathy Koshland, who went on to become, later on, the senate chair, following David, and then after that, a couple years, succeeded Bill Webster as vice provost for planning and facilities. And a lot of other key campus people.

The committee broke up into working groups, and worked for about a year. Their goal was to develop a strategic plan. Strategic planning in this environment of a campus as diverse as this, with disciplines that range from the humanities, whose values and interests are so different from places like engineering — the world views are different, is a real challenge. It's hard to do strategic planning at all, to get enough commonality of view. I give a lot of credit to Bill and David. They did that. They produced a report. Some things came out of that report that had a lot of impact. It was sort of unheralded, because the committee had been put together when we thought we were going to be doing all this growth. By the time the committee finally finished its job, the bottom had fallen out, so we were all worried about other things by that time. The report still had a lot of impact, and I'll just mention a few things that were in there.

We've talked a lot about how universities deal with new, emerging interdisciplinary areas. Maybe the most important conclusion of that strategic planning exercise was that at least some fraction of these two hundred new positions should be used to seed new interdisciplinary areas somehow. We, subsequently, did a lot of consultation with the senate and so forth, and we arrived at the idea of six new initiatives. These would be interdisciplinary. They would have the possibility of holding partial FTEs. You couldn't have all of your appointment in one of these, but you can have half of your appointment in a traditional department, and half of your appointment in one of these initiatives. There was some money for staffing. There was a plan for reviewing them periodically. There was a whole structure for these. I'll see if I can remember. Let's see. There was a computational biology one. There was a nanotechnology one. There was one for cities, emerging technologies and structures for cities. There was a new media one, a combination of art and technology. There was one for the humanities and technology, and there was one for environmental studies. These actually were formed, and even though the bottom kind of fell out, we were able to go ahead and allocate FTE to these. Some of them still exist. The new media one still exists. Some of them ultimately evolved into parts of colleges. Some of them evolved into ORUs [organized research units]. It was always the plan that they would evolve, that they would become something. The initiatives were an important outcome of that strategic planning exercise.

06-00:24:45
Burnett: By that, do you mean that they would acquire their own supply of funds? They would develop their own into something else, and not be supported as much by this initiative?

06-00:24:56
Gray: Yes. Some might evolve into a department within some school. Some might evolve into a graduate group with an ORU and some joint appointments with traditional departments. We didn't really know where they were going to go. There were a couple of them disappeared as independent entities and became parts of schools and colleges. Others still exist as independent initiatives, more or less along the way they were designed. What it did was force the campus to hire people that had one foot in two different camps. It produced an incentive to get away from the cloning tendency, which tends to happen a lot in academic departments, where you tend to hire more people that are good at what the people that are already there are good at.

06-00:25:58
Burnett: Replacing faculty lines.

06-00:26:00
Gray: Yes. And hire people that look different from that. There was a fair amount of that. That was one thing that went on to have pretty significant impact. This problem continues. We're having a huge debate on campus about data science today, and it has some similarities, although that's a special case, because it's so broad. It touches almost everything.

06-00:26:30
Burnett: Could I ask, going back to something you said earlier, in the discussions to make a strategic plan, you talked about the differences in values between different departments and different communities and different disciplines. Can you talk about an example of an instance where the world view difference made it difficult to reach a compromise, and then how that compromise was worked out eventually?

06-00:27:05
Gray: I wasn't on the committee. Let me make up something that I'm certain was part of the discussion. Entrepreneurship was in the air at that time. In the report, as I recall — and I went back and read it, because I knew we'd be talking about this — there's really not any mention of entrepreneurship. At the time, entrepreneurship was being talked about a lot in engineering and business. If you're a professor of Middle Eastern studies or ancient history,

entrepreneurship is really not on your radar screen, so you'd have some difficulty figuring out where that fits in a campus strategic plan. There are pieces of the activity of the campus that only are relevant to subdomains. This report managed to distill a set of things which everybody thought was important. There are probably other examples I'm not thinking of, but that one might be one example.

06-00:28:21
Burnett: One of the things that might have been a problem is the complexity of this, because you now have money allocated among different institutions. Who pays for what? I think we talked a bit about the matrixing of these different things.

06-00:28:42
Gray: That's exactly right. It's the budgetary aspects, and who pays for what, and all of that. We gave these units enough budget to hire a staff person and have some physical location and hold meetings and do stuff, but that had to evolve. It evolved in different ways in different ones of these initiatives.

There were a couple other things that came out of that strategic plan that were important. One that I found a little surprising. Today we're building buildings down on Shattuck, like the new Tolman Hall replacement building, but in those days, we didn't think that was going to be very easy to do, and it's still not easy to do. We are physically impacted. We don't have infinite ability to expand physically. Ever since I've been around here, we've been talking about the possibility of satellite operations. There was a lot of talk about something at Moffett Field. We've tried for decades to find an appropriate academic use for Richmond Field Station, beyond its current use, which is as an engineering experimental station. One of the pieces of the charge that we gave this committee was to think about physical space and evolution of the campus physically. They came back and said, we need to do everything we can to make sure that we're in one place. I think that's had a big impact. Their point was that having the community of scholars rubbing shoulders at lunch and being able to physically sit down in meetings with colleagues who you might collaborate with, and physical co-location, is a huge value for an academic institution. I had not necessarily expected a group of people like this to come to that consensus, but they did. I think that had a big impact. We never did do anything at Moffett Field. The history of these satellite campuses around the country is, yes, of course they work, and they serve, often, a community of learners that are remote, but there's not much of an intellectual community between the faculty that are there and the main campus. Then you get this satellite group of people that is not well-connected in terms of their research programs and the other ways they work together, and that's a challenge. I thought that was quite interesting, and I think that's been a guiding value. Many of the people that were on that committee are still very much involved. Cathy Koshland is still in California Hall.

Cathy is responsible for another important thing that came out of the plan. The campus had fallen into a pattern of fairly weak external reviews of academic programs, meaning academic departments. Cathy, to her credit, felt very strongly — and her colleagues, the committee, endorsed this — that we just needed to do a lot more comprehensive, thoughtful job of reviewing academic departments periodically. As a result of the recommendation, we dramatically beefed up that activity, and now this falls under Tsu-jae King [Liu], who now holds that job. Cathy has moved on to undergraduate education. There's a very comprehensive set of external reviews of academic departments that happen periodically now. It really is good to do that. It helps keep the quality up.

06-00:32:58
Burnett: Can I back up and ask you about space and colocation of faculty and projects? How does that sit in relation to the QB3 [The California Institute for Quantitative Biosciences] projects, where you had shared innovation hubs among campuses? Are there mixed results out of that, or is that a different kind of—

06-00:33:26
Gray: No, it's all part of the same issue. I should have mentioned, by the way, when I was talking about the interdisciplinary initiatives, they're one of this spectrum of things that includes all the campus ORUs, all the graduate groups, things like ERG, the Energy & Resources Group, and the Wills Neuroscience Institute. As you mention, QB3 and CITRIS [Center for Information Technology in the Interest of Society], are not just single-campus. They're multi-campus. But the common thread is that they are all matrixed, multi-disciplinary institutes of various kinds. Space is always a huge issue for that. How do you prioritize the assignment of space? In the case of QB3 and CITRIS, well, it was easy, because the whole initiative that Gray Davis launched was about space. They provided a hundred million dollars each, matched by another hundred million in private funds, to build the space on campus or campuses hosting the institutes. I was going to mention Ed Denton a little later, and just the whole challenge of space management. There aren't very many rules. These come down to value judgments, what's more deserving. How do you make space allocation decisions? It's a real challenge.

But I think another point to make is that, despite the fact that we are constrained on available land, this campus keeps building more space at a really pretty phenomenal rate. Right over here is the Jacobs Center, that building behind Soda. We just finished the—well, sometime ago—EBI [Energy Biosciences Institute] building down at the corner of Hearst and Oxford, and now we're building the Tolman replacement next to that. Despite the fact that we don't think we can expand, we actually are expanding. There's a move to take some of the space that Carol Christ has talked about, now occupied by Edwards Field, down on the west end of campus, use that for academic buildings. So we've been able to find ways to create space on campus. I haven't seen this data, but it would be interesting to look at the additive per-year rate, over the last twenty years, of square footage per year added to the campus inventory. It's very significant. The fact that you can increase the space inventory helps a lot. If you can do that, you can meet a lot of needs for a growing research program, more students. So as long as we can keep doing that, I think we'll be in reasonable shape.

06-00:36:28
Burnett: You were talking about the challenge of rebuilding the faculty, and I was talking with some others about that. The bottom had fallen out of the budget. Gray Davis had dealt with the crisis in the way that he did. One of the things that you learned in that period was that Berkeley was slipping a bit with respect to its peer institutions in terms of the compensation to faculty. How did that realization come about, and what was the conversation about what to do about that?

06-00:37:18
Gray: I worked on this mainly with Jan de Vries and with Bob Berdahl, and then later Bob Birgeneau. Early on, when we first started, in 2000 and 2001, there were two main manifestations. One was housing. The Bay Area was going through a period that's a lot like we're going through right now, where housing prices were just sky-rocketing. We were seeing new, young recruits turning us down, or threatening to turn us down, because they couldn't buy a house. Jud King and I, I remember, went down and gave a talk to the regents about this. This was maybe 2001. Larry Hershman was trying to make the case to the regents that we needed better housing support, and we needed to find a way to provide better housing assistance for faculty. We made this presentation, which told that story, that we were having trouble competing with our peers in our peer group, the elite Ivy League schools, MIT, Princeton, Harvard, and others — Stanford — and schools of that type. We presented the actual hard data to the regents, how had we done over the last five years against the competing schools, the number of people we were trying to recruit, the number of times we lost that fight, both in retention and in recruitment, and so forth. Other than for Stanford, the picture really didn't look that bad. It actually made the story a little hard to sell, because we actually do pretty well.

One of the things we related in that presentation was precisely how we were able to compete. We have a step system of faculty salaries in UC. Within each professorial rank — assistant, associate, full professor — there are a series of steps. Each step has an official salary associated with it. It's higher for engineering and law, but there's a salary number associated with each step. Our academic personnel system puts people at step based on merit. The budget committee, in the advancement process, advances people through those steps based on how they're doing with their academic impact. Some people move faster than others, but that's how those decisions get made by the department chair, the dean, and the budget committee. What began happening through the nineties is we had market-driven exceptions, people whose salaries were decoupled from the step number. If a professor gets an offer from Harvard for a salary that's 20 or 30 percent higher than the step salary that they're at, and if that's a person that the department wants, obviously a very good person, and accomplished and impactful, we would simply create a decoupled salary. Often, we didn't have to match that salary exactly, but we had to come close enough so that it was not their primary consideration in deciding whether to go or not. That's the decoupling process resulting in a salary that's decoupled from the step system.

If you go back to the 1980s, there was a little bit of decoupling, but not much. By 2000, we had — I don't remember the percentage, but a significant percentage, on the order of 20 percent of the faculty on the campus, were getting decoupled salaries. This was beginning to happen in recruitment as well. When you were recruiting somebody from another school, not so much at the junior level, but at the senior level, you had to pay a decoupled salary just to be able to recruit them. This was really corrosive, because you had people who were getting these higher salaries and sitting side by side with people who were on step, so to speak, who hadn't bothered to go and get a competing offer, so they were paying a loyalty penalty because they weren't, and this was a really bad situation. We couldn't possibly afford to bring everybody up to what one might call market rates. We didn't have enough money to do that. But what one of Jan de Vries' innovations was, he proposed, and we adopted, something called a targeted decoupling initiative, where we went in and asked department chairmen to identify people who might well be targets of recruitments. They're so strong and so accomplished that they might be — and we preemptively went and did some of those each year.

This problem has only gotten worse. I don't know the percentage of people on the campus today that are decoupled, but it's much higher than 20 percent now. We've adapted. It costs a lot of money to do this. This affects budgets and everything else. But it's still true today, even eighteen years later, that if you look at the retention statistics and recruitment statistics versus those key competing institutions, with the exception of Stanford, we win most of the time. There are some reasons for that. One of the biggest reasons is people want to live in the Bay Area. This is not the only one, but it's a factor. It's the ground zero of the innovation economy in the world, really, and people want to live here. That helps us a lot. There are other factors we can get to later on. When you're competing with Stanford, they have that same argument. So it's more difficult. I don't know what our success rate is with Stanford now. Back then, it was about win-lose 50 percent. Most of the others, we won 80 or 90 percent of the time. We've done pretty well. Jan brought in some things that really helped with this. We got some pretty aggressive mortgage assistance programs for young faculty. We were pretty aggressive about meeting market on salary, and then trying to deal with the corrosive effects of the inequality that that creates. Jan deserves a lot of credit for helping us figure all that out. The common theme here is, despite all these challenges, which seem really difficult, we still win most of the time when we're competing with the elite competitors. It's a pretty amazing thing for a public institution like this.

06-00:44:58
Burnett: All this is happening in a time of austerity. November 2001, there's a budget report. Governor Gray Davis asked to cut $86 million from the $3.6 billion University of California budget. In that context, there was a regents vote to increase salaries of senior administrators by 2 percent, and as much as 25 percent by top admins. That kind of leads, somewhat, to the executive compensation issue. Richard Atkinson holds the big increases in abeyance. I don't know if that's indefinitely, but initially he does, because of the optics, because of this period of austerity. So you had to figure out, you have to compensate people, but there is a market for talent, and it is a public institution. It's a very difficult bind.

06-00:45:58
Gray: We'll get to that. The executive salary episode in 2005 and 2006 was really, really painful, but we'll get to that a little bit later. Another innovation that Jan came up with was what's called the BRIP, the Berkeley Retirement Incentive Program. One nice thing about figuring out how the money works, you realize fairly quickly that the driver here for cost is faculty headcount. For every faculty member you hire, you need a lab, you need startup costs, you need staff support. Everything tends to be proportional to faculty headcount. We immediately realized, we've got to scale back faculty hiring. We were going to grow the faculty by twenty faculty per year over a ten-year period, ultimately growing by two hundred faculty. The campus typically hires about—if you take separations and retirements, it's typically fifty to sixty a year. We were going to hire eighty or ninety a year. So we had these really aggressive hiring plans. Then that time you're talking about, when the crisis hit, and we went from thinking we were going to go up to realizing we were going to go down, we implemented this retirement incentive.

06-00:47:51
Burnett: It's late 2003 when that happens.

06-00:47:54
Gray: I'm trying to remember whether the professor in the graduate school—I guess that came in in the VERIP years. But anyway, we added some dollars to give incentives to departments so that faculty could retain their offices. We created a fund so that faculty who retired would have some summer salary, a fund to fund some research out of. We created some incentives for senior faculty to retire, the concept being it's really that faculty headcount that drives costs. That helped. But there was that one year, and I think it was '03, where we had started the year, in the fall, by allocating something like eighty or ninety recruitments. That means you start the search, you put the ads out. The deans all have their allocations. Now they're out there advertising. It's underway, in flight. Then, sometime in that fall, we are told that not only are you not going to get any increase, you're going to have to cut your expenditures by some

significant amount. It was obvious we had to somehow scale back the hiring. The way the campus does its bookkeeping, you almost never mix faculty salary dollars and lines with any other kind of resources. They're accounted completely separately. We changed that. We simply bought back the allocations by saying — I forget the numbers — we'll give you *x* number of dollars for *x* years, if you'll give us back that faculty authorization. Now, we could have just canceled them, but we were trying to maintain some sense of support dollars to hire lecturers to replace the lost teaching capacity. And we got them all back. I think we got twenty-five or so back. We saved all those salary dollars and all the other costs. We had to give them some dollars, but still, it was a huge win for us. We were able to scale back the hiring, and from that point forward, we didn't grow the campus at all. I think we shrunk a little bit after that. We did keep increasing the student headcount gradually, not as aggressively as we thought. The summer session did grow, but much more slowly. Everything just slowed down in terms of the growth. We just got a lot more careful about budgeting and spending. We slowed way down on things like executive salaries and so on. We can get into that a little more.

06-00:51:02
Burnett: What's interesting is that there's this ingenuity around non-economic incentives. What do people want? What can we give our outstanding faculty, our retiring faculty? Anything other than money. They arrange longer appointments for professors of graduate research, because there was a limit on that, I understand. So they increased that, so that people could continue to do research, they continue to do some teaching. They get faster approval of teaching courses, and access to this post-retirement teaching fund, as long as the teaching fund goes back—there's nothing that goes into the pockets of the retirees.

06-00:51:50
Gray: That's right, it's all internal money.

06-00:51:51
Burnett: Right. So there's this ingenuity around circulating the money in a way that maximizes the benefit to the campus, but also saves money in that crucial area, that faculty headcount problem. That was the solution that Jan de Vries and you and others were really focused on, and you're credited with that, for thinking in those terms.

06-00:52:17
Gray: It was a difficult time. I remember some of those meetings where we had to tell deans that they were going to have to give up their faculty authorizations. Hiring new faculty is something that deans and department chairs view as one of their most important and impactful contributions, by identifying the very best people and bringing them. It's just really difficult to reverse a decision like that. Anyway, it was part of the landscape back then.

06-00:53:00
Burnett: When you came in, there was a news article about the Paul Gray agenda. You were interviewed about that. There are two priority areas, and then an acknowledgement of challenges that you were going to inherit. The first one was to foster interdisciplinary research and teaching. That was not just you. There was an overall emphasis on that, and we've been talking about that. The other was to use technology to reach students beyond the classroom, and that's something that grows as a trend. The legacy of that across all universities around the world, there's a question around that. Can you talk a bit about what you were thinking at the time, and then what ended up unfolding over this period?

06-00:53:59
Gray: I had actually forgotten about that. That's true. In the College of Engineering, we had a TV classroom, and it was active at that time. Many faculty videotaped and/or broadcast their courses, and I did as well. Almost every course I taught, in the 1980s and early nineties was videotaped, and was distributed in various ways around the country. I thought it added a lot of value for the students, both the students that are here on the campus, because they can go back and review tapes and things, but also it greatly extends the reach and so forth. By the time I got to California Hall, it turns out that we were doing a lot of free course distribution online, mostly, at that time, videotaped, not live, because we didn't have that technology then. There was a studio down in Dwinelle, I think, videotaping a lot of classes. These were being made available through extension and through various other means. Some of them were being played on UCTV, but a lot of them were being used by students on campus to review lectures after the fact. Christina Maslach was actually the driver of this, and she decided, and rightly so, to make this a focus of her work here on campus. I should back up a second. We hadn't had a vice provost for undergraduate education on the campus prior to Christina. When I came to California Hall, there wasn't such a position. Carol Christ, who's now the chancellor, had worked with the Council of Deans and with a lot of the L&S [Letters & Science] chairs, and they had concluded, with Carol's agreement, that there should be such a person. There was a lot of discussion about that, shall we say. A lot of people couldn't quite see why we needed a vice provost for undergraduate education in California Hall. We have schools and colleges that are doing that; why do we need that? Christina had a big impact there, and actually it evolved over time. Now we have a vice chancellor, Cathy Koshland, for undergraduate education.

Christina came in about the middle of my first year. She had been senate chair before. One of the things that she wanted to focus on was this video distribution. My memory is failing me a little bit. We got up to some very large number of classes that had been taped, and there was a lot of distribution. Now we're talking 2004, 2005, 2006. Five, six years later, the whole MOOC [Massive Open Online Courses] movement began. One thing that really enabled all of this was the internet and the ability to distribute—

06-00:57:42
Burnett: YouTube.

06-00:57:43
Gray: —video on the internet. In 2005, you really couldn't distribute video on the internet. There was just not enough bandwidth. Maybe you could a little bit, but it wasn't widespread. That changed everything, because once you can do that, now you can distribute this material ubiquitously. So it was sort of a forerunner. I think maybe you could argue that we could have more aggressively pursued that and rode that horse into the modern era, where we were distributing on the internet and had some more impact than we had. It really was Christina's initiative to grab a hold of that and try to get more course material available, at least on tape, here on the campus.

06-00:58:26
Burnett: Maybe we can save this for the reflection session, but I'm thinking about our conversation about the importance of space, the collocation of researchers and faculty. The question I want to put to you next time is, is there something comparable for the undergraduates? Does place matter? Do you have to be in the classroom, or is it only when you reach a kind of graduate stage or a senior undergraduate stage where face time with teaching assistants and professors becomes really important to the formation — or even just the student experience of being with other students, physically, in the same place? But we can leave that for later. I just wanted to follow on that. You spoke about the challenges in that initial article, handling increasing applicants to the University of California, providing better access for a wide range of students from different backgrounds, and then rehabilitating and modernizing facilities. That was your agenda. Then things change, of course, because of the budget cuts, because of the running-to-stand-still phenomenon. The question around access, it comes home through a number of challenges. In late 2003, John Moores releases a report. I don't know if you want to talk about that at this point.

06-01:00:09
Gray: Sure. Let's talk about those. There were five or six what you might call management challenge episodes, some important and some not. The big issues were the ones we've talked about. It's the financial challenges, the growth that partially happened, and the faculty recruitment and retention issue that we talked about. I could spend a lot of time talking about the deans that we brought to campus. We brought Chris Edley to the Berkeley campus during that time.

06-01:01:00
Burnett: Law school, yeah.

06-01:00:01
Gray: And Tom Campbell, who was former congressman from the South Bay. Those are two recruitments that I really felt good about. They're super impactful individuals that had a lot of impact, in different ways and different

styles, but were really great for the campus. Chris went on to work closely with Mark Yudof for a number of years. Tom went on to take a leave to be the California budget director for Schwarzenegger. It was after Gray Davis was gone, I think. Two really impactful people there. I was really proud of all of those people we were able to bring. Let me mention a couple of episodes. One was Palestinian poetry. These are things that really stick out as memorable episodes. In 2002 — well, let me back up. The English department, and a number of other humanities departments, use lecturers to teach large service courses for undergraduates. In the case of the English department, freshman reading and comprehension is the case in point here. There are a huge number of students in those classes. They use lecturers — some of whom are grad students, and some of them are part-timers. They have a fair amount of latitude. In the case of reading and comprehension, the lecturer can pick whatever material they want to use to give the students something to read and comprehend, that they can then talk about and provide the subject matter to teach reading and comprehension.

In that year, one of the lecturers decided that he would use some poetry written by Palestinian political figures to express the Palestinian viewpoint about the situation Palestinians were in at that point. That, in and of itself, isn’t a bad thing. But, unfortunately, when this student wrote the course description, which gets published online in the schedule of hours, he gave a course description which read like a Palestinian manifesto, really, really politically charged. It ended with the immortal lines, “Conservative students may want to consider other sections.” You may remember this. Well, the *Daily Cal* picked this up. Then it got picked up by the *Sacramento Bee*, and the next thing you know, this immortal line was on every news station in the Bay Area and got covered nationally. This was really hard to deal with. This was not long after I started. It was like 2002. So we scrambled around, and Christina played a big role in this. It turns out that this was just a failure of oversight. These lecturers are supposed to be working hand-in-hand with a regular faculty member who vets these things. Any reasonable faculty member would have vetted this description so that it wouldn't have read the way it did. Anyway, Janet Adelman, who was the English department chairman at the time, and Ralph Hexter, who was the dean of humanities, managed this, and we got the supervision, we got the course description changed, and then things kind of evened out.

I don’t know if you remember this, but the regents got extremely exercised about this, at least some of them. Dick Atkinson was forced to write a position paper about this and stand in front of the regents and read it. It’s a great illustration of Dick’s intellect, because it’s about a six-page document. These are academic freedom issues. Does a lecturer have the same academic freedom that a regular faculty member has? What should be okay and not okay about a course description? What’s okay and not okay about what’s actually in a course like that? These are not easy questions. Dick wrote a treatise on this subject, which makes wonderful reading. He’s a very, very smart person. It makes good reading if you ever want to get a sense of where Dick was coming from.

Anyway, as usually happens around here, things settled down and everything was fine. Everything was fine for about three months. Then the next one comes in. Oh, by the way, one last thing on the Palestinian poetry. My most vivid memory is the moment when I first learned of it. Bob Berdahl walked into my office one morning and he had a copy of the *Wall Street Journal* in his hand, and he threw it down on the table. They had written an op-ed about this Palestinian poetry thing in the *Wall Street Journal*. He said, "What in the world is this?" At that point I didn't know anything about how English courses were taught. That's how I learned about it. Those are moments you remember.

06-01:07:00
Burnett: Of course, yeah.

06-01:07:01
Gray: Anyway, the next example was a few months later. We talked about legacy from the Free Speech Movement. One of them was what are called DeCal classes, Democracy at Cal. These are classes taught by undergraduates for undergraduates. They still exist. You can only take them pass/not pass, and only 2 percent of your graduating credit hours can be DeCal. These are supposed to be supervised by a faculty member. The *Daily Cal* comes out one day, with a story about a DeCal class on male sexuality, and there are a lot of salacious details, including the fact that the final project is to go to a male strip club. This gets picked up, and it's picked up by the local press, also as I recall by the *Sacramento Bee*. Pretty soon, it's all over, and we're seeing it on TV and the evening news. Same thing. The combination of those two things in one year, it was really starting to be not very pleasant. The Regents were very upset about this one also, calling Bob Berdahl to complain. So, anyway, we go through the same routine again. We get, again, Christina, to deal with the mitigation. It turned out to be really useful to have a vice provost for undergraduate education. Several steps were taken — the people involved put a monitor in the subsequent class. It turns out that most of the salacious details were not real. The *Daily Cal* reporting was a bit sensationalized.

06-01:08:40
Burnett: Oh, really?

06-01:08:41
Gray: Well, the visit to the male strip club was not an official assignment of the class. It was something the kids did. But still, even with all that, it needed to be monitored. Those two things really stuck in my mind as just the kind of thing that just happens around here. It's in the air. These things happen. That was quite a thing to deal with in the first year. Anyway, we didn't have any more of those kinds of episodes.

06-01:09:16
Burnett: Those kinds of things were happening everywhere. Maybe not the male sexuality, but there's a recent example at Northwestern that comes to mind. It was happening everywhere, and during the Culture Wars of the early nineties, especially — that was one of the high points — it never really went away. Is there a particular challenge for Berkeley? Has it always been the kind of whipping boy of conservative media, or had that not really fully rolled out yet at that point?

06-01:09:53
Gray: No, no. If this episode had happened at a public university in the Midwest, I don't think it would have made the *Wall Street Journal* op-ed page. I think we are a symbolic campus in a lot of people's minds, and we're like a lightning rod. I don't think that's any different today than it was back then. Maybe worse today, I don't know. But no, that was absolutely the case. You mentioned the Ward Connerly / John Moores episode. That was another management challenge. That was a little bit later. John Moores was a very successful San Diego entrepreneur, who was appointed to the regents in, I believe, '99, by, probably, Gray Davis. By 2003 or so, when I got to know John, he was actually chair of the board. He was appointed chair of the board of regents that year. Remember, we had moved from the 1980s through Prop 209 on the campus. Our campus had adopted something called comprehensive review on admissions, which meant that you looked at each case of — let's just take freshmen admits. You look at each case individually, the particular personal characteristics, achievements, economic status, the school they came from, and weigh those factors, in addition to test scores and GPA.

06-01:11:36
Burnett: But not race.

06-01:11:37
Gray: But not race, no. Not race. John became convinced, somehow, that the Berkeley campus in particular, and more generally the whole system, but especially the Berkeley campus, was using comprehensive review as a way to circumvent 209. This belief was that, in fact, we were giving preference to minority kids, historically underrepresented minorities, relative to everybody else. He, as a regent, asked for all the raw data on the admissions over a period of years, took that data, and using his own staff and his own computers and his own approach, did all sorts of analysis to demonstrate his thesis. It became a real issue, because he was talking to the press about this, more or less continuously. We analyzed the same data, came to different conclusions. You can cherry-pick data and make it say almost anything, and he was able to find specific individual cases where a specific, historically underrepresented minority student was admitted with a lower SAT score than a non-minority student that was denied with a higher SAT score. Well, that does happen. You're going to get that result now and then with comprehensive review, because there were other factors that weighed more heavily. But that didn't cut any ice with John.

At one point along the way, the regents appointed a study committee, chaired by Joanne Kozberg, who was a regent, and Larry Pitts, who was the UCOP provost at the time. I was on that. A number of other campus people across the system were on it. We had many meetings and worked for a period of four or five months. We just didn't make any progress. John was adamant. We just couldn't convince him. There was just no meeting of the minds. At one point during all that, I remember Bob Berdahl and I and a couple of UCOP administrative people drove down to meet with John. John had a beautiful palatial home right on the eighteenth fairway at Pebble Beach, and we drove down there and sat in his living room and spent a couple hours trying to convince him. It was a perfectly friendly, nice conversation, but he just was not persuadable. That would have all been fine, except that he would talk to the press about every week on this and lay out yet another finding. This became a real issue with the rest of the regents, because most of the rest of the board of regents were not sympathetic to his ideas. Eventually, the whole thing faded away. The regents actually, I don't think the right word was censured him, but they publicly disavowed his views. He stayed on the regents for a couple years and then stepped down, long before his twelve-year term was up. I think there were some small adjustments made in admissions. I don't remember exactly. At least to a first approximation, nothing really changed. But a lot of damage was done to the credibility of UC's admissions in the eyes of the public, where you have a regent taking that position and being so public about it. He never disavowed or changed his mind. He just gradually faded away. That was painful. That episode was difficult. A lot of us spent a great deal of time and effort on that, and it didn't really come to any particularly useful conclusion.

06-01:15:55
Burnett: No. It just felt like a bit of a waste.

06-01:15:59
Gray: Then there were two other controversies that stand out. One was the patent controversy in '04, '05 that we've already talked a lot about in one of the earlier sessions, about patents. I won't say any more about that, except, again, if you fast-forward to today, the campuses have arrived at a seemingly pragmatic approach, where, instead of trying to do "one size fits all" on patent policy, you recognize that there are areas of campus where patents are critically important, and we should be doing it, and can perhaps realize revenues there, others where it's not so appropriate and traditional. But more importantly, instead of trying to realize revenues through patent licensing, per se, it's better to think of the patent portfolio as a piece of relationships with the corporate people who are going to translate those patents to useful products and make it just part of the overall relationship that could have many other elements. It could have research sponsorship. It could have corporate philanthropy. It could have start-ups. It could have entrepreneurship. Think of patents as one element of a much more comprehensive relationship, as opposed to trying to derive maximized revenues from patent royalties alone. I

think that general way of thinking about patents has become pretty much the thought process within UC, and certainly on this campus.

The last one I thought I'd mention is the salary controversy that you talked about. Bob Dynes started here as president in 2003, and was here, I believe, about four years. He came at a really tough time, the absolute worst time in the budget crisis, because that was when the really big cuts were happening. I think he was pretty preoccupied with that. The origins of the salary issue date to an earlier era, back when David Gardner was president. When David Gardner left, you may remember there was a lot of controversy about his severance package. Dick Atkinson inherited the negative consequences of that, and one of the results of that was that Dick, together with the regents, adopted a lot of very detailed processes for approving salaries of senior management group people. Not only salaries, but things like car allowances, and anything about compensation of a management person. Most of the deans and above, people in the UC system are on what's called a senior management group appointment, which is different from a faculty appointment. That was fifteen years earlier. If you then progress through the intervening years of the Atkinson years, they were probably excessively burdensome, and the campuses fell in the habit, and the UCOP staff fell in the habit, of not exercising all of them fully.

So by the time Bob Dynes came in, a lot of those weren't being implemented, even though they were on the books. I don't think they comprehended that quickly enough, and over the period of the first year Bob was there, the *San Francisco Chronicle* had done a lot of public record requests, and essentially uncovered the fact that these processes were not being followed religiously. That really caused tremendous difficulty, because it looked like — and maybe in some instances it was true — that we just weren't following the right process when it came to setting these executive compensation levels. It wasn't everybody, but there were instances where that was not being done properly. It was just really painful for Bob. The regents were very upset. I think it can honestly be said that he kind of inherited the problem, and it could have been rectified if it had been focused on more quickly. The press just had a field day, and it was painful. On this campus, we didn't have any of the egregious cases, at least not that I recall, that were featured in the press, but we had audit after audit after audit. We had a lot of activity to try to explain and be transparent about what was going on. It was not a fun time. What was really painful was just watching Bob have to deal with that. It really was painful for him.

06-01:21:47

Burnett: I suppose there's what becomes a fixed narrative in the press, and therefore, to an extent, among the public. This is a public institution. It's a time of austerity. I think, leaving aside some kind of malfeasance, or not following proper procedures, just the compensation itself becomes a problem in the public mind. They don't see why someone should be making more money when other staff are having their salaries frozen. I think it was an issue for Mark Yudof, even though there was no malfeasance. It was just, "we don't like him making that much money."

06-01:22:36

Gray: Well, it is. It's been an issue ever since I've been here. Executive salaries — it's very hard for the taxpayers of the state to understand why a university president or campus chancellor should get paid what they get, when the governor only makes far less. Our chancellors in the UC system are paid at a level that's in the bottom quartile of university presidents across the country, particularly when the privates are considered. It's just part of the landscape with public institutions. It's probably going to stay that way into the future.

06-01:23:30

Burnett: I think so. There are some other struggles that you were dealing with in managing the organization. Do you want to talk about some of those that you encountered?

06-01:23:45

Gray: Having now watched some successful chancellors, I've realized just how difficult it is to manage the place. It's such a fundamentally complicated institution. You have a complex, three-part mission of teaching, research and public service, but now public service has morphed into almost two missions. There's now this additional role of economic impact, where state funded public institutions are expected to be engines of economic development of their state. That's somewhat of a new element compared to twenty-five years ago. You have a complicated, multi-point mission. You have a very large number of constituencies. The faculty, the students, the staff, the legislature, the local politicians in Berkeley, the regents, the UCOP staff, the taxpayers of the state of California. You have an extraordinarily complicated array of constituents. Making decisions in that context, it really requires some structure.

Now, in retrospect, I realize different universities do this differently. We had a series of meetings that happened on a schedule that we used to make decisions, on the day-to-day, normal course of business. We had a council of deans, in which the deans get together once every two weeks. We had an annual cycle for budgeting for the allocations to academic units, and an annual cycle of FTE allocation. Very systematic, process-based. We made in-year budget decisions in a group called the VCAC (Vice Chancellor's Advisory Committee), which met once a month. All the vice chancellors got together in a room, and any out-of-cycle, extraordinary thing that came up, like you needed to fix a roof leak in a building, anything like that, you figured out, are you going to do it, yes or no, who's going to pay for it, how it's going to — those got dealt with on a month-to-month basis and a systematic — it was like family court. Somebody brings in their case. Okay, we need this. Yes or no and who is going to pay. There was a lot of process involved in the day-to-day decision making.

Then there are the extraordinary things that happen, like 9/11, and the SARS epidemic. You may not remember this, but one of the reasons that Gray Davis got recalled is his handling of the California power supply situation. We had a shortage of power-generating capacity in California. We had a significant number of power outages in the early 2000s. When a power outage happens here, and the campus shuts down, the dorms shut down, at three o'clock in the afternoon for example, and it lasts until the next day, it's a big problem, because where do you put the students? They can't go back to their dorm room, stuff like that. We had a fair number of those kinds of things. Bob Berdahl, I thought, had a very effective way of dealing with these situations. The first thing he would do is get everybody that had directly relevant responsibility, in one room. I remember, in the 9/11 case, for example, I happened to be in San Diego on that day, but he assembled everybody in the chancellor's conference room. I actually was on the phone. You had each person there who had a relevant role. The police, the public health people, student affairs, university relations, and a number of others. There's a lot of value in that. When you have something as complicated as this campus, getting everybody together in one room to hear from every viewpoint, is really valuable. I guess that was a lesson I learned from Bob. In 9/11, there was a period of time, early that morning, when everybody thought the country might be under attack and more would follow the initial events. A lot of campuses shut down.

06-01:28:29
Burnett: LBL [Lawrence Berkeley National Laboratory] might have been a target.

06-01:28:32
Gray: There was a lot of decision-making to be made there. The lesson I got from that, along with later ones, like — well, the SARS [Severe Acute Respiratory Syndrome epidemic of 2003-04] was before I was over there, but similar kind of situation — you've got to make sure you get all the people with relevant information in the room. The way the campus handled the SARS one was interesting, because the public health aspects we had covered. We have great people in our public health school that were extremely helpful. We instituted some policies for returning Asian students that made perfect sense but we didn't communicate the rationale very effectively for Asian students and alumni, so there was a negative reaction to this there. That was patched up and all was well afterwards, but I remember that well, because it illustrates the importance of having all the key people in the room to make decisions in situations like that. I thought that was a useful learning process.

06-01:30:35
Burnett: It is like a city, isn't it? It's like a large city, at least in terms of its "GDP."

06-01:30:41
Gray: I think being chancellor of a place like this is much more like being a mayor of a middle-sized city than it is like being in the private sector, because it's a complex, diffuse mission with a vast number of constituencies and

stakeholders that you have to be cognizant of. In most of the private sector, the metrics are a simpler — of course, it's a bad generalization, but often it's simpler. In publicly held companies, the mission of creating and protecting shareholder value trumps most other considerations.

06-01:31:24
Burnett: Others have said that you're an important part of the smooth running during this period, that you are very thoughtful and methodical. The words that come up, again, are "careful, thoughtful, cautious," and not in a bad way, in a very good way. I think we talked about this prospectively, when we were talking about your time at Fairchild, about where the particular talents that you have come from, and how you contributed. We've talked about a lot of other people who were really key and really crucial. Let me put it this way. How do you thrive in this environment? What gets you animated? When do you feel your talents engage, and what are they, when you come to these questions and these problems and these challenges?

06-01:32:33
Gray: Well, I'm glad to hear people think I did a good job. I'm not going to necessarily second that, but that's nice to hear. I never thought much about that, actually. Let me think about that for a second. This is going to sound very pedantic, but just being thorough is important. In a job like that, there are a lot of things that are easy to do. The hard decisions are usually ones where somebody's going to lose and somebody's going to win. There's going to be baggage for the campus and for some people, and for you personally. It's easy to say yes to things. But it's hard to say no. Or it should be hard to say no, because you're really trying to support people. When I found I had to do something hard, which was pull back faculty positions from deans where they'd already started searches, I made it a point to — I used to take people to the Faculty Club a lot, buy them a glass of wine — but take the time to explain in detail why you had to do that, and try to do damage control. When you had to do a hard thing, do everything you can to at least explain to those people, spend the time to really explain why you had to do what you had to do. On the easy things, like saying yes, well, you don't need to spend much time on that. They're going to shake your hand and walk away.

I guess the other thing was never let anything fall off your to-do list. I always had this long list of things to do, and I had twenty or thirty or forty things on it all the time. I never let anything fall off. Whatever got on there, there was some end where you said, this is either finished or not. There's some end state. Those things on the to-do list, most of them required somebody to do something. So make sure there's some individual, whether it's a dean of a school or a staff person or somebody, that's working on it. The next thing to do is probably call them up and say, "What's happening?" It's sort of a work process thing, I guess, of just making sure that you don't let things fall off the table that don't get done. That sounds incredibly sort of, in one way, obvious, and in another way, kind of boring and sort of pedantic. It's surprising how simple things like that matter, and how, if you don't do those things, it doesn't take very long for people to realize that you're not really following through on things, and you say things but then nothing ever happens. I think that's really important. The other thing, that we've already talked about, is just the people thing. I won't say all that again, but I think by far the most important thing is just to get people energized and enabled and support them and then make sure they're successful. You've already alluded to that.

06-01:36:55
Burnett: There is a bit of engineering in that, that you are thinking about work flow and process. Some people talk about a problem that folks have is they get something 95 percent done, and it's that other 5 percent, bringing it over the finish line. I guess you might say something like you do sweat the details. Even though it's at a very senior position, and there's tremendous delegation in that, you do have to watch the finish line in all these—

06-01:37:26
Gray: Following up, yeah. You tell somebody to do something, and then two weeks go by, and you've got to go back and say, hey, is this done? I guess there's another way to say it. I hadn't thought of it. I used to tell my grad students all the time, "You're only as good as your worst presentation." That way of thinking is not a bad one to bring into a job like this, because you really are pretty much only as good as your worst effort. I tried to keep the quality level up of executing on things.

06-01:38:11
Burnett: So you are in charge of this. It's almost like a governmental thing. There's a governance side to it. There is the faculty senate, and there's all of that that you have to deal with, and there are the multiple stakeholders. At the same time, it's an organism that is building and expanding to some degree. At least, there was building during — there were these projects. Ground was broken in 2002 on — now I'm blanking on the hall. But it was finished in 2006. So, really, during that time, you had—

06-01:38:53
Gray: I think that's Stanley Hall you're talking about.

06-01:38:54
Burnett: You watched a building go up during that time.

06-01:38:56
Gray: Yeah, there was a lot happening. The capital projects — there's another great topic. I think all campuses struggle with this. We've struggled with capital projects, and I do recall that we realized we should be doing better when we had a lot of difficulties with the Haas Pavilion. Haas was classic. Changes were made during the project to the scope. There were difficulties with cost overruns. There had been some unrealistic costing at the outset. It seems almost built in. Part of the difficulty was that in that era most of our capital projects had mixed funding, with some state funds, some donor funds. Often,

the project is started before the complete funding picture was identified. There were many bosses. There's usually some dean or some academic unit or other user that's going to occupy the building, and they change their minds and they have certain demands. There are a lot of complexities to completing projects here that have made it a challenge over the years. Ed Denton was appointed Vice Chancellor for Capital projects in the late 90s to try to address some of the challenges, and he made some progress. In the years since I was there, there have been some new, innovative things tried. I think things have gotten better. Maybe that's a good segue into — just to finish up, since we're running out of time here — two things I had mentioned.

One is when Bob Birgeneau came in '04. I considered being a candidate for that, and I just decided I wasn't the right person. I didn't feel like I had the right skill set to be a chancellor. Plus, I was kind of burned out. I'd had ten straight years of doing administrative jobs. Bob, as you know, had been dean of science at MIT — he's a very distinguished physicist — then went to Toronto as president there. Had learned a lot at Toronto. There's no substitute for spending a number of years as president of a big research public. Then he came out here and was, from my perspective, a great chancellor here, and did a great job. I liked working with him. He had a very, very different style from Bob Berdahl. Bob Berdahl was a very consultative person who wanted to talk to a lot of people whenever he made a decision, and that worked well for him. Bob Birgeneau is a more decisive leader. He talks to a few key people, but likes to make up his own mind fairly quickly, which is also a good quality. We worked very well together. I worked with him for two years, and then I was just ready for a break. George Breslauer came in and succeeded me. I had a great time getting him oriented. One thing Bob Birgeneau brought to campus that we needed, and that I think helped a lot, was a sensitivity to and passion for equity and inclusion. At the time, I probably saw that as maybe overemphasized, when he first started. Now, fifteen years later, I see that it was the right thing. It's become such an issue for universities in general, and I think he helped us. I think we're better off because he made that a major emphasis when he started. He appointed the first vice chancellor for equity and inclusion, and that was important. He's been great, and I loved working with him.

One of the first things he encountered was the stadium project. So I'll just finish off with that. The stadium was just a nightmare. The place was falling apart. I laid awake nights, worrying about this, because if we had an earthquake when that thing was full of fifty or sixty thousand people, we were going to have a mass catastrophe there. It was not earthquake-safe. There just wasn't any good solution. None of the alternatives looked good. Fixing it up was going to cost staggering amounts of money. One obvious option was tearing it down and having our team play at the Oakland Colosseum, which most reasonable people would have suggested. It didn't take very long in talking to our alumni base to realize that was not practical. A lot of our alumni here met their wives at football games in that stadium. It's been a part of their lives forever. Moving football to another venue was a non-starter, really, because we're so dependent on those people and keeping them engaged. It was just a conundrum. When Bob came, we had many conversations about the fact that we've got to do something. Bob Berdahl just never was able to kind of figure out — it was just too difficult. We couldn't figure out what to do.

The stadium was planned and constructed after I left Cal hall, but I made one contribution. My idea was "Why don't we get a task force together of all constituencies? And I've got just the right person to chair that: Karl Pister." Karl has never forgiven me for this. Karl chaired that group, and six or seven or eight years later, we had the stadium — well, when did it open? I don't know, 2010. Five or six years later, we had the stadium. You can find all kinds of people who will second-guess that, but I suspect that if you're realistic, probably that was the only realistic alternative, really. Incredibly expensive, and we're going to be paying that off for a long time, but the alternatives were probably worse. It's solved. We have a stadium that's a great facility, and I think the hardest thing about it is access. This is not an easy place to get to. Karl is such an incredible asset for the UC system, and that was his last real large undertaking. He really did a great job on that. Remember when we had people in the trees? Talk about an adventure. He stuck with it, and the campus stuck with it, and we got it all done. I believe, when you get twenty years down the road and people look back, even though there's going to be some second-guessing because of the cost, I think people will see that it was probably the best alternative. All of the stadium work happened after I left Cal Hall [California Hall, the UC Berkeley Chancellor's Office] – Bob, George, and Karl along with many others made that happen.

06-01:47:00
Burnett: We were just talking about the importance of place to research, but there is something like the soul of UC Berkeley, and that has an enormous impact on alumni. So the place of Berkeley has tremendous importance for the people who come through here, who teach here. So that was probably a good call when you're thinking about that. It would seem to be an important aspect of the identity of the institution.

06-01:47:32
Gray: Yeah, I think that's right. Well, we can maybe talk about some of that when we do our final session.

06-01:47:45
Burnett: Right. Very good.

[End of Interview]

Interview 7: May 9, 2018

07-00:00:18
Burnett: This is Paul Burnett interviewing Paul Gray for the University History Series. It's May 9, 2018 and this is our seventh and final session. So we were last talking about your time in the executive vice chancellor position and weathering the various storms. And there were a few small and some large ones, as well. And I'm wondering if you can talk a little bit about working with the chancellor at that time and what you were doing with him.

07-00:00:55
Gray: Thank you, Paul. Good to be doing this, and it's been a lot of fun. I'm kind of sorry to see us come to the end because it has been a lot of fun. I said a little bit about Bob Birgeneau last time and some of the things we worked on together, but I did leave out a couple of things that ought to be noted about his chancellorship. We worked really well together. He had a very different style from his predecessor, Bob Berdahl. Bob Birgeneau is a very decisive person and that's a good thing in a chancellor. Bob Berdahl liked to gather a little bit more input over a little longer period of time. That style works, too. But two things about Bob Birgeneau's tenure really stand out in retrospect. Most of this happened after I stepped down. We worked together for two years and then he went on to serve eight or nine years by the end of —

07-00:01:50
Burnett: Yes, 2013 he finishes.

07-00:01:54
Gray: So most of this happened afterwards. I told a little bit of the history last time about the stadium and how it came that that got built with the help of Karl Pister. But, more generally, Bob was very aggressive about improving the campus's infrastructure, particularly buildings, in order to support the mission of the university.

Two examples of that were the British Petroleum partnership, which came in, I believe, '07 or '08, and was a multiyear, very highly funded research program in biofuels by British Petroleum. That went on in one form or another for almost ten years. It funded a lot of research here and ultimately resulted in the construction of a building, what ultimately became the energy biosciences building, funded at least in part with funds from that agreement. That was a pretty bold thing because the BP agreement funded part of the cost of that building but not all of it, and there was some debt involved. Actually going ahead with that project required some risk taking. But I think it was a good risk because today, now that the BP program ultimately has come to an end, that building is used for a lot of other things, including the new Institute for Genomics, Jennifer Doudna's institute, which is going to be in that building, and including some of the bioengineering faculty. That department has grown now and they're all over the place. So taking that chance and going ahead with that project and building that building was one example of Bob's decisiveness.

I think it was, in retrospect, the right thing to do. Kind of a bold thing to do at the time.

He also built, along with a lot of other people, the Li Ka-Shing Biosciences building near the same site, on Oxford Street, another very large, very important biosciences facility for the campus. If you look at them together with the stadium and lots of other smaller capital projects through those years, they were pretty ambitious. They involved a lot of cost, many times requiring taking on some debt. I think a chancellor who was perhaps more conservative financially, fiscally, might have had some hesitation about taking some of those on. But I think if you think about the Berkeley campus, and we'll get to this a little bit later today, and the uniqueness of it, if you can't stay at the forefront in physical facilities that support the fundamental discovery of science that we do here, you can't be competitive. You can't compete in the tier that we participate in at the very forefront of science and engineering. I think he foresaw that we have to stay competitive and we have to have these facilities and we need to go ahead and take the risks that it takes to get those done. So I think in retrospect those were good decisions.

07-00:05:24
Burnett: This is a shift. In the Heyman years there's this move to really get external funding because of the state's withdrawal of support from the university, including from even the federal government, winding down some of the national facilities and so forth. But in a sense, Berkeley has always had this support outside of the state. There's been the Hearst support, for example, which created the modern campus. And so the excellence on campus has something to do with this support that is outside of the regular public university support and that's just in a sense a revival of that legacy to some degree.

07-00:06:13
Gray: Yeah, I think that's true. Let me mention one other thing that Bob brought to campus. When you do his oral history you'll hear a lot about this. Bob came from a background that was not wealthy at all. He often tells of his early years when he was able to go to a research university because of financial aid and other kinds of help and wouldn't have been able to go without that. Throughout his career he's really focused on access and helping disadvantaged students get access to a university education. When he was here at Berkeley that was a key issue. He did a lot of things to try to improve that. One of them was to introduce this idea of a middle class financial aid scholarship. He believed that the really disadvantaged students whose families were at the bottom end of the income spectrum, we had ways to help them. But the ones in the middle, middle-class families, often didn't get either any aid at all or not very much of their tuition covered. And he addressed that. He instituted and implemented a middle-class, need-based financial aid program here on the campus, the result of which is that today about 40% of the undergraduate students here don't pay any tuition at all, something that doesn't get covered

very often in the press but is a really impactful thing that is part of what makes this campus what it is. One of Bob's basic ideas was that it actually helps us from an access perspective to have higher tuition because the more wealthy families to pay more tuition, which fills in money that can be used to subsidize the low income and middle income students. That's a concept that he tried to articulate but which he never made much progress in convincing the regents and the general public that it was okay to raise undergraduate tuition and fees, as you can see because we haven't raised those very much in recent years. But I think he really made a lot of progress in helping this middle part of the income spectrum of families get access to UC. That was really an important contribution.

07-00:09:00
Gray: I just wanted to mention those two things about Bob's chancellorship. I'm really glad you're going to be doing his oral history because he'll have a lot of things to fill in. I've left out a vast number of other issues he had to deal with during those years.

07-00:09:15
Burnett: We'll cover some of those, I think, in time. So this is a time of concern about access, which is exacerbated by the crash and the crisis, and we'll talk a little bit about that, and the rise of the Occupy movement and so on, and this continues to this day. I don't know if this is fair to ask, kind of an opinion question, not necessarily inside your domain. The public universities in California have responded to the best of their ability, I think. And I wonder about the preparation. And this is something that will come out in these National Academy [of Sciences] and National Research Council reports, about access and preparation of students from K through twelve. I guess it's perennially on the radar. Is that something that you were talking about and thinking about with folks in the 2000s period?

07-00:10:32
Gray: Preparation is a critical issue in higher ed. If you take the broad spectrum of California higher education, everything from community colleges, CalState [California State University], and UC [University of California], preparation's a gigantic issue. And it has a big impact on retention in, for example, the community colleges and CalState. But if you look at the UCs, this phenomenon that we talked about last time that I'm going to touch on again, the fact that the number of qualified UC-eligible high school seniors in the state is going up, not because the population's going up but just because more kids are going to high school and graduating from high school. That number's going up and the number of seats within UC is increasing very slowly. The result of that is that the quality of the students that are enrolling on this campus and to the other selective UCs is so high that preparation doesn't really come up on the radar screen very much. They're all very, very good students. The total number of students who are accepted and actually enroll is down below 20 percent of the number of who apply. The preparation of that small highly selected group is pretty good. But that's a special case. If you

look at higher ed more generally across the country in all the different levels, all different states, it's a huge issue. So we have a little bit of a special situation here on this campus and in the other selective UC campuses. I suspect that at the less-selective campuses, like Riverside and Merced, it's a big issue.

07-00:12:21
Burnett: Well, I'm wondering if you want to say more about your time as executive vice chancellor? If you feel that we have explored that as fully as we're going to?

07-00:12:31
Gray: I think we've covered it. Let me come back at the end with some observations about that.

07-00:12:36
Burnett: Okay. Well, so in 2006 you are retired.

07-00:12:42
Gray: Right. I left in July of 2006 and my wife and I took a long sabbatical to Imperial College London. Our host there was a faculty member named Chris Toumazou, who by chance is sort of the equivalent of Tom Budinger at Imperial College. He founded and led their Biomedical Engineering Institute, which now has a giant building in West London and is a very impactful person. Chris is a long-time friend. We spent that fall in London. Oh, boy, those sabbatical leaves — for assistant professors who are seeing this, I need to tell them, be sure you take advantage of those times because not only is it a great time personally but you get a chance to pause and reflect on what you're going to do next and what's important and think outside the box about areas you hadn't thought about. It's just a great experience. We did that and then came back in January of 2007. The most memorable thing for me from that spring was Rich Newton, who we've talked a lot about. But that was when Rich died. And I remember his memorial service very well because I was a speaker there. Events like that have a big impact in the campus community. That was something that shocked everybody because here's this brilliant guy that suddenly passes away.

07-00:14:11
Burnett: And so young.

07-00:14:13
Gray: Yeah. And there were two memorial services within a month or two of each other. We filled Zellerbach [Auditorium] both times, and it was just one of those occasions when everybody kind of comes together and reflects on what's really important to us. It was such a tragic thing actually. And Rich's wife Petra, and he had two teenage daughters at that time, they were fabulous. They were just great people. Petra gave very moving speeches at both of those events. It was just a time of coming together for the campus, really pretty remarkable, a very memorable thing. That happened in early '07. Also, that

period, '07, '08, was the time when the Marvell stock option backdating episode was going on. I spent probably half my time on that during that year period.

07-00:15:11
Burnett: I didn't realize it was that consuming for you.

07-00:15:14
Gray: Well, there was substantial reputational risk, and a lot of risk for the shareholders. I felt a very strong obligation that we had to handle this right and manage it right. I spent a lot of time on that. Anyway, that all got solved and was okay. And then in 2008 I got involved with the Moore Foundation. The person who got me involved there was Ed Penhoet. Ed is a remarkable figure in the history of the Berkeley campus. He came to the campus as a post-doc back in the sixties, maybe early seventies, in biochemistry and he ended up staying and joined the faculty in biochemistry. He was a faculty member there for some period of years and then he left to co-found Chiron, one of the early biotech companies and was very, very successful down here in West Berkeley. I'm not quite sure how many years he was there, probably eight or nine years probably. He was the CEO of the company. The company was very successful, ultimately got bought by another large firm. Then in 1998 he came back to the Berkeley campus as dean of public health, and that's where I got to know him. He and I were fellow deans and we made that trip to Saudi Arabia that I talked about earlier. And then in 2000 I became EVCP so I worked a lot with Ed during the first two years I was in that office. And then in 2002 Ed decided he wanted to do something different. So he went down and became first head of the Science program and then later president of the Moore Foundation. He was there from 2002 until 2008 or so. The foundation had been established in 2000. It had a bit of a rocky early few years, and Ed went in and stabilized things a little bit. In about 2007 he decided he wanted to come back to do something different, including a lot activity in venture capital, so he decided to step down. They were looking around for a new president, and he asked me if I'd be interested. And I said, "Well, I'd like to talk about it." So I went down and met with Gordon, had a memorable lunch with him. The evolution after that was that Steve McCormick, who had been president of The Nature Conservancy, who had served on the College of Natural Resources Advisory Board, and who was a vastly more qualified person in the non-profit world than I was, was appointed president. Gordon decided he wanted me to join the board, which I did in 2008. That was something that was extraordinarily fortunate for me.

Let me just give you a snapshot of the foundation as it evolved and existed then, just taking a little bit higher-level view. In the US, giving in general, charitable giving in general has a magnitude of about two percent GDP [gross domestic product] in the United States. Two percent. That's a big number. Most of that, about three-quarters of that, is charitable individual giving, people giving the way you and I would think of, to your church, to the Red

Cross for example. Some fraction of it, about 12%, is by private foundations. The Moore Foundation currently has a seven billion dollar endowment, gives away about $300 million a year, and that is about the eighth or ninth biggest foundation in the United States. There are two other big foundations in the Bay area, the Hewlett Foundation and the Packard Foundation, both about that same size. We have a hundred staff in Palo Alto and a building on Page Mill Road. It's sort of interesting to recount how the foundation got started. Gordon and Bob Noyce founded Intel in 1968. Now, fast-forward thirty years to 1998, and Gordon is chairman of Intel. This is a year before the dotcom bust. Intel has gone from a start-up to a $400 billion, by market capitalization, company. Now, that'll change very quickly. And another unique thing about Gordon is that he's a frugal guy. In the early years, at least, drove an old car, lived in a small house. He never sold a significant amount of his Intel shares. And so by 1998 he owned a significant fraction of this $400 billion market cap and he had an extraordinary amount of wealth, and decided that he wanted to start a foundation. He retired as chairman of Intel within a year or two of that and started the foundation. But between 1999 and 2001 Intel shares dropped by a factor of almost ten, going from around seventy-five or so down to about ten dollars. There's a wonderful story about how the people involved then were trying to madly diversify the portfolio once Gordon had made this allocation of his shares to the foundation. And in the end, when the foundation got going by 2001, the endowment stood at about five billion dollars. It would have been much bigger if they'd done it a little earlier.

Gordon being a chemist, with a chemistry PhD [doctor of philosophy] from Cal, believed in the importance of measurability, the concept that if you can't measure it, you can't manage it. He and Betty articulated criteria for deciding what we're going to do, with four filters. Number one, is it important? Number two, can we make a difference? Number three, can you measure the difference? And, number four, is there some sort of portfolio effect with the other things that we're doing? And they had strong personal interests in the environment, habitat restoration around the world, strong personal interest in basic science, fundamental discovery, chemistry, physics, biology, and a strong interest in patient care born out of some personal experiences that they had had with hospitals and things of that sort. And they also had a strong interest in Bay Area land preservation, which they do a lot of. So that's how the foundation got started, with those four filters and with those areas of interest. They had wanted to do some investments in higher education, but it turned out that most of the allocations in science were going to higher ed anyway, so they folded those two things in together. So that's the genesis of it. When I got involved the board was four family members plus Gordon plus six outsiders. A wonderful group of people, just great people that I have really enjoyed working with.

I should say that what I just described sounds simple but if you have the requirement that you're going to measure outcomes, it’s much harder just giving money to charitable causes. You have to have a strategy to bring about the difference your trying to make and then how you're going to measure that change. And it has to be an important problem that's national, global, or at least regional in scope. That takes a pretty sophisticated strategic plan for each initiative that you're going to take. That's what these hundred people in Palo Alto primarily do, along with a lot of outside thought leaders. They develop and implement some sort of strategy or theory of change that allows you to tell whether or not you've made a difference after some period of time. Usually it's between five or ten years.

07-00:24:50
Burnett: How new was that in the foundation space? Is this something that was percolating in the air?

07-00:24:57
Gray: That's a good question. It's pretty new. Today most foundations aspire to measurable outcomes — a good way to phrase that is strategic philanthropy. It's philanthropy that makes a measurable difference at the end. That was not the predominant style of philanthropy over the last hundred years, but it has become much more widespread recently. Most foundations today aspire to do at least some of this. Maybe not a hundred percent but they aspire to this model. It's a movement within the community of philanthropy. This is not easy and I think you can find a lot of situations where you can't measure the outcome effectively very well, often because it takes too long. Basic scientific discovery, for example, can take one year or fifty years. How do you measure whether you succeeded in doing that? A lot of time you have to use proxies. Examples for the case of scientific discovery are did you create a new field? Is there a new journal that was created as a result of this scientific activity? You use indicators of impact rather than the actual impact. So that's inevitable because often you can't really measure directly the outcome. In patient care you might be asking did the health of the US population on this particular disease metric improve by *x* percent? Well, it might take twenty or thirty years for that to happen. So often you're using proxies.

Some initiatives do lend themselves to quantitative measurement. One example is habitat protection. One of the largest programs at the foundation has been aimed at protecting habitat in the Amazon. The objective there is to reduce deforestation and preserve habitat in the Amazon Basin. The Amazon Basin is about 5 percent of the world's land area, about the same size as the United States. But it has over 20 percent of the world's biomass because it's so heavily forested. So it plays a huge role in habitat for biodiversity, in global climate, lots of things. Twenty-five years ago, at that point in time the Amazon had been deforested by about 20 percent relative to its historic original state. And it was being deforested at about 1 percent a year, driven by agriculture, illegal forestry, and a bunch of other things. In the intervening years, through the efforts of many, many actors, including governments and foundations and so forth, that rate has been reduced by about a factor of five. Today it's a quarter-of-a-percent or less per year. Now, it's ticking back up. I'll get to that. But the point is that it's a metric you can measure pretty effectively given modern satellite based instrumentation. We've been the biggest private foundation funder for habitat protection in the Amazon but there are many, many other actors and funders including many government agencies in the Amazon and around the world. Since we talked about that, in the last few years that deforestation rate has ticked because of two factors. One is the global demand for the agricultural products. Cattle ranching is a huge problem, cutting down forest and putting in cattle ranches. Illegal timber is another. The economic drivers for those with a billion people in the developing world entering the middle class in the last twenty years is so great that the pressure keeps building. Another factor is that the Brazilian government has gone through a very difficult period of four or five years and the mechanisms that were set up, the management of the national parks, the management of the protected areas, has broken down somewhat because of that. So now the nonprofit community and the foundation world is very aggressively trying to find ways to address that yet again and do better.

I used the Amazon as an example but the foundation has a lot of other programs. For example, they put a lot of effort into nursing over the past decade. We sponsored a new nursing school at Davis, and funded the introduction better nursing practices across the Bay Area in various ways, with measurably better health outcomes. There's been important impact in basic science, including helping establish a new field within Marine Microbiology and an initiative in Data Driven Discovery. The big data initiative [Berkeley Institute for Data Science] on the Berkeley campus is one example of that. Along with a lot of other funders, we support a lot of Bay Area open space preservation initiatives which have helped a lot in avoiding the bay area looking like downtown LA.

07-00:31:16
Burnett: I saw Gordon Moore speak at a Betty and Gordon Moore Foundation event and he was talking about the strategy and part of it is the ability to get out if there isn't progress. So I imagine there's a balance of a requirement or an imperative to have long-term sustainable support of something but also knowing when to cut.

07-00:31:49
Gray: Yes. For the hundred people down there, a big part of the job is exactly that. There's a life-cycle management process for each one of the projects. There's an expectation that, for example, if you're going to fund some science project like the big data initiative, if it succeeds other funders and the institution around it should come in and it should be self-sustaining. It shouldn't need foundation support forever. There's a structure and process around each one of these initiatives to complete these reviews. Unless there's some extremely good reason not to, then the expectation is after the duration of the initiative, perhaps 5 to seven years and in rare cases perhaps ten, the foundation gets out

and goes on and does something else. That's an important part of the basic approach to philanthropy.

07-00:32:50
Burnett: Can I ask one more question? To pull back to the London sabbatical, Imperial College, in 2006, you spoke about an opportunity to take stock, recalibrate, and think about what's next. Was this in your thinking of what was next or something like that?

07-00:33:12
Gray: Something like it.

07-00:33:13
Burnett: What was in play at that time?

07-00:33:18
Gray: I knew I wanted to do something else that would be fun and challenging. I didn't really have any ideas about what that might be. I don't think I had had any conversations with Ed about the Moore foundation at that point. I really didn't know exactly what I was going to do next. But I knew I wanted to do something. I might have done a start-up in Silicon Valley. Also, I had been in conversations with some venture capital people in the Valley about becoming a venture partner at one of the firms down there. I was seriously thinking about doing that. I'm glad I didn't because it would have been fun but the top priority there is about making a good return for your investors. I like the value system and the goal set of the foundation world better, where you're really trying to make a difference on something that really matters in the world as opposed to having this priority of having to worry about the investment side all the time. So I think it was a good decision for me. But I could have easily ended up doing that.

I was on the board for five or six years and then in early 2014 Steve McCormick left suddenly. They needed an interim president and I served as president down there for a year, which I valued immensely. Being on a board is one thing and you see the PowerPoint charts and you have one little toe in the water. But actually running the place for a year, that was a real education and I learned a lot more about how philanthropy really works.

07-00:35:20
Burnett: And just to be clear, from when to when was that?

07-00:35:22
Gray: January of 2014 till January 2015. It was a great experience. The nonprofit world, particularly the foundation world, is populated with people who are a lot like those in a university. These are people that could be in private industry, could be doing anything, but chose that line of work because they're committed whatever the mission is, the environment for example. I really enjoyed the environment a lot. You might think it's easy. What's so hard about giving away $300 million a year? But it's actually hard work because if you're

going to really be true to these measurability criteria and the impact, moving the needle, it takes a lot of work to develop those strategies. It was fun.

07-00:36:21
Burnett: Well, can I ask you about the board then? Because there are these four areas. There's the four filters but then there's the areas of interest. Environment, basic science, patient care and Bay Area land preservation or land preservation writ large. So the board composition. You're an engineer and a scientist and someone who has expertise in management of large institutions, higher education. Were there people who had the rose pinned on them for one of those four specific things or was it—

07-00:37:01
Gray: That's a great question. This is top of mind now because we have a lot of retiring board members and we're thinking very hard about this question. To a first approximation, yes, there is some alignment of individuals with program domains, but it doesn't match up very well. Our board members are Bruce Alberts, who's a well-known biologist from UCSF [University of California San Francisco], and a former National Academy of Sciences president. John Hennessy, who's the former Stanford president, and a computer scientist. Rosina Bierbaum, who was the Dean of Environmental Science at University of Michigan. She's our environmentalist. And then the other two folks are financial types. Jim Gaither, who's a prominent Bay Area attorney and investor who was chairman of the Stanford board of trustees for many years and is a generalist. And then Ken Siebel, who's a financial investment manager and who's been associated with Gordon for many years. So it's a heavy preponderance of science and engineering and one environmentalist and a couple of financial and business people. We need to shift that a little bit. We don't have anybody other than Harvey Fineberg, who I need to talk about, who's a healthcare person, and we need that.

But your question actually gets to another point, which is what does the board do. Foundations vary a lot in this domain. A critical decision comes when it's time to get out of a given area and you have to decide what to do next. In many foundations the board comes in with bright ideas, which is not bad in and of itself but if not managed well you end up with a portfolio of projects that look more like a bunch of board member pet projects. That's very, very hard to manage and hard to have cohesion. We don't operate quite that way. If we have some new capacity to allocate, we usually involve a panel of outside people. The staff of the foundation runs a process and we do a landscape survey and try to ascertain what it is we want to do next. About every three years we have a board retreat where we blue sky things. But in the end, in most cases the staff, aided by external advisors, comes up with a strategy and ideas and the board is a passive reactor to that. That's a very important distinction, because I really do think you need cohesion and some strategy, uniformity, and logic and structure to the whole enterprise. And that gets that for us. So it's very much a staff driven, external advisor driven, bottoms-up process in trying to figure out what to do next. The big data initiative was like that. We have a science advisory board, a bunch of distinguished external advisors. They helped develop that idea. Then the staff proposed it and that's how that came about. It wasn't a board idea. Now, foundations vary all over the map on that particular dimension on how the place works.

07-00:40:36
Burnett: Well, I imagine the passive role, what that means is that there is an evaluative dimension. The board is there to ask "does this work?"

07-00:40:46
Gray: Yeah, ask questions. We ask the questions. That's what we're there for. Exactly right.

07-00:40:50
Burnett: And everyone on that board has to have experience with moving these large projects forward.

07-00:40:56
Gray: It's very important to have generalists because while domain knowledge is important you also need a bunch of people that don't know much about that area but just ask the obvious logical questions about why are we doing this and how are we going to actually measure that outcome and that sort of thing. My main job during that year 2014 was to help the board find a new president. Harvey Fineberg had been somebody I knew at the National Academies. He was president of the Institute of Medicine, which is now called the National Academy of Medicine, and a brilliant person. When we did our search, which was a national search for a new president, we persuaded Harvey to come and he showed up in January of 2015. He's been doing a great job ever since. And so now I'm back on being a regular board member and have been ever since. So being involved with that foundation has been a tremendously rewarding thing for me. It's just a wonderful thing to be connected with.

07-00:42:15
Burnett: There's one more piece of the Moore Foundation. There's a founders' intent document, right?

07-00:42:20
Gray: Yes.

07-00:42:20
Burnett: And there was a lot of discussion about this and this is obviously from Gordon Moore. So we've talked about evidence-based metrics for moving things forward and the strategic philanthropy side of things. And another key piece is risk. Can you talk a little bit about that? Are there instances where there has been a dramatic reversal in a project that—

07-00:42:50
Gray: It didn't go well?

07-00:42:52
Burnett: Yeah. Or the board said, "No, let's not do this." Those are two separate questions actually.

07-00:43:01
Gray: Yes. This is another topic *du jour* in the foundation world. As you might imagine there are several organizations of foundation professionals. They have meetings and seminars and risk is a topic that gets talked about a lot. And, like many other foundations, we discussed six months or a year ago how much risk are we comfortable with. We hadn't really had explicit discussions about that up until maybe a year ago, but we had a foundation all-hands meeting that I participated in a few months ago about that very topic. I think the consensus was that even though we didn't explicitly realize it, we do fairly often take on projects that have big risks if the impact of being successful is a big. I don't want to take the time here to cite them, but there are lots of examples where we're investing twenty or thirty million dollars a year in projects which may or may not work. One current example is this in that in the conservation program we're moving to a market-based approach where we're trying to inject sustainability into the supply chain. One simple-minded example of that would be if you go into a Safeway and buy package of roast beef or ground beef, there would a label on the package that tells you exactly where that came from, where it was grown, and whether or not it was from a certified, sustainable supply chain, so you might preferentially purchase that over a non-certified product. That exists a little bit in some areas but not globally and not totally. In order to achieve that you have to involve all the participants in the supply chain, which is unbelievably complicated, all the way back to the rancher down in Brazil, who participates in a way that's auditable and can be verified. But the hope is that in western countries, at least, and increasingly across the world, consumers, as well as investors and other market participants, will pay for and select sustainable products. That can be a tremendous driver to contain the forces of deforestation and other degradation of habitat. We're trying to build components of that infrastructure. That's a huge risk because there are a million ways that could fail and we're only one of hundreds of players in that. Plenty risky. I don't think anybody, in our foundation at least, thought about it quite as quantifying risk down to a percentage number, but I think there's an instinctive willingness so that if the payoff is big enough, of course we'll take the risk. Even if we only have a small percent chance of succeeding, if it's going contribute to solving global warming, well, heck, let's take the risk. I don't think I ever remember the foundation board saying no to a project because it was too risky. They do say no when they just don't think it's going to work. just not likely to have the effect you're talking about and even if it does, the impact's not going to be very great. And the board very rarely says no. The board says, "Hmm, maybe you'd better go away and think about that some more and come back when you have it figured out," and sometimes they never come back.

07-00:47:18
Burnett: You have external advisors. There's deep specialized expertise that's always in play. But at the middle level would you say that it's fair to say that the science at the center of the foundation is benefit-cost analysis? Is that kind of what's—

07-00:47:42
Gray: Yeah, that's fair.

07-00:47:43
Burnett: Yeah?

07-00:47:43
Gray: That's fair. I think that might not be on a spreadsheet. But intuitively that's the thought process that's going on. I think that's accurate. Part of every grant, every initiative and grant proposal is an assessment of risk, and what we are doing to mitigate that. But nobody actually puts number on it, like “there is 10 percent probability of this happening.” I don't think we get down to quite that level.

07-00:48:22
Burnett: Well, it sounds like it was a wonderful experience. Steve McCormick comes in from The Nature Conservancy and he apparently is responsible for globalizing that. Because essentially for the longest time, since 1952, it was a land-acquisition operation and he turned that into a global conservation mission. I can't help but think that that had an impact on how the Moore Foundation expanded its operations into these domains. I don't know if that's true but it sounds like a Steve McCormick impact.

07-00:49:00
Gray: Steve contributed a lot to the environmental side of what was going on at the foundation just because of who he was. He's a consummate environmental professional. I'm not sure Steve actually proposed the markets based initiative but his way of thinking fostered the environment that that came out of. And I think he deserves some credit for getting that going. Establishing protected areas, which was the basic strategy of the first ten years, had and still has a lot of impact but can only take you so far. When the pressure gets great enough, those protected areas are only as durable as the local governments, the indigenous people, the state government, the national government, whoever's providing the forest rangers and infrastructure, the things that keep that area protected. If those institutions break down or the political winds change, it's not durable. And so it can only take you so far, especially if the pressures continue to get greater and greater. That was really the thinking that led to looking at the markets initiative as a more global way. And I think Steve deserves credit for getting the thought process started for that.

07-00:50:41
Burnett: It sounds like you've had a tremendous impact in the Moore Foundation and you also received a lot of satisfaction, fulfillment—

07-00:50:53
Gray: Absolutely. I don't know about the impact part but I sure got a lot out of it. It's been a lot of fun. Oh, I should just finish up talking about Ed Penhoet a little bit more. It's hard to find somebody that's had the impact in so many different fields. Have you done his oral history? Is he on the docket at all?

07-00:51:18
Burnett: I haven't. Sally Hughes interviewed him [in 1997] because she did a project on Chiron.

07-00:51:27
Gray: The guy started a highly successful biotech company, was incredibly successful in the private sector, was venture capitalist, was a dean of public health here at the Berkeley campus. Very impactful person in the academic world. And in Washington he was a long-time member of the PCSAT, the President's Council on Science and Technology. He had a big impact in Washington doing that. He's really a renaissance man. I'm a big admirer of Ed. He was on the board for a while with me and then he got off that but has stayed on their investment committee. He's still very engaged down there.

I thought I'd talk a little also about that time I got involved with the National Academy of Engineering as a counselor, which is equivalent to a board member. The National Academies are a congressionally chartered organization started in the 1860s, the time of Lincoln, originally as the National Academy of Sciences. The mission was to advise the national government and the government in general on science issues that affected public policy. Fast-forward a hundred years, they added National Academy of Engineering and the Institute of Medicine in the 1960s. That's recently been reorganized to be just the National Academies of Science, Engineering, and Medicine. They have a beautiful building on the Mall in Washington right across from the Vietnam Memorial. Today, it's a fairly large organization that provides advice to the government, including congressional committees, different agencies in the executive branch, and also to a lot of state agencies, again on issues of science and engineering and medicine that are relevant for public policy. They do several hundred consensus studies, convenings, and other kinds of reports per year, always involving a panel or a group of outside experts recruited from around the country and brought together to consider the question that's been posed to them by whoever's sponsoring the study. Its value is independent, objective scientific advice on often contentious matters of public policy. I served for six years. Another important role of the academies is recognition of eminent people. Getting elected to the National Academy of Engineering, Science, or Medicine is a big honor. Universities love to brag about how many academy members they have on their faculty, and it’s a metric that a lot of people use to compare universities with each other in terms of their research profile. In the case of engineering, we elect about sixty new members a year. It was a wonderful experience going to Washington and sitting through all those meetings where public policy issues get discussed. I was also a member of the board of the National Research

Council, which is the organization that actually does all those studies, so I got a chance to sit through all those reviews of the different parts of that NRC program. It's very, very educational. I just learned a tremendous amount. Not sure I had a lot of impact in all those meetings but it was certainly educational.

Two Berkeley people are prominent there on a continuing basis. Dan Mote was a Berkeley campus mechanical engineering professor, and was chair of mechanical engineering at the same time I was chair of electrical engineering here. Dan went on to be the vice chancellor for university relations here on the campus when Chang-Lin Tien was chancellor. He then left here to become the president of the University of Maryland, and served for five or six years, I believe. Then he went on to be president of the National Academy of Engineering when I was on the Council of the National Academy. So Dan and I worked very closely together and still do.

07-00:56:32
Burnett: Yeah, he's still the—

07-00:56:34
Gray: He's still the NAE president. He's ending his term next year. Dan is eighty, if I'm not mistaken, so he's not going to do another term. They're looking for a new president. But working with Dan was tremendous—he's an incredible person.

Another prominent UC person in Washington is Bruce Darling. Bruce was vice president of the UC system for a number of years, initially for fundraising and development, coordinating the campus fundraisers. The president's office has a fairly substantial flow of gift funds itself. Bruce later on took on the role of supervising all of the national labs. He had a number of different roles at UCOP [University of California Office of the President], working both with Dick Atkinson and Bob Dynes, and I think he worked with Mark Yudof during part of Mark's time. And then about 2012 or '13, he was recruited to be the executive director of the National Research Council, which is essentially the administrative head of all of the activities that I described. There are the three presidents of the three academies, the National Academy of Science, Engineering, and Medicine, who are the policy leaders. Bruce is their lead administrative and operational person and manages the whole thing. It’s a big important job. With those two people, UC is well represented back there.

07-00:58:24
Burnett: Can you talk a little bit about some of the key — because you mention a couple hundred reports are produced. A handful get picked up. A congress person might pick it up and lead a crusade or it might have been commissioned by — the commissioning comes from congressional committees a lot of the time, is that right?

07-00:58:46
Gray: Yes, that's right.

07-00:58:47
Burnett: Most of the time?

07-00:58:47
Gray: More often. Yes, that's right. The first one that comes to mind is the “Rising Above the Gathering Storm” report. I believe the first one was 2005, along in there sometime. Actually, I'm not sure who funded it but it was partially the academies themselves that launched that report. It was really driven by calling attention to the underinvestment by the country in both basic R&D [research and development] and engineering and science education writ large. It highlighted our position in the world relative to all the other countries, India, China, Japan and lots of other, including Western Europe, who were investing more heavily than we were, or at least were investing on an increasing basis, in all of those areas. The report was sounding the alarm. A very good report with a fantastically distinguished panel. The report came out in 2005 or 6 and shortly after that the 2008 crash happened. That resulted in a series of stimulation allocations by the Congress under the ARRA [American Recovery and Reinvestment Act] to try to get the economy moving by funding mainly shovel-ready projects. The Obama Administration put a lot of money into a number of the initiatives that had been proposed in the Gathering Storm report. And that was a great thing. It was good timing. If there hadn't been a Great Recession who knows whether that would have been funded. But it was fortuitous and it had a big impact.

Another major report that gets a lot of press was “America's Energy Future,” which is a similar kind of thing, also mainly stimulated by the Academies themselves. They went out and found people to sponsor it. That was a little bit later, in 2009 I believe. It highlighted an underinvestment in energy, both from the standpoint of climate change and from the standpoint of national security. And I think it stimulated a lot of people to think. It's kind of hard to draw a straight line to things that happened but there's no question that it had a lot of impact in raising people's consciousness about energy and its importance.

As I mentioned, though, there are roughly 200 a year and a lot of them are more narrow and specialized focusing on the interests of a particular congressional committee on a particular topic, so they don't get that much national visibility. One of the key values of the National Academy reports are their objectivity and that they are evidence-based. They undergo a series of independent reviews that is a lot like the review you would get if you submitted a paper to a journal. After the committee produces its report it goes to the report review committee, which I now serve on. We send it out to a bunch of other independent reviewers. We assemble all that and go back and forth with the committee and get the report so that it's scrubbed pretty thoroughly. One of the big problems is that that takes a lot of time. A typical time of flight from the time an agency requests a report until the time they actually get a physical report in their hand is anywhere from a year to two years, and probably averages a year-and-a-half. A lot of times that's just too long. There's some issue that they need to do something about and it's all over before a year-and-a-half or two years have passed.

07-01:03:25
Burnett: And that's pretty fast when you think about a large research project.

07-01:03:28
Gray: Yes. The current leadership there are trying very hard to do something about this. But the whole thing is volunteer run. The committees are volunteers, the reviewers are volunteers, and it's really hard because these are people that do this in their spare time. It gets very hard to speed things up when you have that kind of people doing it.

07-01:03:54
Burnett: Isn't it true that a lot of science and engineering is volunteer?

07-01:03:57
Gray: Yes, I think that's true.

07-01:03:59
Burnett: A lot of the work, especially in the United States, is unpaid labor. People have salaries from other things but that's how it functions. The other thing that makes things more challenging is a larger social and political context that is challenging science. And people have been talking about an anti-science animus since the early nineties but it's acquired a new front, I suppose, in the last few years. I never thought I would see evidence-based practice becoming a romantic rallying cry in the streets but that is where we are now in this time. I don't know what you would want to say about that. It I think speaks to the complexity of the position of the National Academies. Yes, you want to expedite things but you don't want to be vulnerable to accusations that the work was slipshod. With climate science this is the constant problem: “Oh, you haven't done your correct scientific process.” So that's something that you're facing when you're dealing with some of the questions that are coming out of essentially a political space, if it's coming from congressional leadership, that something's in there.

07-01:05:23
Gray: They have to be bulletproof. And if it takes two years, it takes two years. They must never lose the validity of being thoroughly scrubbed and being totally objective. There's always a human element. Every reviewer, every panel member, comes at things with some kind of perspective. But you can make them pretty darn good, as good as anybody can get. If it takes two years to get that, it's worth waiting because of exactly what you said. The world is getting too flooded with information that's not fact-based and we need more of the evidence-based thinking. This is one source of that. I certainly wouldn't advise them to think about weakening the review process.

07-01:06:21
Burnett: Well, before we leave that period, we've talked a lot about impact and you have downplayed a lot of your impact in various domains, which is perhaps a characteristic of modesty. In 2008, the IEEE [Institute of Electrical and Electronics Engineers] recognizes your contributions to the field of electrical engineering with the Robert Noyce Medal in 2008. And there's just a little blurb on the website — "For pioneering the development of analog integrated circuits." Now, this award has been given since 1999. There are only two other award winners who are professors. I don't know if you knew that.

07-01:07:10
Gray: I didn't know that.

07-01:07:11
Burnett: Yes. Henry I. Smith at MIT [Massachusetts Institute of Technology] for his contributions to lithography and nanopatterning and Takuo Sugano for kind of a vague description of his contributions to engineering. And the rest are industry leaders: the founders of companies, the presidents and vice presidents of companies and divisions of companies that made signal contributions: Intel, IBM, Samsung, and SanDisk. So we have covered that period of your scientific career. I'll ask you to exercise your objectivity and kind of describe what made you a good candidate for the Noyce Medal in that context. It's obviously recognizing contributions to engineering. But you're one of only a couple of academic folk. Can you talk about your impact on the field of engineering, your impact on the industry, what made your contributions important?

07-01:08:22
Gray: Hmm. So I'm thinking if I'm sitting on that committee and looking at my CV, what am I thinking about?

07-01:08:31
Burnett: Right. Exactly.

07-01:08:32
Gray: Now that I think about it, I recall that award did surprise me because of the reason you said. I don't fit the pattern. My guess is that I was the provost of the UC Berkeley campus for six years and the UC Berkeley campus is a big part of the Bay Area innovation ecosystem. And that somehow got me over the hump of being like an industry figure. I think that had to be the way they were thinking. Something like that.

07-01:09:10
Burnett: Well, the digital-analog research program at Berkeley, remove that from the history of electronics engineering. Just take it out and include in that the shoulders that you were standing on, the SPICE, BIOSPICE, all of that, all of your graduate students. Take that out of the sequence of innovation. What do you have?

07-01:09:36
Gray: You mean what would be the impact of Silicon Valley?

07-01:09:39
Burnett: Removing it. Yeah, if you didn't have that.

07-01:09:42
Gray: Well, probably somebody else would have done the same thing a little later.

07-01:09:50
Burnett: Of course.

07-01:09:53
Gray: But let's assume that somehow nobody figured—

07-01:09:56
Burnett: Nobody did it. Right.

07-01:09:57
Gray: Then it would have taken a lot longer to get these things going [picks up smartphone]. So these use a lot of that stuff. Of course, somebody would have figured it out but it might have taken a few years longer. Who knows? It's impossible to say. It probably wouldn't have taken very much longer because there's a lot of bright people around. We just happened to figure out things earlier. But it had a big impact in all the chain of events that led to having this kind of mobility and these kinds of devices [smartphones]. I mean, what you're asking me, I understand your drift here. One anecdote I'll bring in is another innovator by the name of Dov Frohman who got a big award, inducted into the Computer History Museum last weekend. I was there. Dov Frohman invented the flash memory at Intel in 1971. Great story, great anecdotes and all that. But we were speculating — and this is a pretty unique structure — what would have happened if nobody had ever invented the flash memory? You know when you buy sixty-four—

07-0`:11:10
Burnett: Gigabytes, yeah.

07-01:11:11
Gray: —gigabytes? That's what you're buying. If we never had flash memory, you would probably have a little tiny disc drive in your smartphone because flash replaces what disc drives do. And disc drives got pretty small and pretty compact — they did unbelievable things with disc drives. Probably some other technology pathway would have been developed, but it's very hard to imagine a disc drive inside one of these things [smart phone]. But what would have more likely happened is three or four or five years later somebody else would have figured out either that EPROM technology or some other technology to do that. Dov had this wonderful anecdote about Gordon which I'll tell because it's Gordon Moore incarnate. Flash memory, then called EPROM, was a crazy idea. Intel at that time was building microprocessors and they were getting out of the D-RAM [dynamic random-access memory] world.

Flash memory, this non-volatile memory, it was sort of an off-the-wall science project. So Dov was working there as a young guy and he and his buddies came up with this demo of a four-bit by four-bit flash memory on a chip. They built a demo board and they took it into one of the management meetings at Intel. They did everything in meetings. Dov said he gave his demonstration and they went around the room and everybody in the room thought it was a crazy idea. "We don't need this and it probably won't work anyway." They got all the way around to Gordon who was sitting in the corner. When they got to him, the room goes silent. Everybody looks at Gordon and he thinks about it for a minute. And he says, "Let's do it." And today we have flash memory. That's so typical of the way Gordon is. When I’ve worked with him over the years in situations like that, he's usually the last person to speak. He can figure things out and makes that judgment.

07-01:13:14
Burnett: That's wonderful.

07-01:13:15
Gray: Dov is an amazing character.

07-01:13:19
Burnett: All I wanted to do — in the history of science and technology we try to move away from the “Great Man history” thing. I didn't want to make you uncomfortable. I might have. [laughter] But the point of that was to say that you're in a flow. You're in history and there were amazing people surrounding you and they provided you with an opportunity to develop things and you took off with it and then you turned around and mentored all of these graduate students. You took up the challenge of administration of a highly dynamic place. I don't want to isolate you and say you've had these great single contributions but all this to say that you're part of a larger ecosystem that has been tremendously innovatory. Now I can let you off the hook.

07-01:14:27
Gray: Okay, thank you.

07-01:14:27
Burnett: And then we can turn then to finish up talking about board membership and some of the things you’ve been doing post-retirement.

07-01:14:42
Gray: Well, I think those are really the highlights. I'm still on one start-up board, Sentons, which is [run by] another former graduate student. And they're doing great. They make components that sense touch on smartphones and it allows you to put a virtual button anywhere on a smartphone using software. So you can put a button anywhere.

07-01:15:07
Burnett: Even on the back.

07-01:15:08
Gray: Sliders, back, anywhere. One of the major manufacturers is going to announce a cellphone next week, believe it or not, that incorporates that functionality so we'll see how they do. But that's a lot of fun. It's so much fun to see Silicon Valley when it's working. When you see a group, just about fifty or sixty people, they've been working for five years, they've been night and day flying to Asia, doing this. They might hit a homerun with this. They might really change the world of smartphones. The probability of that happening for any given group like that's what, ten or fifteen percent maybe. But I think they might succeed. And it's just so much fun to see that excitement and see the energy that you get from that.

07-01:16:01
Burnett: Right. And you are on the board of the Computer History Museum.

07-01:16:05
Gray: Yes, yes. Right.

07-01:16:07
Burnett: John Muir Hospital board.

07-01:16:08
Gray: Right.

07-01:60100
Burnett: And so you're active in the community and you're interested in the history of science, as well. But let's turn then to thinking about this ecosystem as a way of talking about innovation. Your reflections on what it takes to be successful. One way of doing this is to talk about how not to do it. How have you gotten innovation wrong and what do you think is the way forward in the administration of higher education, the facilitation of innovation for an individual? What are some of your reflections on that?

07-01:17:01
Gray: Find the smartest people you can, support them as much as you can, and let them make their own mistakes. That's pretty simple-minded. The starting material and getting the smart kids we get in here is a big part of the success we have here. Well, let me go at it a different way. You suggested I look back over the six or seven sessions we've had and what would I take away from that and how would I summarize it? One answer to why we've been able to do the things we did is the Berkeley environment. And what is it that makes this a unique place? I think that's something worth trying to get at a little bit. And this is not new news. People say this all the time. There's no other place, no other higher-ed institution that has the excellence in a broad range of academic disciplines that’s second to none. Faculty, students. There's no place in the US and, for that matter, the world that has a better, more capable and accomplished set of faculty members and students, but at the same time has an environment that's open to young kids that come from disadvantaged backgrounds. Every brochure we produce here on the campus says that, so I'm

not saying anything new. But it's a big part of the environment here and why it's successful.

I just did a little survey because I knew we'd be talking about this. The most important single thing about sustaining a place like Berkeley is the sixty or so new faculty that you hire every year. Who are those people? Are they the best coming out of the universities or around the country or the world that particular year? What percentage of time do you get the number one choice that you're after? How successful are we with competing with all the other great institutions around the country? And it hasn't slacked off. It sounds like we're still getting our first choice seventy or eighty or ninety percent of the time. And when you think about all of the trials and tribulations this place has been through, starting in the 1960s with the Free Speech Movement and all of the budget cycles and the booms and busts and the VERIP [Voluntary Early Retirement Incentive Program] years and all of these trials and tribulations, it's sort of amazing that we haven't seemed to have been hurt more by that. And I'm trying to think why that is. One is just that tradition of excellence. Excellence does feed on itself. People want to come here because it's a great place and it's a great place because top people want to come here. There is a flywheel effect, that’s for sure. That's one thing. The second thing is this incredible blend of an undergrad student can come here from a disadvantaged background, first in their family to go to college, and go sit in a class with Randy Schekman teaching the class, a Nobel prize winner, or Jennifer Doudna, who's going to be a Nobel prize winner. That's pretty amazing. These statistics, like almost half the undergraduates don't pay any fees. That because of Bob Birgenau' s — not just him — but this idea of trying to buy out the fees for the disadvantaged and middle-class students, and then the Pell grant recipients, such a high percent. That metric together with the number of Nobel prize winners and the number of National Academy members, you don't find that set of metrics together in one institution around the country. I think that's a big part of it.

I think the third part of it is just the fact that we're part of this Bay Area ecosystem and this incredible innovation ecosystem. The metric I use, I think we've said this before, but a third of the venture capital investment in the United States happens in the nine Bay Area counties every year. This goes on year after year after year, way higher than Southern California or Austin or Redmond, Washington or Route 128. And that creates this ecosystem of innovators, of thought leaders, of entrepreneurship. And we're part of it. Berkeley, Stanford, UCSF are pretty much the academic core of that. And people around the country see that and they want to be a part of it. Even though everything costs way too much here and all the other urban ills we have, people want to be a part of that. I think that's a big chunk of the reason we have continued to be able to do what we're doing. So I think those three things are the big part of it.

07-01:23:10
Burnett: I guess it doesn’t mean that there isn't a gathering storm; I think there is on the national basis. There's a concern over access. There's a concern over sustaining the innovation. We know that other countries are investing more and more in their own research systems. But from where you sit you feel like this continues to work and it is partly because of the institutions that have been built around it to insulate it from the shocks. Because there are shocks in California more than other states. You've mentioned this earlier. There's more of a boom/bust rhythm to the state support of the university. So the university has had to evolve countercyclical forces that are in the private sector and the foundation space to allow the university to flourish in bad times. That seems to be the situation.

07-01:24:20
Gray: There are some challenges. If you think about what is on the horizon that could really be an issue here. There are three or four of these. One of them is this fourth leg that you talked about, we talked about earlier. The three core missions of the university, research, teaching, and public service, now has this fourth piece, for the public institutions, which is an expectation of being a major contributor to economic development in the region. I guess you could think of it as part service and part research. But it's something that wasn't there, at least not for most of the publics in the US, fifty years ago. There was a little bit but not much. Wisconsin was one of the early ones, I think driven by the Stanford example, people want to see their research universities play a major role in local and regional economic development. A big part of it is driven by elected representatives and state legislatures that need an argument to justify continuing funding. You know, there are all these funding pressures. If you can say that the university is contributing to economic development that's a powerful argument.

And it's all fine except it complicates things around here because there are tensions between the entrepreneurship piece, the business formation piece, the whole industry relationship and other academic values. And I think that's been navigated pretty successfully here but the pressure's only going to continue to increase. It's only going to get worse. Or better. Some people would think it's better. I don't think there's a good or bad to it but it's part of the landscape. And I think we've got to be very vigilant to make sure that doesn't degrade the academic values of the campus. Total academic freedom. Talk to anybody about anything. It's okay to have crazy ideas. Every faculty member doesn’t have to start a company. Keep that. So that's one issue. Another issue, the counter to that, is keeping enough resources for the books to balance. It’s the larger economic picture, all the different sources of revenue, and all the different costs, and whether are we going to be able to maintain a quality of life for the top faculty members that we recruit. That boils down to staff support, physical facilities, teaching loads, colleagues, and a million other things. At the same time have to sustain this good educational experience for the undergraduates and graduate students. That is much more difficult with decreasing state support. We can't just keep increasing fees because the whole idea is access. The net fee income can't go up that much more. Something's got to give. It could be more students per faculty. That could help. It could be a bigger endowment. That could help. But are we going to have good enough leadership and be smart enough and have good economic environment long enough to actually execute on that, to do what needs to be done? Probably, some of all of that, probably a bigger endowment, more gifts, more students per faculty, more use of educational technology to be more productive in delivering the undergraduate education, some combination of all of those. I think they can get there but the jury's still out. Time will tell.

And then the last thing is technology — you mentioned this several times. What's education going to look like thirty years from now given what's happening with educational technology and expectations that students have a better learning experience? Things have come a long way and things are better now but it's just hard to predict how that's going to evolve. The opportunities are there. I think the opportunity is there to really dramatically improve the educational experience that these kids have and be more efficient about delivering more education per dollar spent. But are we going to be smart enough to actually be able to do that? That's a tough call.

07-01:29:22
Burnett: Well, I think we had an initial vogue of the MOOC [massive open online course], the online classroom. I think we're starting to learn that it's a mistake to think of it as a complete replacement, that it's going to supplement, it's going to enhance, but the university practice itself puts such a premium on place. It matters that you are in the same place. And, of course, some physical plant, like some labs need to be in a particular location and you need to co-locate researchers. But that is how we do things. We put such a premium on being here on this campus and we want researchers to be across the hall from one another as much as possible. And we want students to have access to those folks in person if possible. The Bay Area produces this technology that permits people to be connected around the world in much more real ways through real-time video and all of this. And at the same time we really think that place matters and I think that Berkeley is still in that mode of making sure that students can physically come and be with a top researcher, graduate students can do the same, and work together physically in the same space. And I'm not sure how much that's going to change but I agree that is going to be enhanced, it's going to be supplemented by technology in the future. Absolutely.

07-01:31:12
Gray: Before we wrap this up, I wanted to just say a little bit about my family. Over the years a lot of times my students would come to me and ask advice about which job to take and a lot of time it involved family tradeoffs. And I always told them that jobs come and go but your family is first — you only get one of those. I've been incredibly lucky. My wife Judy is fine. She's in good health.

We have a place in Bodega Bay that we go to every other weekend, spend three or four days up there. We really have a wonderful situation. We sold the big house, the Spanish-style house that I talked about that we had those engineering parties in and we bought a smaller place out in Lafayette that's much easier for her to negotiate. So she's in good shape. My proudest thing really is my two sons. My older son Matthew is an attorney with a big law firm in San Francisco. They do land use. Their biggest client is the developer that is doing Hunter's Point Naval Shipyard, the Concord Naval Weapons Station and Treasure Island. So he basically spends all his time on those projects, which are actually fascinating. And his partner is David Groth. And David is an instructor at San Francisco Cooking School and they've been together twenty-five years. So they're great. They're doing wonderfully. And my younger son Ryan has an engineering design company in Boise, Idaho with about fifteen employees and he's the managing partner there. And they design high-tech gadgets for entrepreneurs and also for large companies there. They're sort of like IDEO. They're a design company and they contract design of various gadgets as they're needed. His wife Erin is a nurse. Wonderful, wonderful person. And has two young sons, six and four. Everybody's doing well. So I feel like the luckiest man alive because my family is all in great shape.

07-01:33:29
Burnett: Well, I think the message that comes out is be aware of challenges, meet them, but that a certain amount of optimism helps.

07-01:33:43
Gray: Yes, absolutely. Thank you so much, Paul. This has been really terrific.

07-01:33:48
Burnett: Dr. Gray, thank you for sitting with us.

[End of Interview]