# Oral History of Ivan Sutherland: Part 1 of 2

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**Sproull:** I'm Bob Sproull, this is the Third of February, 2017. I have David Brock with me, as a co-interviewer, and we're interviewing Ivan Sutherland. Ivan, let's talk a little bit about getting things started, with you and your brother Bert, I think in Scarsdale, New York.

**Sutherland:** Yes.

**Sproull:** With many adventures, that probably presage your whole career.

**Sutherland:** Well my father was a civil engineer, who had been born in New Zealand and loved mountains. And he decided that the way to be an engineer in the mountains, was to build hydroelectric dams. So that's why he became a civil engineer. He was a PhD from the University of London, what he called "City and Guilds," which later turned out to be Imperial College, London. And my brother got a copy of his PhD thesis, which we have now. It has to do with the design of a water tank. But he got his PhD probably in the '20s, in London. He had been an Anzac, a New Zealand soldier in World War One. And the New Zealand government arranged that their troops could be discharged in Europe. And then the New Zealand government would pay their fare home, after spending a period in Europe to get education, or travel, or whatever they wanted to do. And he took advantage of that, to go to the University of London and get his PhD. And also met my mother in France, and then he went back to New Zealand, and a few years later she went there, and they got married. At least they claimed to have gotten married, in Melbourne, Australia. And my mother always said that when she came to the US, the State Department took her marriage certificate and never returned it.

<laughter>

**Sutherland:** So I have only her word that they ever got married. But I rather think it's a charming idea that they actually didn't <laughs>. They were together for 46 years, so, seems to me it doesn't matter.

<laughter>

**Sutherland:** So I was brought up in a family for which education was considered very important. And all my young life, there were interesting things. When we would go traveling, there were always things to see. "What kind of bridge is that? Why is this junction done this way?" And so on. My father's idea of a holiday was to go visit dams. He had, as a hobby, collected information on essentially all of the dams in the world, that were more than a hundred feet high. And he had information on all of them, and he visited many of them. And when we would travel in the summer, we would go to various places, and of course he knew many of the people. And so we would get tours of the inside of the dam. One of the places we went to was the Conowingo power plant, which is somewhere in Pennsylvania[1]. And it has a wood stave penstock, which is basically a barrel, that was.. I don't know, three or four miles long, that carries the water from the dam basically, to the power plant. And this thing leaked.

<laughter>

**Sutherland:** So as we went along it, we could see water squirting out of it here and there. Because the barrel staves were wood, and they weren't entirely tight. And I think that dam, at the time had the largest butterfly valve in the world. And it was unwatered, for some reason, they had taken the water out to repair the turbine or something. So we got to go inside the scroll cage, which is the place where the water goes around, before it feeds into the turbine. And here was this butterfly valve, it's just a piece of steel that's 18 feet wide, and on a pivot, and it was leaking a little bit too. And it was dark in there, there were some lights and so on. But that was one of the things that made a big impression on me, as I must have been in sixth or seventh grade, or something. So..

**Sproull:** So were all the dams your father worked on hydro dams?

**Sutherland:** Oh yeah, they were all..

**Sproull:** So was he interested in the hydro piece, or the dam piece?

**Sutherland:** He was interested in the dam piece. He didn't distinguish. Any dam that was over a hundred feet high was in his collection, okay?

**Sproull:** Uh-huh.

**Sutherland:** But almost every dam which is more than a hundred feet high..…generates electricity.

**Sproull:** Yeah.

**Sutherland:** I mean.. why not? Right? And so they were principally hydro dams. Yeah. So I remember a game that my parents used to play with me, and I've recommended this to many people with children. And the game was called, "I'm thinking of a number." And the way it went was-- I'll ask Bob one of the questions. I'm thinking of a number, and if you square this number and add two, you get eighteen. What is my number?

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[1] The Conowingo Dam power station is in Maryland.

  

**Sproull:** Four.

**Sutherland:** Four. That's the correct answer. And…

<laughter>

**Sutherland:** …to keep the two boys amused while we were traveling, questions of this sort would appear, over and over and over again. And of course at the time we didn't recognize that these are algebra problems.

<laughter>

**Sutherland:** …posed as word problems. And so I knew how to do algebra before I ever met it in school. Just from the "I'm thinking of a number" game. And this is typical of what my parents did. Now I'll tell you another story about my mother. I thought it would be good to have a multiplication table posted on the wall, next to where I did my homework, so I wouldn't have to multiply.

<laughter>

**Sutherland:** And Mother was very obliging. She had some paper that had one-inch sizes squares on it, and she was happy to fix that up for me. And I then was able to make a multiplication-- it was eight and a half by eleven paper. So I could go up to eleven and up to eight, which is eighty-eight, I still remember.

<laughter>

**Sutherland:** And I could fill out such a piece of paper. But it wasn't enough to be of help to me as a reference. So she was happy to scotch tape together four pieces of such paper, and then I could make a multiplication table that went up all the way to 22 by 36. No, I'm sorry…eight and a half by eleven, so it's sixteen, right? So that was fine. But that's too much for a young fellow to fill out, in one sitting. So I would fill out a part of it, and then I'd fill out another part. And where was it to be kept between sessions? Well it lived underneath the living room rug. It was put underneath, because that was a nice place to keep it flat and safe. And I got it about three quarters done, and the cleaning lady found it and discarded it. And that was a disaster. On the other hand, Mother had more eight and a half by eleven paper.

<laughter>

  

**Sutherland:** And was very happy to tape them together for me. So I started another one. And I must have started three or four of those things, and never finished one. And late in her life, I accused my mother of being the person who'd actually stolen it. Believing that it was more important to be building such a multiplication table, than to have one. Which is correct, of course. And I <laughs> thank her very much, in retrospect, for having stolen them. But she said, "No." With a very straight face, she said, "No, I wouldn't do a thing like that." Unfortunately my father was already dead, so I couldn't accuse him of the crime <laughs>. But I'm pretty sure it was one of those two, who disposed of my..

<laughter>

**Sutherland:** You see, this is typical of the environment I grew up in. I'll tell you another story about my mother. How did Bert and I learn the Morse code? Well we were amateur radio-- we wanted to be amateur radio operators. And to become an amateur radio operator, you had to know the Morse code. So we had a Morse key, with a buzzer, sitting on the table in the hall. Where you'd come in the door, there was a table there to accept mail and so on. And we would send code to each other, and practice. And one day the mailman came in, and he said, "What's this?" And we said, "It's a Morse code key." And he started banging out Morse code, faster than we had ever heard it. And it turns out he had been a radio operator in the Pacific theater, during World War Two. So this all happened probably in the early '50s. So he said, "I'll teach you the Morse code." And that sounded like a pretty good deal, because he clearly unders-- he knew it backwards and forwards. He'd spent all his years in the Army, sending and receiving Morse code. So the rest of the summer-- it was summertime, the rest of the summer he would come and give us a half-hour lesson every day. So sometime before lunch, he'd come to the door, he'd come in, and he'd give us our lesson. And then he'd go on about his route. His name was Ted, I never knew his last name. It was only years later that I figured out the appearance of this, from outside the house..

**Sproull:** <laughs>

**Sutherland:** …would be very damaging to my mother's reputation. And I'm sure that my mother had figured this out on day one, but she didn't <laughs> give a damn. Her boys' education was far more important to my mother than her reputation in the neighborhood.

**Sproull:** So..

**Sutherland:** I still remember X. Slide, Kelly, slide. That was his mnemonic for X. Dash, dot, dot, dash, is X.

**Sproull:** Did you ever use the Morse code much? Did you become..

  

**Sutherland:** Occasionally, yes, occasionally.

**Sproull:** …radio operators?

**Sutherland:** Occasionally. Well as ham radio operators, we used it a lot.

**Sproull:** Yeah.

**Brock:** You mentioned that your mother and father met in France. Was that during the war?

**Sutherland:** It was after the war. My mother had been born in Scotland, in 1901. World War I was ’14 to ’18, so she was 17 when World War I ended. And essentially all of the eligible men of her generation went to World War I, and essentially zero of them returned.

**Brock:** Right.

**Sutherland:** There was no one to marry. And she was determined to escape from Scotland, and so she went to Grenoble, ostensibly to study French grammar. And in the boarding house in Grenoble, there was this New Zealander, whom she found very attractive. And ultimately they got married. So.. all is well that ends well.

**Brock:** Yeah <laughs>.

**Sproull:** So you had talked a little bit about.. your story about learning to read. You were not apparently a good reader, as a kid. Is that right?

**Sutherland:** Well I didn’t find Dick and Jane inspiring.

<laughter>

**Sutherland:** So I basically refused to read. And I have one bad eye, and that was the excuse that I used, as like…just an excuse. So my father made books for me to read from. And he would clip pictures from his engineering magazines, a picture of a giant earth-moving truck, or a digger, or something. And then he’d write two or three sentences underneath it. I still have some of these things that he made. Which are gems, to get a young fellow who was not enamored of Dick and Jane, to learn to read. And I didn’t read until I was in third grade.

  

**Sproull:** And you still don't spell.

**Sutherland:** Yes, that's right.

**Sproull:** <laughs>

**Sutherland:** I find it amazing that Bob Sproull knows how words are spelled.

<laughter>

**Sproull:** So talk a little bit about-- I think your mother was also instrumental, in squiring you and Bert around on various adventures, and meeting quite a fascinating collection of people.

**Sutherland:** Yeah.

**Sproull:** While you were still in grade school.

**Sutherland:** My mother was…she was quite entrepreneurial, I will say. And she was interested in something called "general semantics." Which is basically the study of what the meaning of language really is. And the General Semantics Society had conferences, and she liked to go to these, and occasionally she would take us along. And somehow through these conferences, she met a man named Edmund Berkeley. And Edmund Berkeley was an interesting character. He had been at Harvard, and gotten I think a PhD at Harvard, under Aiken, who was the key professor there. Fred Brooks later on got his PhD from Aiken. And Grace Hopper, of course, was Aiken's number one assistant, had been there during the war when they were building…machines. And so Ed Berkeley was an early pioneer in the computing business. He had a little company that he called "Edmund C. Berkeley and Associates, Inc." And he published a magazine called "Computers and Automation." And did other things, I don't know what all his things he did. But Mother met him at one of these General Semantics conferences, and they became friendly. And Berkeley had quite a strong influence on both Bert and me, in the early years. We used to go down to New York City, he was on 11th Street I think, in New York City. And we'd take the subway to 14th Street, and then walk the other three blocks. Bert knew the way, I wasn't quite sure of the way. But Bert would get us there, and we'd go see him in his offices. He had built a thing called "Squee," which was a robot that had a scoop in the front, and it had a photocell on it. And it had a steering wheel in front like a tricycle, and a couple of wheels on the back. And the front wheel was driven by a motor. And when it saw a light, it would move its front wheel to aim at the light, because it had two photocells. And then it would drive forward. So it would seek a light, and then pick up a ball that was located under the light. And then it would see a different kind of light, and take and drop the ball there. That was its raison d'etre. And we built some things of a similar sort. We thought the tricycle steering gear was too complicated to make. So we built one that had two wheels, that drove like a wheelchair. So the steering was much simpler. And it had two photocells, so if the left photocell saw a light, the right wheel would drive forward. If the right eye saw light, the left wheel would drive forward. And the result of that, was it would steer towards the light and go towards the light. Bert and I made a series of these things, different sizes and different technologies, and one thing and another. And Berkeley encouraged that, he was very supportive and helpful. Now Berkeley I think he claimed to be the person who named the ACM. And he told me one time that he called it the Association of Computing Machinery. “Why machinery?” He said, “Well machinery is all kinds of things. The ordinary meaning is mechanical machinery, but there’s also social machinery. The courteous words, please and thank you and so on, are what lubricates the social machine. And there’s other kinds of machinery. The machinery of government, for example.” And he said, “Computing machinery is clearly computing engines. They’re called engines after all, they are machinery.” And so he thought the Association of Computing Machinery was the appropriate name. I traveled with some senior people from the ACM, who were grumbling about the “machinery” word in the name. And I had to say to them, “Well I heard about this from Berkeley, who claims to have provided the name. And he explained the meaning of machinery to me,” and as I’ve explained it just now. Now he had also caused to be built a very simple computing machine, called “Simon.” Simple Simon. And Simon was a relay-based computer, about the size of a briefcase. It had probably a hundred relays or so in it. And it had a tape reader, which would read paper tape. And it was basically a bus, onto which a piece of information was put and then transmitted through perhaps an arithmetic element, and then received somewhere else. Now it was a very large machine. It had two-bit words..

<laughter>

**Sutherland:** …so it could represent numbers zero, one, two and three. And it could add, and it could do logic on these numbers. By dint of double precision arithmetic, it could add numbers up to 15 to other numbers up to 15. And we were allowed to take this thing home. So I wrote code for Simon, to make it do various things. And one of the things I did, was to make it divide. Now this is while I was in high school, so I was probably 14, something like that, I don’t know. So I got to use my own personal computer, at home…

<laughter>

**Sutherland:** This is 1953 or something, when this is an unheard of event, right? Now the fact that I wrote a divide routine, appears in Berkeley’s book, called “Giant Brains.” My name is mentioned, and he said there was a high school student who-- The important thing about divide, is that divide requires a conditional. And Simon was a paper tape-operated machine, and it couldn’t have a conditional. It had to run the tape from beginning to end. And although you could do logic, there was no way to do a conditional. So the first thing I had to do to make a divide routine, was to add a wire to Simon, to make it have a conditional. And the only conditional I could have was “Stop.” So it had conditional stop. According to some number that was in Simon, it could stop or not. So my division routine worked by cases. Division by zero it rejected immediately.

**Sproull:** <laughs>

**Sutherland:** Division by one was straightforward, it took the numerator, put it out. Division by two is not hard, you shift and put it out. Oh, division by zero was half an inch of tape, division by one was another inch of tape, division by two was three inches of tape. The rest of the six feet of tape was division by three.

<laughter>

**Sutherland:** And I don't remember how I did it. I really don't remember <laughs> what the code was. But it was a lot of code. And at the end of each step, if that was the divisor, it would stop. So it either divided by zero, with complaints, or divided by one, or divided by two, or it went to the end of the tape. And it was quite a challenge to do that. Of course, how do you edit paper tape? There was a sign on a DEC computer I saw once, that said, "If there are computers in hell, they will use paper tape."

<laughter>

**Sutherland:** And how do you edit paper tape? Well you can cut and splice, or you can paste it over and, you know…

**Sproull:** Hmm.

**Sutherland:** …and so on. So editing this six feet of program was a major challenge. But I was a patient and persistent guy, and I got the whole thing to work. And I'm quite proud of having written a division routine for a two-bit computer, when I was in high school. So I can almost literally say, I've been in the computer business nearly all of my life.

**Sproull:** Yeah, absolutely.

**Brock:** May I ask a question about that experience, with taking Simon home and doing this work. And I'm wondering if you, and perhaps your brother at this time, were the witting or unwitting subjects of an experiment by Berkeley, about getting youth involved with computing and computing machinery?
**Sutherland:** That is a perfectly plausible hypothesis, which never occurred to me until now.

  

<laughter>

**Brock:** Okay.

**Sutherland:** Other similar hypotheses, where I was clearly being a guinea pig, have occurred to me.

**Brock:** <laughs>

**Sutherland:** But this one, this particular one, never occurred to me.

**Sproull:** So the other luminary you got to know in high school was Claude Shannon. How did that come about?

**Sutherland:** Well Berkeley introduced us.

**Sproull:** Ah.

**Sutherland:** Berkeley knew Shannon, of course. And Berkeley called Shannon up I suppose, or sent him a note. Email hadn't been invented…

**Sproull:** <laughs>

**Sutherland:** …I don't know how the communication went. And said, "There's these two boys that you should meet." Now my mother hated to drive. She was a very timid driver, and she hated it. And Shannon was of course at Bell Labs, which is 20 miles roughly, south of New York City. And we lived in Scarsdale, which is 20 miles north of New York City, roughly. So this was a substantial drive, it would be a couple-hour drive before interstates had been invented, so it's much easier now than it was then. But Mother put us in the car, and took us down to visit Claude Shannon. Years later I wrote to Shannon, when I was going to go to MIT, and said, "I'd like to visit you when I get there." And he remembered that visit. And he told me about it later on. He said he concluded when we arrived that the older brother, Bert, was visiting, and the younger brother, me, was tagging along for the ride.

**Sproull:** <laughs>

  

**Sutherland:** He said that was his impression during most of the visit. Said then towards the end of the visit, I piped up with some question, which he remembered-- I don't remember what the question was. But he remembered it as a penetrating question, which made it quite clear that there were two of them.

<laughter>

**Sutherland:** Shannon told me that himself.

<laughter>

**Sutherland:** But yeah, I thoroughly enjoyed the visit. I remember quite vividly some of the things he showed us. He showed us the machine that played a game, for making a path from this end of the board, to that end of the board. And the opponent made a path from this end of the board, to that end of the board. And it was not possible for both paths to be created. And this machine was built with thermistors, which every time the victim pushed the button, it would light the victim's light. Then a little while later, the machine's light would come on in a symmetric place. Which was a winning strategy.

**Sproull:** Yeah, yeah.

**Sutherland:** But all that the machine was, was a bunch of these resistors, which as they warmed, their resistance dropped. And so it would bring on a light. So it was a trivially simply machine. But the important thing is I remember how it worked. So obviously at-- I was probably eighth or ninth grade at that time, obviously I understood how it worked at the time. Because I still remember. And of course he showed us his maze-solving mouse. There are many pictures of him with this maze-solving mouse. It was a very clever device.

**Sproull:** So you mentioned building things, as a result of your encounter with Ed Berkeley. Did you and Bert build anything after seeing Shannon?

**Sutherland:** Oh yeah. We said, "Well we can build a mouse too." Now Shannon was far cleverer than we were. And Shannon had the Bell Laboratories machine shop at his disposal, we didn't. So our mouse was never very satisfactory, it never worked very well. Shannon's mouse used reed relays, embedded in the floor of the mechanism. His had five squares by five squares, with walls that could be moved. And in each square there was a reed relay. So when you put the mouse that had a permanent magnet in it, down in that square, the reed relay would close. And the machine would know where the mouse started, and it would move the mechanism underneath that caused the mouse to move around. And we didn't have reed relays, so it was a much harder-- we had a much harder task than his.

  

**Sproull:** So are there any other memorable sort of high school…

**Sutherland:** Yeah, well…

**Sproull:** Were you headed toward a life of engineering, while you were in high school?

**Sutherland:** One of the things Bob and I found yesterday as we went through the storage place, was a telephone dial. Do you remember? I said…

**Sproull:** Yes, you did.

**Sutherland:** …"That's a telephone dial"? Now when I was in high school, the telephone company was a controlled monopoly. And getting equipment for telephones was like finding teeth for hens. And we wanted a telephone dial, because we had ambition to build an adding machine. And somehow, Mother got us a telephone dial. I never inquired as to what she had done to weasel a telephone dial out of the telephone repair man. There may have been some skullduggery involved. I certainly hope there was. But this telephone dial appeared, and it was in our storage place…

**Sproull:** Yeah.

**Sutherland:** …and Bob and I found it yesterday…

**Sproull:** And it was brand new, right? It was wasn't salvaged from some failed telephone.

**Sutherland:** Oh no.

**Sproull:** So didn't you and Bert frequent Canal Street, for all your parts?

**Sutherland:** Oh yeah. Canal Street, New York City, was where all the surplus stores were. And we used to go down there regularly. Father would take us down initially. And now that brings up a whole 'nother story. When I was in grade school, Father purchased for 50 dollars, I believe, and that was quite a lot of money in those days, a machine. And this machine was a hundred pounds or so, of fine ball bearings, shafts, flexible couplings, cams, handles, prisms, periscopes, all kinds of stuff. And I found out much later, I found out it was a Sperry P4 computer.

**Sproull:** Wow.

  

**Sutherland:** And you can find on the web, you can find things about the Sperry P4 computer. But I had one. And where was it to be put in the house? I mean it had to be somewhere where the boys would interact with it regularly, and where they're be comfortable, you know, "Well, let's put it in the kitchen." I mean this is the center of family life, in a reasonable household. So it was put in the kitchen. It had a periscope that stuck up, so it was mounted on a low table, you could peer in. And then it had handles that you could turn, and the periscope that stuck up the top would turn correspondingly. Turns out it was the gun control computer for a B25, or B19, I don't know which airplane it was for. And it had this periscope that stuck up the top, so you could see the enemy aircraft, and aim at them, and then it had firing buttons. And it would adjust the position of the machine guns, to lead the opponent aircraft by the right amount, and so on. Well it had a second periscope. The second periscope was six feet tall, and we had no idea where it fit. Now when I say "we," I certainly had no idea where it would fit. Whether my father knew where it went, I don't know, I never asked him. But one day I discovered where it fit, it would fit on the bottom. It was obviously the periscope that looked out the belly of the plane.

**Sproull:** Right.

**Sutherland:** Well it was a pity if we couldn't mount it, right? Well it was in the kitchen. Well a hole was cut in the floor…

<laughter>

**Sutherland:** …and the periscope was duly installed, so it stuck down into the basement. I mean this is typical of what my parents did, right?

<laughter>

**Sutherland:** This is all in the interest of the education of their boys. And I remember many things about this computer. One of the things it had in it was a ball and disk integrator. A ball and disk integrator is a disk which turns at some fixed speed. There's a ball that rests on the disk, which then couples the disk to a shaft. So depending on the position of the ball, it's a variable speed drive for the shaft. And this was used to control the motion of the periscope. So as you turned the handles, the periscope-- as you turned more, the periscope would turn faster in that direction. So you could track the enemy aircraft, probably. But I remember seeing that, and figuring out how it worked, and discussing it with my father and so on. And so the notion that you could make mechanical devices of this sort, was clear to me before I ever entered high school.

**Sproull:** Was this something that got taken apart, and put back together, and still worked? Or…

  

**Sutherland:** No.

<laughter>

**Sutherland:** This was never taken apart. A pity. And I gave it to my daughter for the grandchildren, and she gave it to a museum in New Jersey. So I believe it's in a museum now in New Jersey.

**Sutherland:** But I discovered what it was, and looked it up on the web, and there's information about it. I said, "I recognize that." Oh, and then I was visiting somewhere else, I was visiting the guy who is the founder and principal-- he's the president, I think of Centaur. Centaur Technology is a company that makes X86 computers in Austin, Texas.

**Brock:** Right, yeah. I saw a documentary film about them.

**Sutherland:** Well it turns out that the boss man there collects stuff. And there in Centaur was a computer, exactly like the one that I had in the kitchen. I said, "That's a Sperry P4 computer." He said, "How did you know that?"

**Sproull:** So is it time to move on to college?

**Sutherland:** I'm happy to do whatever <laughs> you wish.

**Sproull:** Well let's try moving on. We can always come back. So you went to Carnegie Tech.

**Sutherland:** Yes.

**Sproull:** How did that happen? Your brother had gone to RPI…

**Sutherland:** My brother went to RPI. My brother was in the Navy ROTC, and he went to RPI because they had a Naval ROTC. I applied to a few places, not very many, but Carnegie gave the best scholarship. Westinghouse had the Westinghouse scholars at Carnegie Tech, and there was no issue about parental income associated with Westinghouse scholars.

**Sproull:** I see.

  

**Sutherland:** The other big scholarship at Carnegie Tech was the Sloan scholarship, which had reference to parental income. And so the joke we had with the Sloan scholars, was that the Westinghouse scholars had the brains, and the Sloan scholars had poor parents. Not true, of course.

**Sproull:** <laughs> Right.

**Sutherland:** I found out that the head of Xerox PARC, Pake[2], had been a Westinghouse scholar at Carnegie.

**Sproull:** Oh. So when you were heading off to college, what were your ambitions? Or what did you think you'd be doing in college? Were you looking for an engineering school?

**Sutherland:** Yeah, I was in engineering school. I studied electrical engineering. I'd been a ham radio operator, and got interested in electrical things. I remember…I must have been in ninth grade, and my brother was in eleventh grade, and my brother knew trigonometry and I didn't. And we had learned about amplitude modulation. And it turns out amplitude modulated radio waves produce sidebands. And you can calculate what the sidebands are, by multiplying two sine waves together. You get a sum and difference kind of thing. And the trigonometric identities tell you what they are. And I remember my brother teaching me just enough trigonometry, so I could understand what the sidebands were. But it was clear electrical engineering was the thing to do, so I went to Carnegie to study electrical engineering. And I think it was a good choice.

**Sproull:** So were there memorable things about electrical engineering at Carnegie Tech?

**Sutherland:** Oh, I can tell you a memorable thing about Carnegie Tech, the flu struck Carnegie Tech. I lived in Donner Hall, which was one of the men's dormitories. And the flu struck, and the university basically closed. I mean everybody had the flu. And so Mother came, and Mother had been a nurse, from previous times, she had been a midwife in London, and a nurse. So she came to take care of her son. And by the way, to take care of the other sick guys in Donner Hall. And while she was there, she stayed in my room, I mean where else was she going to stay, right? So we ran into the dean on the street. And the dean said, "Where are you staying?" She said, "I'm in Donner Hall." <laughs> And he raised his eyebrows, but he didn't complain.

<laughter>

**Sutherland:** It's a sort of Florence Nightingale story.

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[2] George Pake.

<laughter>

**Sutherland:** Oh well, I don't know, there was a number of things at Carnegie.

**Sproull:** Well I remember one of the people you I think took classes from there, was Arthur Milnes.

**Sutherland:** Yeah, Arthur Milnes. Yeah.

**Sproull:** Circuits, maybe?

**Sutherland:** No, Arthur Milnes was interested in solid state physics at Carnegie. And it was a brand-new subject, I mean there was very little known about it. And he taught an electronics course, for a senior-level electronics course, which was mostly laboratory. It was all day Monday, every Monday, all day. And it was a tremendous course, the best course I think I ever took. And he had made devices for that course, so we had things to experiment with. And one of the things that he had, was a bar of silicon about that long, which had an ohmic contact at each end. So you could run a current through it. And it had a rectifying contact, just inside of the ohmic contact. So you could inject minority carriers wherever you chose. So if you put an electric field across it, by running a current down it, and then injected some minority carriers, they would drift down the bar and appear. And you could see them arrive at the other reverse bias junction. And so you could measure the drift rate. And you could see that if you put a pulse in, the pulse spread as it moved down. And then you could see a Hall effect of things, if you put a magnetic field on it, you could observe a Hall effect. And we did all kinds of experiments, with these devices that he'd made. Which were.. terrific things. I happened to have, at that time, a couple of power transistors. They were about that size, and I had mounted them on a brass plate, as a heatsink. And I had some terminals on them, you know, screw-in, a kind of banana terminals. And we came to measure transistor curves, and I asked if I could use these. And he said, "Of course you can." So I had my own transistors, to measure the transistor curves with.

**Sproull:** So was this the first time you'd been buying transistors? Or…

**Sutherland:** No.

**Sproull:** You were a relay guy until…

**Sutherland:** I had done some relay stuff, but then-- No, transistors came in, and I remember somehow from Bell Labs, my mother got half a dozen transistors when they were brand new-- they were point-contact transistors, brand new. And we had these, they were never fired up as far as I could tell. But then as part of these adventures of building light-seeking robots, we got transistors. The CK722 came out, and you could get a CK722 for a couple of bucks. I think the prices came down to a few pennies later on.

**Sproull:** Yeah.

**Sutherland:** They were in little blue cans. And so we had those, and we made circuits with them, to amplify…amplifiers for the light, to then drive the motors. So I had made quite a number of transistor circuits early on.

**Sutherland:** But Milnes's course was an eye-opener. Now the other very good course that I had at Carnegie, was a course called…something about magnetics. Leo Finzi was the professor there, who did nonlinear magnetics. And so he had some magnetic cores, which were, you know, that size things with many turns on them that were square-loop hysteresis cores. And we did a bunch of experiments with those, for magnetic amplifiers of various sorts. And one of the experiments we did, was you had a small core and a big core, and you hooked them up. And as you switched the small core with a rectifier, after several switches the big core would have gotten enough drive to switch also. And you could see that-- you could see it stop changing, as you did. So there were a number of experiments of that sort, which remain vivid in my mind. I guess the laboratory stuff that I did at Carnegie, was the best part of the instruction I had. I also remember the motors, there was a rotating machines course. And these weren't this size stuff, they were this size stuff, right?

<laughter>

**Sproull:** Yeah.

**Sutherland:** With banana plugs that were a quarter inch in diameter that went in, and cables that were number two wire or something. And so you'd fire up these big machines and make them run. Learned about series motors, series-wound motors, and shunt-wound motors, and multiphase motors and so on. We did some experiments which were quite high power, it took three-phase power out of the line, put it into a motor and then measured the torque so it was driving a generator, which put the juice back into the line. So you didn't actually consume very much energy, but the energy in the pieces of rotating machinery was quite high. I've had fun at Portland State, talking with the guy who teaches rotating machinery at Portland State, and asking him questions. I asked him one question, which I don't know the answer to, and he didn't either. If you look at three-phase transmission lines, they appear in various-- the towers appear in various shapes. And one of the common shapes has six wires in this kind of configuration, where the center two arms are longer than either the upper or lower arm. And of course there's the lightning arrester on the top. And I asked him the question, which I think is an interesting question, why is the center arm longer? And it may be for a mechanical reason, to help you get the wires up there in the first place. It may be for an electrical reason which I don't know, okay? I have no idea what the reason is. Perhaps as a result of seeing this, or hearing this, somebody will tell me.

<laughter>

**Sproull:** So I want to come to a slightly different theme. So you also fussed with mechanical things. You have your own machine shop, you love making parts, and this and that. We haven't talked about any of that. When did that get started?

**Sutherland:** Well, there was a basement in the house, which had a drill press, and bandsaw, and a lathe. And a grinder, a grinding wheel. The grinding wheel was hand driven, so you turned a crank, and the grinding wheel was geared up so it went at a huge speed. And I learned quite a lot about momentum, from this grinding wheel. Because it was quite hard to get it going, and once it was going it was quite hard to stop it. Very interesting to actually see something, which has this property of storing enough mechanical energy, so you can know that it's happening. Ordinarily you don't run into such things. And there was a lathe, it was a South Bend six-inch lathe, which my brother still has. It had change gears on it, to do-- it was capable of cutting threads. But you had to get the right ratio between the turns of the spindle, and the drive of the screw that made the threads. So it had a bunch of gears that you could put on and take off. And then there was a bandsaw. I was allowed to use the drill press early on; drill press not very dangerous. I was allowed to use the lathe under supervision from my father. And later on I was allowed to use the bandsaw. I cut myself rather badly on the bandsaw one time. I was doing something I shouldn't have been doing, and I cut one of my fingers up-- well the fingernail up, halfway up the fingernail. And my mother bandaged me up, and sent me right back down to the shop. I was not admonished at all. I think she figured, quite correctly, that I had learned quite a lot by injuring myself. And there was no need to emphasize the lesson.

**Sproull:** So did this itch get scratched in college, at all?

**Sutherland:** I'm sorry?

**Sproull:** Did the mechanical itch get scratched at Carnegie Tech, at all?

**Sutherland:** Yeah, it got scratched. I built one of these light-seeking robots there. Which is.. it was the best one I ever built.

**Sutherland:** The best one I ever built, I built at Caltech later on. But there was a series of them, they're different sizes and different styles. There's three of them I still have… Carnegie put together an exhibit of the walking robot, which we'll come to later on. And they sent me a photograph that they had in their archives, of me as a college senior with this light-seeking robot, which I still have. And so Marly and I took a matching photograph, of me with the same tie on in as much like the same posture as I could possibly get, with the same machine. And we sent it back to them. And those two photographs now appear in a little essay I wrote about my history in computers. Which the Computer Museum should have a copy of, I can give you a copy.

**Sproull:** So did you have access to a shop at Carnegie Tech?

**Sutherland:** Yes. I had access to the-- well and then later on, I had very good access to the shop, to build the walking machine.

**Sproull:** No, I mean as an undergraduate.

**Sutherland:** But as an undergraduate, yes, I had access to some shop. And I forget-- obviously it was in Hamerschlag, and it was up high in Hamerschlag. I think there was a student shop there that I was able to use…to do various things, yes.

**Sutherland:** When I got to Portland State, one of the important things to me at Portland State is the machine shop for the mechanical engineering department. I went to the head of mechanical engineering, who's a guy I like a lot, and said, "I'd like to." And he said, "Okay." And he introduced me to the professional machinist who runs the place, who kept a careful eye on me the first day that I was there. I wanted to do something with the lathe, and he kept a careful eye on me. Then he figured out that I knew when to ask a question, and otherwise I would be okay. And he now gives me the run of the shop.

**Brock:** With these light-seeking robots, I was wondering why you returned to it, you know.

**Sutherland:** No idea. It was something I knew something about, not a very hard thing to make. And I've always thought about mechanical things, there's some art involved. I mean they're just pretty. I had on my desk for a long time, a blade from a turbine engine for an aircraft, which is just a piece of steel, but it's a thing of amazing beauty. I mean, it's got the stuff that fastens it to the wheel strongly enough so it doesn't fly off from centrifugal force, and then it's got this beautiful shape which changes as it goes along, and it's got a nice finish to it. But the real beauty of it is the crystal structure. It's made metallurgically to be super strong, and then some of them are hollow because you have to cool them, okay, and the cooling air is 400 degrees F, okay, but then it goes up through the middle. So these are things that are just pretty in their own right. And I think returning to that kind of robot. it was that each one was better crafted and had some features that the previous one didn't have which were appealing to me in an artistic way.

  

**Brock:** Interesting. Were you thinking at all in terms of-- I know these light-seeking robots and devices were a big motif in the kind of story of cybernetics, and I was wondering if that fed into your--

**Sutherland:** I don't know. Berkeley launched this set of interests. I know he may have, you know, had deeper reasons. I don't know them. No, I think it was strictly an artistic thing. In fact, I think that engineering and art are very closely related. And a man that I worked with in California named Glen Fleck who had been Charles Eames' number two assistant. And Fleck was a very interesting guy in his own right. He designed museums and he was a designer with a capital "D" who designs things for people to use and so on. And he said, "Do you know, the only difference between engineering and art," he says, "is the purpose." He says, "An artist produces something which he finds attractive and is useful to him for some reason. Whereas an engineer produces something that anybody can see is attractive and is useful to them. And the only difference is the size of the audience. That in fact, the two crafts are very much related." And, you know, engineering and particularly civil engineering, and architecture kinds of things are very closely related to art. The structure not only has to stand up, but it has to be attractive in some artistic sense. There's some truly ugly bridges. Okay. I mean, they're really, truly awful. But there's also some very graceful and pretty ones. The new bridges in Boston of this style of the-- with the suspenders that go down are really very attractive. There's a couple of them that have been built recently in Portland and they're very pretty. And they're pretty in the sense that you can see from the structure how they work. What you don't see from the structure is how they got there. I mean, the most interesting thing about a bridge to me is it not only has to work when it's there, but you have to have been able to put it there. Because at some point, it wasn't finished and it still had to stand up, right. And so cable-stayed suspension bridges are basically a cantilever. So you build the middle tower first and then you build it out from the middle and that's how it stays up. I watched the Sewickley Bridge in Pittsburgh, near Pittsburgh, being taken down. And how do you take such a thing down? Well, you take it down from the outside-in, being careful not to take more off one side than the other side, lest it fall over.

**Sproull:** <laughs> So back to Carnegie Tech. Did you do any computing at Carnegie Tech? Was there any computing there then?

**Sutherland:** Oh, yes indeed. So, Perlis was there when I was an undergraduate. And I ran into Perlis a couple times. But I didn't really do any computing as an undergraduate. And Newell was, of course, there. That's when I was an undergraduate. But I didn't interact with him much. And then I got to know Perlis very well when I was at DARPA, which is a few years later. And Newell, I got to know Newell very well also. And I think Perlis and Newell were great men with a capital "G" and a capital "M." I mean, there are on the web you can find a hundred odd Perlis-isms. Which are just, you know, little one sentence little gems, right. "In computing, anything is possible, nothing is easy." And there's a whole series of them, but he was just a marvelous guy. It's my privilege to have had a career in which I met and got to know reasonably well a number of very wonderful people that are just totally amazing.

  

**Sproull:** So another theme that I think at Carnegie Tech we need to explore is the Army. Tell us about the Army and Carnegie Tech. <laughs>

**Sutherland:** Oh, there's that. So I was in the Army ROTC. Well, you have to know that, you know, the Vietnam war was in full force and the draft was rampant. So what are you going to do, right? So I joined the ROTC. At least if I went in the service, I would go in as an officer and not as a grunt. And they had a program to teach young officers how to be officers and gentlemen. And one of the courses I took was a course in leadership. The Army quite correctly believes that leaders win wars. Well, that's perfectly true. And so they gave us a course in leadership thinking incorrectly that they could teach it. But what they taught instead was sort of case studies of great leaders. Patton carried pearl-handled revolvers. He was known for that. And MacArthur had a little dog that he took around with him. And what I took out of that was that the great leaders allow their humanity to show. Churchill smoked a cigar and had a big grin. And Eisenhower was known for his smile and the Eisenhower jacket and so on. So I think these people allow their humanity to show, and that seemed an important thing and that's one thing. And the second thing is they're eloquent. That if you're to lead people, you have to be able to explain to them what it is that you want them to do. And you can't do that if you're an inarticulate person. But other than that, what is leadership? I have developed an operational definition of leadership. Leadership is rare. Why is it rare? Leadership is that property of a human being which will cause a hundred or more others to follow him. It follows that it's at least only 1 in 100 skill, right. And if great leaders, you know, will cause 10,000 or more people to follow them. So it must be a 1 in 10,000 skill, right? But how you teach it is, you know, a mystery to the U.S. Army, in fact, a mystery to everybody. It's some property of a human being that's a combination of articulateness and appearance, carriage, conviction, trust, a whole bunch of things that are kind of ephemeral things.

**Sproull:** So, shall we move on? Next was Caltech, which you went to right after Carnegie Tech. And by now, you must have had some inkling of where you were headed, yes, besides West?

**Sutherland:** Well, I was headed for a Ph.D., that was perfectly clear. My father had one and it was no question that that's what I would do. And I don't know if there was an ambition, but it was clear. The head of the Electrical Engineering Department at Carnegie Tech was Everard Mott Williams, and Everard Mott Williams called me into his office when I was early in my senior year, I guess-- maybe, yeah, maybe late in my junior year. And he said, "Every year, I need to discover what the price of a graduate student is. What's the going rate for a top quality graduate student?" he said. "So I will have the departmental secretary fill out your forms if you are willing to apply to the following 15 graduate schools." And he said, "And I will pay the application fees." So I applied to nearly everything that was plausible, okay. And the deal was that I had to show what the responses were to Williams. And this was how he, you know, sensed what the competition was doing. And I had met in Pittsburgh a woman named Marcia Hermina Getting, and that's a whole other story, but... And I had proposed to her sometime in my junior year, I think, and we got married after I graduated. And my ultimate choice for graduate school was the plausible graduate student school as far away from my mother-in-law as possible. And that was why Caltech. That was the deciding factor for Caltech. I mean, it's a perfectly good school, but between Caltech and MIT, Caltech's further away, right. I didn't go to Cornell because Cornell paid for a trip to Cornell to visit Cornell to, you know, see how nice the campus was and so on. But the trip was in January and it was quite clear that January in Ithaca, New York is not a place you want to be. At least not a place that I wanted to be. <laughs>

**Sproull:** So then did you visit any of the other prospective places?

**Sutherland:** I don't remember. I really don't remember.

**Sproull:** Because this was not a time-- interviews for master's programs were not de rigueur.

**Sutherland:** No, they were not de rigueur.

**Sproull:** And you were applying for a master's program?

**Sutherland:** Well, either master's or Ph.D. I don't think any of the schools made the distinction at that time. The master's degree was often kind of a booby prize. If you didn't-- if you flunked out of the Ph.D. program.

**Sproull:** Right, right. So off you went to Caltech.

**Sutherland:** So I think I got accepted to nearly everywhere. I was--

**Sproull:** So you must have been a good canary in the coal mine here in the sense that the head of the department puts forward his best possible test case.

**Sutherland:** I think that's what Mott Williams was doing. And I graduated number one in the EE class, so. I mean, there was some grade evidence that that was true.

**Brock:** To get all positive responses.

<laughter>

**Brock:** I mean, the whole--

  

**Sproull:** Right, right.

**Brock:** The whole scheme only works on acceptances.

**Sproull:** That's right, yeah.

**Sutherland:** I tell this story, to any number of undergraduates, because it's a true story and I think it is typical of folk of that age, at least I hope it was typical. I remember walking down the corridor in the Hamerschlag Hall as a senior hoping that I wouldn't run into any of the faculty because I was a little frightened of them. And it's only years later that I figured out that a faculty member would be delighted to spend, you know, a few minutes talking with a bright student. I had no idea that that would be their response to this. I didn't want to consume their time unnecessarily and so on. And I remember that sense of fear of the faculty. And I've shared that with any number of young people to explain to them that, you know, these older folk are just folk like everybody else, right. But I certainly didn't understand that then. So Marcia and I went off to Pasadena, which was a good thing.

**Sproull:** And had you ever been that far west before? Well, maybe on dam visits.

**Sutherland:** No, I had been that far west. I went to summer school at the University of Colorado between my freshman and sophomore year, and at the University of Washington between my sophomore and junior year. So I had been West. Yes, I had definitely been West. I was in Seattle all one summer down at the University of Washington. U-Dub, I've learned later it was called and with a view of Mount Rainier down in Rainier Vista. And I took a field theory class there, if I remember, which had discussion of curl and divergence, and I somehow worked my way into the mechanical engineering shop there, so I was able to-- and I built one of these machines while I was there. That was an interesting summer. Seafair was on, and one of the events-- Seafair is the big summer festival in Seattle. And they used to have the unlimited hydroplane races on Lake Washington. An unlimited hydroplane is a thing-- an amazing thing to behold because it's a boat which goes at, you know, a fantastic speed supported by two little steel plates and one blade of its propeller. As it goes, that's all it needs to hold it out of the water. And these unlimited ones were, you know, 1000 horsepower engines. Dangerous as can be, but those races were held during the summer. I think, I don't know whether it was before or after that, but at Seafair, Boeing unveiled the 707. It was unveiled at Seafair one year, and the test pilot for the 707 flew the 707 over Seattle. And he did a slow roll over Seattle in the 707. He damn near got fired for it. Because as Teddy Walkowicz told me years later, that if there'd been an accident, it would have put jet aviation back, you know, a hundred years at least. But there wasn't. A slow roll is, you know, that kind of a motion and the airplane never knows it's upside down. So it's a very benign maneuver which the pilot obviously knew. But can you imagine, all the people that are out to watch and this thing comes over and does this slow roll?

<laughter>

  

**Sutherland:** Oh, and the prank is the Junior Chamber of Commerce dresses up as pirates at Seafair and they do various pranks on the city. And the year I was there, they kidnapped the mayor's daughter and put her up in a fine hotel. And she was, I think she was in on the game. And, you know, everybody was looking for the mayor's daughter. "Where is she? Where has she gone?" The pirates took credit for it and so on. <laughs>

**Sproull:** So back to Pasadena. So how long were you there?

**Sutherland:** I was there one year. They had a one year master's program, courses only, no thesis. Caltech makes the master's degree fairly easy and the Ph.D. fairly hard. MIT makes the master's degree fairly hard and the Ph.D. fairly easy. I didn't know that, but after my master's degree at Caltech, I transferred to MIT.

**Sproull:** <laughs>

**Sutherland:** I couldn't have done it better had I planned it, okay.

**Sproull:** <laughs> So it was just courses. Was there any focus to the courses that you were taking?

**Sutherland:** Well, there were, I don't know about focus. They were very fine courses. There was an excellent course in servomechanisms taught by Charlie Wilts whose book we found, I think. I don't remember, but I have his book somewhere. And it was, you know, all about how do you make servomechanisms stable and that kind of thing.

**Sproull:** Any computing experiences?

**Sutherland:** Well, computing at Caltech was a little backward.

**Sproull:** But there was-- there was aerospace in the area that was doing computing.

**Sutherland:** But digital computing grew up on the East Coast. It's quite clear that the West Coast was a bit behind. So one of the reasons I went to MIT was to do computing. And Marvin Minsky and Oliver Selfridge came out from MIT and I had lunch across the table from them at the Athenaeum. And they were waxing eloquent about computing at MIT and about the TX-0 that was there for students to use and how it was all going on at MIT. And I listened carefully to that and said that's what I want to do. Now MIT had as part of this application to graduate school, MIT had offered me a handsome fellowship to go to graduate school. So a year later, I wrote them and said I'd like to come to graduate school after all, having turned them down. And they said, "Well, we'll certainly admit you, but we can't offer you any fellowship." Fortunately, I had a National Science Foundation Fellowship which was transferrable, so I went with the National Science Foundation money, and that was a good thing to do. That's when I wrote to Shannon and said I'd like to, you know, come visit you. Shannon wrote back and he wrote a very nice letter back and he said basically, you have to come see me at the house, so and he told me where he was. So when Marcia and I arrived in Boston, we went to see Shannon at his home. Marcia was eight months pregnant with Juliet. And Betty Shannon put her arm around Marcia and said, "Come with me. You will need this baby keeping equipment. You'll need these baby bottles. You'll need this sterilizing equipment. You'll need this diaper rack. We're finished. You can just have them." Okay. And that was the beginning of a wonderful relationship in which Claude and Betty Shannon served in loco parentis for this graduate student and his wife. And it was, you know, it's the way a professor and graduate students should interact. I mean, in some sense, your major professor in graduate school is acting in loco parentis for you while you're there. And many of the graduate students that have been in my care and are in our care now, we treat that way. We recognize, both Marly and I recognize, that we are acting in loco parentis for them.

**Sproull:** So but MIT was a foreign territory in terms of who was, besides Minsky and Selfridge and Shannon, I mean, what was the department like? What were the facilities like? What were other students doing? How did you-- how did you navigate?

**Sutherland:** I don't know. Carefully, I guess. <laughs>

**Sproull:** Well, so here's a key question. You ultimately wound up working out at Lincoln. So what was-- what was the deal about Lincoln and Cambridge?

**Sutherland:** Okay. Well, there's a whole other story. This was to do with luck. And that it's not what you know, but who you know that matters, okay. How come I got into Lincoln Laboratories?

**Sproull:** Yes.

**Sutherland:** Okay. Well, when I applied to MIT, I also applied to Lincoln Laboratory for a summer job. Internships had not yet been invented but summer jobs were, you know, well-known. Only the name has changed. So I applied to Lincoln Laboratory for an internship and Marcia is pregnant, so, you know, having some resources is kind of important.

**Sproull:** Yes.

**Sutherland:** And I didn't hear anything. No news. Got to be February, March, no news. And then a note came from Lincoln Laboratory saying, "We're happy to offer you this summer job."

**Sproull:** So this would be between Caltech and MIT.

**Sutherland:** That's right. This is after my-- So February and March is while I was at Caltech.

**Sproull:** Right.

**Sutherland:** So years later, I found out what had happened. And it's a good thing I didn't find out at the time, because I might have been deeply offended. It turns out that Marcia's uncle was a man named Ivan Getting, first name spelled the same as mine but pronounced in the proper way. Do you know who Ivan Getting was?

**Brock:** A well-known scientist or a mathematician? Am I-- am I wrong?

**Sutherland:** Ivan Getting was the founding president of Aerospace Corporation. He had been a Harvard Junior Fellow. He'd been a Rhodes Scholar. He was the VP of Research at Raytheon when the microwave oven was first developed. He was an early member of the National Academy of Engineering. Not a founding member, but I think the first year or something. I mean, he was a first class top guy.

**Brock:** Right.

**Sutherland:** I had met him when I was courting Marcia. I was a senior or a junior or senior at Carnegie Tech. And he had come to dinner at his brother's house and asked to spend some time with me afterwards, and I went and talked to him and he was a nice man. And after I had talked to him, Marcia said to me, "How did the interview go?"

**Sproull:** <laughs>

**Sutherland:** And, and it's evidence of my naiveté, I had no idea this was an interview; I was just having a nice chat with this nice man. And apparently I passed, because I was allowed to marry the-- And then I know, I absolutely knew that I had passed on the next visit that Uncle Ivan made when his brother turned to him and called him, "Ivan," rather than "Ivan." Okay. That, you know, that was convincing evidence that the family had accepted me, right. So, so he had been Chief Scientist of the Air Force when Lincoln was founded.

**Brock:** Oh, okay.

  

**Sutherland:** So he had had something to do with Lincoln Laboratory being formed. And he apparently had visited there and said I'd like to see Ivan's application. And so they had to find it. It was lost. This is what I was told is that it was lost, and so they had to find it. And then, then they read it and said, "Oh, right." And then I got this offer. More than that may have transpired, I don't know. That's all I was told, okay. And I would have been offended, I think, had I thought that he pulled strings to get me that job, because I, you know, I was all for getting things on my own merits. What I've realized since is that I had to trust him to have decided what my merits were, and that he, if he pulled strings, he pulled strings because he thought it was good for Lincoln Laboratory and not just good for me. And, you know, personal references are very valuable, and one has to recognize that personal references are based on personal knowledge, which is the most valuable thing you can have in making a reference. But at that time I was, you know, I was kind of a purist and I might have turned the job down had I known that he'd had something to do with it. Anyhow, that's how I got to Lincoln Laboratory.

**Sproull:** So if it was a summer job, meaning they gave you an assignment, you had something to do.

**Sutherland:** Yes. I had a summer job. Right. The tunnel diode had just been invented. And Mitchell, I forget what his first name was, my boss, gave me a tunnel diode and said, "See what you can do with this." Now a tunnel diode, you must be an electrical person. You've asked questions that are…

**Brock:** Well, I'll explain myself over lunch.

**Sutherland:** So a tunnel diode is a non-linear device which exhibits negative resistance, unlike a neon tube which is similarly that sort of thing. But the neon tube has peculiar voltage characteristics. The tunnel diode has peculiar current characteristics. So you can make a relaxation oscillator with a neon tube. It makes a flasher. Or you can make a relaxation oscillator with a tunnel diode. And this is, I had a master's degree but was just starting as a graduate student. And I was given this tunnel diode and said, "See what you can do with this." Well, I wound 10 turns of wire around a pencil and hooked that and a dry cell, a 1.5 volt dry cell, in series with the tunnel diode, and I was able to see the oscillation on the oscilloscope. I was a ham radio operator at the time and I had been told that operating in the 6-meter band was pretty high frequency, and so you had to be careful with how you did stuff. And this tunnel diode and 10 turns of wire around a pencil was oscillating in the middle of the 6-meter band, okay? A pretty high frequency. And moreover, it was a non-linear oscillation. It was not a sine wave, it was a saw tooth. And I could see that on the oscilloscope. That's the day I stopped being interested in ham radio. Non-linear electronics is far more interesting than the linear stuff that radio is largely built around. And it was quite a vivid experience. Yeah. Right. So that was my assignment then. Then the next year I was a summer student there again, and I went in to see Wes Clark who had built the TX-2 computer. And I went in to see Wes and he was--he was 35, I was 10 years younger than he. And he was, you know, he was a group leader, an important guy at Lincoln, and I was a graduate student and I was a little scared of, you know, going to see him, and I went to see him and said, "I'd like to use your computer." And he puffed on his pipe and didn't say anything. So I said, "Well, do you need more time to think about it?" And I had told him what I wanted to do. I wanted to make pictures. And he puffed on his pipe and then he said, "No," and my heart fell. I said, "Oh, shit. My hopes are now shattered." And he said, "No," he says, "I don't need more time. You're on." So, well, that was a whole different story. And later on, he and I became very good friends and I went to the service where he was memorialized and I was very fond of this man. He was a-- he was a very big influence on my life. He was one of the great designers. He was both a designer and an artist. He understood that good stuff has to be simple and that if it's simple, it's easy to understand and therefore pretty. And I think he understood that very clearly. One of the things that I'm donating to the Museum now is a set of macro modules which are, and I'll say more about that later. He, at Washington University, he built this-- his idea was to build computing machinery that could be extended without limit. So however much stuff you had, you could have 10 times as much stuff and it would still work. And the problem, of course, is that the cables are going to get longer, and so you have to somehow account for the delay in the cables. And you cannot do that with a clocked system. You have to do that asynchronously so that things happen when they can rather than "now," because the size of the system says if you use a clock for the clocked paradigm, you have to have simultaneity over the entire size of the system, and the speed of light is whatever it is, and so you can't have, Mr. Einstein explains to you, that simultaneity doesn't exist over space, because time and space are intimately related. And this shows up in all kinds of ways. How do you synchronize the transit of railroads? Time in the United States became codified only when the railroads needed to have schedules. Before that, there was no need to have time similar in New York and Chicago. There was no point. But when the railroads went from New York to Chicago, you had to know when they were going to leave New York and when they were going to arrive in Chicago, so the time in New York and Chicago had to be somehow related, and you could only do that because there was a telegraph which was fast enough so that you could actually do that. Yeah, well…

**Sproull:** So let's go back to Wes.

**Sutherland:** There's a lot of-- there's a lot of stuff about time that--

**Sproull:** Yeah. Well, we'll come-- we'll have plenty of time to come to that, so to speak.

<laughter>

**Sproull:** So, so Wes was a group leader and the TX-2 was sort of his machine. How is that supported and why was Lincoln doing it?

**Sutherland:** Lincoln was supported by the Air Force to explore, you know, the needs of the Air Force for technology. Transistors had recently been invented, and so the group that Wes headed…Wes had worked with Jay Forrester. He had been part of Jay Forrester's activity earlier, which was supported by the Navy. And so he'd had quite a lot of history of advanced computing. But what they wanted to do was to figure out what the operating behavior would be of transistors in large numbers. And so they built TX-0 and then TX-2 for that purpose, and the Air Force paid for it for the purpose of not computing, but for the purpose of understanding the behavior of large numbers of transistors. So it didn't have to meet any particular computing demands, and so Wes was able to use the computing power in whatever way he saw fit. And Wes did something which I think shows enormous perception of the future. He said, "We're going to use this machine as a personal machine for individuals to use to learn about computing." And that didn't become common for many years-- until many years afterwards. So Wes took TX-2 and treated it as a window into the future of what computing might be if everybody had one of his own. Okay, now there was only one, so only a few people could have one of their own. And fortunately, I was one of those. Now I couldn't have done the work that I did for my Ph.D. without that access to computing. You simply could not have done that thesis anywhere else. Not only because of the equipment on TX-2 that made that possible, but also because of the way the time was allocated. And I got hours of time on TX-2 all to myself. Now admittedly, it was at 4:00 in the morning. But never mind. I mean, I had the hours of time when I could just diddle with what I was doing and learn, you know, what it meant to have this kind of interaction or that kind of interaction. And without that time, without that resource, it would never have happened.

**Sproull:** So this might be a good point for you to explain a little bit about the other people who were using TX-2. I presume some of them were colleague-like people and some of them may have helped you learn about various things. It must have been quite a dynamic community of folks there.

**Sutherland:** There was a dynamic community of TX-2 users. One that Bob will know is Les Earnest was there. He was a TX-2 user. That's where I met Les Earnest. And Charlie Molnar was there. Charlie Molnar was a lieutenant in the U.S. Air Force who was stationed at Air Force Cambridge Research Laboratory and he came over to TX-2 to do various experiments. I don't know what they were. There was a group interested in audio stuff. Larry Roberts was the principal utility programmer for TX-2. He wrote the assembler that, you know, people used to write their code, and he did experiments about encoding pictures for transmission from here to there. His thesis was an exceptionally good one which showed that if you added pseudo-random noise to a picture you could improve the response of the picture at the other end in spite of noise. I forget what the details were. But he did-- he did quite a nice thesis <inaudible>.

**Sproull:** There was also Stockham doing similar things.

**Sutherland:** Yes. Tom Stockham was there doing sound things. Doing audio things. So there was-- there was a dynamic group. Wes had been quite interested in the nervous system, how nerves worked and so on, and so one other machine that he built was called the Average Response Computer, which was basically a specialized machine that you could use to try and learn what nerve impulses were like, because it would average many, many nerve impulses, to take the noise out so you could see what the nerve impulse was separate from the noise. So there was a group involved in that, and I think they wanted to have a wet laboratory for neurological experiments adjacent to TX-2, but that was not-- that was not in the cards. The Air Force, I think, wasn't that interested in nerves. <laughs> Probably 50 years later, they might have been, but…

**Sproull:** So how did these groups compete for access to the TX-2? Did Wes control it all? Was there some bureaucratic--?

**Sutherland:** Yes. Wes was the-- Wes was the czar.

**Sproull:** Okay.

**Sutherland:** And he said what you got.

**Sproull:** So, so let's backtrack a little bit on your experience. Because was this the first stored program computer you had played with?

**Sutherland:** No. I had used TX-2-- For a year after-- I went to Lincoln Laboratory and I worked on tunnel diodes one summer. And then I was a year at MIT. And they had the TX-0 there. And then I became a TX-0 programmer. And there as a lively group of TX-0 users mostly associated with the Tech Model Railroad Club, of which Jack Dennis was the advisor. Jack Dennis was the advisor, faculty advisor, to the Tech Model Railroad Club. And it was also many of those people used the TX-0. Alan Kotok was there. Do you remember Alan Kotok? I think he's the late Alan Kotok now.

**Sproull:** But how did you fall in with the TX-0 crowd? Was this obvious?

**Sutherland:** Oh, it was-- No, it was there and it was obvious that it was the thing to do, all right, and I think it was fairly easy to get access to it. I don't-- I don't remember how access was allocated. But I did a program that was, somebody said it was one of the more “far out” programs. It was a maze solving-- it was a maze solving program, so.

**Sproull:** But I presume it was not a great challenge to figure out how to program these computers. It wasn't-- One didn't have to take courses or learn at the elbow of so-and-so.

**Sutherland:** You just figured it out. I mean, <laughs> I don't know how you learned to. You picked up the manual and read it and it wasn't that hard.

**Sproull:** Right.

**Sutherland:** It was pretty straightforward stuff. It was an assembler. It was a pretty good macro assembler that you used. I don't know who had written it, but. And then there was a debugging program. It was years later that I figured out what the name meant. It was a debugging program called DDT. And, oh, no. No, the TX-0, the debugging program was called Flit, F-L-I-T, which was the hand-pumped sprayer that you used to kill insects. And then the one for PDP-1, which was in the next room, was called DDT.

**Sproull:** Yeah.

**Sutherland:** And you probably used DDT.

**Sproull:** Right.

**Brock:** Was the TX-0 and the other computing resources at MIT at this time, was that within the Electrical Engineering Department? Or were they shared somehow? Or independent? Whose machines were they?

**Sutherland:** I don't know. Sorry. There was the Research Laboratory for Electronics, which was the-- which was the research organization in the EE department. They were located in the building where the EE department was, but I don't know how they were administered and I don't know who the administrator for the TX-0 was. I have no idea. That was above my pay rate.

<laughter>

**Sproull:** But you said it had been built by the Air Force as well. Is that right?

**Sutherland:** Yes. TX-0 had been built by Wes at Lincoln Laboratory. And then, they decided to move it to the campus as the right disposition for it when it was, you know, no longer useful as a test bed.

**Sproull:** So, so back to the Lincoln gaggle using the TX-2, so, so was this a kind of friendly social group as well? Was it, did this group of people have anything going on besides sharing a computer?

**Sutherland:** Oh, there was some social interaction involved, but not a whole lot. I wasn't a particularly social person at that time, but I went to some parties. One of the guys that was around the TX-2 was Tom Stockebrand. Tom Stockebrand was a character and a half all unto himself, right. He was a Caltech graduate. He wanted to come to a demonstration that I was giving of Sketchpad one time. He asked Fred Frick who was the big boss whether he could come. And Frick looked at him and said, "Well, you're wearing shoes today, Tom, so certainly you can come." That gives you some insight into him.

  

<laughter>

**Sproull:** Did you meet Severo Ornstein at the TX-2?

**Sutherland:** Severo played-- Severo, he was not called Severo, I think. He was called Randy.

**Sproull:** Oh, right.

**Sutherland:** Yes, I met Randy Ornstein. He was there. He played the piano at lunchtime. And he was-- he was--

**Sproull:** But what was his role? What was he-- what was he doing with TX-2? Working for Wes?

**Sutherland:** He was part of the staff that made it work.

**Sproull:** Yeah.

**Sutherland:** I don't-- I don’t think he was doing anything at that time.

**Sproull:** Yeah.

**Sutherland:** But he was part of the staff that made it happen.

**Brock:** Two quick questions. One was, was a security clearance required of everyone who worked at Lincoln Labs or just certain members of the staff there? Did you have to have a clearance to go in?

**Sutherland:** I don't think I had a clearance. I don't-- I, in fact, I'm reasonably sure I did not have a clearance. But guards… I don't remember whether I had to sign in or and out, or whether I just walked in and out. In the back of the Lincoln building was the blockhouse where there was a SAGE…that the number one SAGE system was in a blockhouse at the back of Lincoln. And that was secure territory. You didn't go in there.

**Brock:** Okay.

  

**Sutherland:** But I think the rest of the laboratory was unclassified.

**Sproull:** Was there any coupling between the SAGE project and the TX-2 stuff? Or did they just happen to both be at Lincoln?

**Sutherland:** Well, the big coupling was the memories. I mean, the big problem with computing was memory, how do you make memories. And Jay Forrester had invented the magnetic core memory, and it had been developed principally for SAGE. And then TX-2 had a magnetic core memory, the biggest one that had been built. It was 65,000 words. And that turns out to be too big, and it has to do with the signal to noise ratio of the sense lines. And you can only run the sense lines through a certain number of cores and then the signals become too messy. And clearly, the TX-2 memory was too big. The comfortable size for a core memory was not 65,000 words but 16,000 words. And so, the IBM people who had built the SAGE produced commercial machines, the 704 and the and so on, which had 32,000 word memories but they were actually two banks of 16,000 words each. And that turns out to be the useful size. Magnetic core memories come in sizes, exponents of 2, but they're always even exponents of 2, because they want to be square. So if you make them twice as big, they're actually four times as big, so. It's 2 to the 2n for some value of n. So that's why you get 16 and then 64, not 32 or 30-- 32 would not be a square memory.

**Brock:** In terms of other TX-2 users, I believe in listening to or watching a lecture that you one time gave, you talked about Herschel Loomis, who I think was doing also some screen oriented work with the TX-2.

**Sutherland:** Hersch Loomis did the first graphics program on TX-2 and he made basically Etch A Sketch. He programmed Etch A Sketch. You know, he had knobs and when you turned this knob, the dot moved that way, and when you turned this knob, it moved that way. So you could draw using the knobs, but it was pretty awkward and pretty crude.

**Brock:** The line would persist?

**Sutherland:** The line would persist, right.

**Brock:** Huh. And did that interest you or make any impression?

**Sutherland:** Well, I knew-- I knew Herschel Loomis.

**Brock:** Okay.

  

**Sutherland:** We were friendly. But, but I didn't think that was the way to do drawing. I mean, I had tried to make drawings with Etch A Sketch and it was not-- it was not fun. I mean, you have to get--

**Brock:** The sorts of features that you put into Sketchpad.

**Sutherland:** That's right.

**Brock:** I see.

**Sproull:** Is it time to turn to Sketchpad?

**Sutherland:** We certainly can do so. I think the listing is right there. We can look at it, if you want.

<laughter>

**Sproull:** Well, so, but nobody can read it. You and I-- You and I have looked at that and not made much progress.

**Sutherland:** It's written in assembly language for the TX-2 as slightly modified by Larry Roberts for Sketchpad. One of the things the TX-2…TX-2 had 32 index registers and it had very good index arithmetic. So one could treat index registers as accumulators, which gave you 32 of them. Now some of them were also used as program counters. But basically, index arithmetic was the secret to successful TX-2 programming. And so Larry put a feature into the assembler which allowed an instruction to reference two index registers, for example, to add one to the other, and so on. And, that notation is in that TX-2 listing. Sketchpad used it enormously widely. And the character set used on the TX-2 was provided subscripts. And so, this was a double subscript. And it's literally a subscript in the character font. And they were Greek letters. So, something or other sub alpha beta something or other was the kind of instruction. And those are in that listing. And they're a little hard to read. For one thing the listings were done on a xerographic printer. The first xerographic printer that had ever been made by the Haloid Xerox Company to be hooked to a computer was on TX-2. And it had a big roll of paper, which came through, and came out of the Xerox printer into a steel bin, which had a handy cover to put over in case there was a fire because the fuser sometimes would get too hot and the paper would come out on fire. Well, you had to cover it up. But apparently, Lincoln induced the Xerox Company to produce it. And they had a special charactron made, which had this font on it and was able to subscripts and so on. And that listing is printed in this font on that xerographic printer. And it's a little hard to read. But it's there. I mean if somebody's ambitious, they can--

  

**Sproull:** Well, it's got other problems too. There aren't very many comments.

**Sutherland:** Of course not. Of course not. I knew what the code was. Why did I need comments?

**Sproull:** Well, indeed.

**Sutherland:** It wasn't until later that I appreciated comments.

**Sproull:** It was also a PhD program. We all know what those look like.

**Brock:** Would one need Larry Roberts' assembler or some documentation around that to aid in the interpretation of the listing?

**Sutherland:** I don't know what you would need. There is some information around about it.

**Sproull:** So, another problem is the TX-2 changed every Wednesday.

**Sutherland:** Yeah, there is that. Right.

**Sproull:** And so, I actually-- have you ever tried to track down any description by Wes or others of what the TX-2 instruction set was?

**Sutherland:** Oh yeah, there's good documentation on it. There's quite good documentation on what TX-2 was, yes.

**Sproull:** Didn't you also tell me that the Sketchpad-- the assembler made considerable use of macros.

**Sutherland:** Yes, extensive use of macros.

**Sproull:** Right. And so, the macros-- but the macros are defined in the program, they weren't hidden in the assembler or something.

**Sutherland:** No, they are defined at the beginning of the program.

  

**Sproull:** Okay. So, it's not impossible that it could be deciphered.

**Sutherland:** It's not impossible to read it. But--

**Sproull:** It would be tough.

**Sutherland:** It would not be a trivial task.

**Sproull:** Well, so you've spoken earlier about the general motivation in making pictures. Some of it tracing back to putting engineering drawings on your textbooks in school, for example, because that's what your father had available to cover your textbooks. But can you kind of cast us a bit-- for-- did you walk up to the TX-2 saying I want to make pictures? Did you walk up to the TX-2 and say oh, I think this is a machine that has the right stuff for making pictures? How did all that get put together?

**Sutherland:** The TX-2 had a CRT on it. And under the CRT were four knobs. And there was a light pen of some kind. The light pen had been developed for SAGE for targeting airplanes, right? And we got quite a good light pen was developed by the people at MIT at the campus with the right optics in it. And so, when we got one of those and put it on-- I say we got one. One was obtained somehow. And somebody put it on. So, I got to use it.

**Sproull:** This is like the telephone dial.

**Sutherland:** Yeah, right. It was by magic, not by my mother in this case. So, yeah. And that was important. Then I made a tracking program for the light pen. It had a little cross that would appear. And as you moved the light pen, the cross would follow the light pen. So, it looked like the light pen was a flashlight, which shined this cross into the CRT. But that was the wrong impression. The cross was shining into the flashlight and was being moved to stay following the flashlight.

**Sproull:** So, was that sort of the first program you wrote that started to build up more stuff?

**Sutherland:** I don't remember the order of things. But I knew that was important to do. Almost immediately-- well, I had seen the TX-2 the summer before. And I knew that it had this CRT on it. When I went to Wes and said, "I want to use it," I said, "I want to use it for engineering drawings." I mean I was quite up front about that. I had had the idea that it could do that earlier. And so, I proposed that to Wes and he said yes. And years later, he said to me-- you know, he said, "I built TX-2 for you." He said, "Of course, I didn't know who you were at the time." But he had hoped, I think, that some person would come along and do something like Sketchpad with it. And I happened to be the guy who did that. But it was fortuitous A, that I got a job at Lincoln Laboratory, and B, the most important thing was Wes's wisdom in saying we're going to use this machine in a way that makes this kind of work possible. If Wes hadn't done that, it wouldn't have happened. And I think Wes's foresight showed in that. It showed in the next thing he did, which was the LINC, the Laboratory Instrument Computer, which was a personal computer targeted at laboratory use in biological laboratories. And it had a huge impact on how biological research was done. There were eighty or so of them posted by NIH here and there in biological laboratories. There's a book about that. And its impact was enormous on how computing got used in biology. And I think that was-- the foresight that Wes had was the important part to value. Wes was always a little enigmatic. When Wes would talk about things, he often had more than one meaning that he was conveying at the same time. And it was a little hard sometimes to understand what he was really after.

**Sproull:** He would almost speak as if he was presenting a puzzle that you were supposed to solve part of.

**Sutherland:** Yeah. He was-- I think enigmatic is the right word for Wes. He was a little enigmatic. And that was true throughout his lifetime. He was always like that. I don't know why, but that's the way he was. And I think it stood in his way of receiving the credit for the important contributions that he made because he wasn't one who said, "Well, it's pretty simple. This is what it is." He would say, "Well, it's got several layers." And he'd talk about whatever it was. My father used to have an expression for the family, a sort of family motto. "The difficult, we do immediately. The impossible takes longer." And I think he got it wrong. "The difficult, we do immediately. Simplicity takes longer." And simple is important. Mark Raibert came to me once after we'd worked on robots together. And he said, "Ivan," -- he said, "I learned something important from you." I said, "What's that?" This is one of the nicest compliments I ever got. He said, "I learned from you that simplicity is okay." Simplicity is more than okay. Simplicity is essential to science, that until you understand it and can explain it in a few simple words, you haven't really got it. And the great pieces of science, the great insights in science, are incredibly simple. $E = mc^2$, there's only five symbols in the whole damn equation. It's an amazing thing. And why it's the speed of light? Well, that's a whole other question, which I don't understand. But there's only five symbols. And you know $F = ma$, right? Newton's laws, not complicated at all but amazingly applicable. And if you can get something reduced to a place where it's simple enough that anybody can understand it, you've really got something. There was a fairy tale that I grew up with called "Rumpelstiltskin". Rumpelstiltskin was an elf who would do your bidding if you knew his name. And he was a magician. So, he could do anything if you knew his name. But nobody knew his name. He kept it carefully concealed. And I think this is an allegory for science that until you know its name, that is to say until you've named it and know it well enough to give it a name, you don't have it. But once you've given it a name, and you understand it well enough that the name is a meaningful thing to give it, then you've got it. And that's kind of the key to science. Claude Shannon once explained to me why he called it a bit. I mean Claude Shannon invented the bit. And he gave it a name. You get to name these things when you-- right? And I asked him, "Why did you call it the bit?" He said, "Well--" he said, "It's a very small amount of information. And so, it deserves a short word," he said. "And the bit is already an English word, which means something small, and so, I thought it was applicable." And once you do that, everybody knows what a bit is today. The name stuck. My mother explained to me, many years before, that English is two languages stuck together, I was almost going to say concatenated, but I chose to say stuck together for the reason that you'll understand in a minute. One of the languages is Roman. It comes from the Latin. And all of the long words, concatenated for example, come from that part of the language. And the other part of the language is the Anglo-Saxon, which is all the short words. And you can't swear in Roman words. You can only swear in Anglo-Saxon words. All the swear words are Anglo-Saxon. And all the words that children learn as youngsters are Anglo-Saxon. And the Anglo-Saxon words stick better than Roman words. They are more memorable and more useful. And the bit is clearly an Anglo-Saxon word.

**Sproull:** So, I want to come back to Sketchpad for a bit. So, there must have been some a-ha moments. There must have been some frustrating moments. There must have been some false starts that-- where programs got thrown out and replaced. Do you remember any of those that might have lessons or be noteworthy?

**Sutherland:** I remember an a-ha moment very clearly. I wanted to make a condition on three points that they be collinear. And I tried any number of things. I said we take these two, and we project that line. And we put this one on to there. We take these two and project that line, put this one on to there. And the a-ha moment was symmetry. That if you want three points to be collinear, it's important to have an algebraic expression which doesn't care which point is which. You can't pick two of them and calculate the third. You have to do some calculation that's based on all three of them in a symmetric way. And what is that way? It's the area of the triangle that they subscribe. And if they're to be collinear, the area of their triangle is zero. It's as simple as that. Compute the area of the triangle. And if it's zero, they're collinear. If it's not, they're not. And when I said that, you'll notice I didn't say-- I didn't distinguish a first point, a second point, and a third point. And that's important. And that was an a-ha moment. It was an a-ha moment not only about collinearity but about symmetry. Symmetry is an amazingly powerful idea. What is it that could be more like my right hand than my left and yet more different? The symmetry. We have right-handed coordinate systems. And we have left-handed coordinate systems. And they are totally different. I gave a lecture about symmetry at Portland State one time. There was one student in this lecture series and lectures who always asked questions, who was always making a nuisance of himself. And so, I handed him the right-handed bolt, and the left handed-nut, and asked him to put them together.

**Sproull:** How about some frustrating moments for Sketchpad?

**Sutherland:** Now, I remember another a-ha moment, which didn't have much to do with me, but it had to do with somebody else. I watched one of the other users of the TX-2 who had some shared variables that were shared between his-- for his programs. And he assigned them numeric addresses in memory. And I asked him, "Why don't you assign them symbolic addresses in memory and let the assembler say where they are?" Well, he wanted to know where they were in memory, which is irrelevant. So, I watched him move them repeatedly from one numeric address to another so he could keep them in order assigned. I forget why. But there was this a-ha moment which says symbolic addresses are enough, that the name of a thing is enough to describe it. You don't have to know exactly what the thing is. And there's this wonderful piece in "Alice in Wonderland," where the victim is told the name of the song is called George. I forget what the actual words are. And, "Oh, then the song is about George?" "No, the name of the song is called George." "Oh, then the song is titled George." "No, the song is titled Mary. But the name of the song is called George." Now, Lewis Carroll was a mathematician. And so, this is a thing about multiple reference. And there was this insight I got by watching this guy move this thing many times is that all you have to have is a reference, not the thing. And that's quite clear in my memory. Now, frustrating moments I've disremembered.

**Sproull:** Okay, so let me poke. So, how did you debug on that machine? What did a bug look like? I mean I realize you probably saw a picture you didn't expect to see, or you saw no picture or something. That's always been one of the wonderful things about graphics. But you had a bunch of toggle switches, and what did you do? Was there a DDT for it?

**Sutherland:** I don't remember. It was a wonderful mechanism in TX-2 called the metabit, which allowed you to stop the machine when it got to a certain instruction that had this bit set. And I forget how that was used in the debugger. There must have been some kind of symbolic debugger. But I don't remember what it was. But the code was all written in this macro assembler. And you could-- online, you could change the code and reassemble. And so-- and I don't know what it was. But the key debugging mechanism that I remember was you would set some metabit somewhere, and the machine would stop. And then you could watch what happened. And you could see on the lights what was going on. So, you could single step if you wanted and see what was happening. I don't-- debugging is not vivid in my memory.

**Sproull:** Interesting.

**Sutherland:** Of course, my programs never had bugs.

**Sproull:** Oh, of course.

**Brock:** I would be interested if you could kind of paint a picture of what it was like to write Sketchpad, you know, where you're working, just the process that you went through. Were you working at home on lined paper, and then coming in, and then the process for getting the code into the machine? And if you could just describe what it was like for you, your kind of practices for creating the software.

**Sutherland:** Well, I guess that's another lesson I learned is there's no substitute for thought. When we made the head mounted display, Danny Cohen said, "Well, we've got six degrees of freedom. We'll just put six matrices together. And then we'll debug it to figure out what order they should be in and so on." And I explained to him that the number of orders that you can have of six things, which can be reflected and so on, is larger than you're ever going to be able to debug. You've got to think it through and figure out what things are. And I think I learned that from programming on TX-2 that I would go home and think about what didn't work and then think about how to fix it. And then I'd write some code. I often typed the code in myself. But there was also a secretary who would type code for you. If you wrote it neatly enough so she could read it, she would type it in. And so, I often got her to write a section of code, which I'd add to the program, edit that in, and then run that. But it was-- what was definitely the thought was all offline. The online time was used to do the experiments to see what worked and what didn't work and maybe make trivial changes where there was a bug that was obvious to fix. But the big steps of oh, I'm going to have to do this whole new thing that's going to add capability, they were all done at home, mostly at home, and offline. I had an office at Lincoln, but I didn't use it very much. I don't really remember where I spent my time. I mean I also had an office at MIT. I shared an office at MIT with Len Kleinrock. And so, I learned all about his son, who was Marty I think. Who was a three or four-year-old at that time. And Russ Pfeifer and one or two others. Oh, and Larry Roberts of course. So, we had a four-man office at MIT on the campus. And I think I spent a fair amount of time there.

**Sproull:** Let's finish up a little bit about Sketchpad. So, there was an endgame involved in writing it up and it becoming a dissertation and some negotiations with your thesis committee. And was there an oral exam or any kind of procedural thing to get through?

**Sutherland:** There had been an oral exam as part of the qualification to be a PhD student to which Shannon didn't show up. He came in late having left me in the clutches of some other faculty member who was known to be a tough character. Then Shannon came in and rescued me from that. I may remember the faculty member's name, but it-- but then I gave a talk about Sketchpad in 10-250. I don't know if you know the MIT campus. 10-250 is a lecture hall that has steep things. It was the big lecture hall in building 10. And I gave a talk about Sketchpad there, which was the final oral presentation. But I didn't think of that as a toughie. That was just a talk about Sketchpad. And then the Licklider crowd showed up, and I gave a talk to them, which I think helped get Project MAC started.

**Sproull:** The Licklider crowd was the psychologist-- no.

**Sutherland:** No, Licklider was DARPA.  DARPA had, by now, gotten interested in what they should be doing in computing. And Licklider brought a crew of people, including Fubini[3] whom I got to know quite a bit later, to MIT to see about computing at MIT. And I gave a talk to them, which I don't remember who was all there. I don't remember the talk very well. But I think that had some influence on getting the DARPA computing program going. Certainly, Licklider was promoting that.

**Sproull:** So, that-- we'll get more chance to talk about Lick later. But what about the rest of your committee? So, you had Shannon on the committee.

[3] Eugene Fubini.

  

**Sutherland:** I had Minsky on the committee, and Steve Coons was the-- so the committee was three people. It was Steve Coons from mechanical engineering, Minsky, who was-- who was Minsky, and Shannon. And I had been to each of their homes and knew them all personally.

**Sproull:** Speaking of Steve Coons, he was a colleague of Doug Ross, right?

**Sutherland:** Well, I don't know colleague of Doug Ross. Steve Coons was a force unto his own. He was an independent guy. I don't know what his ties were.

**Sproull:** So, what was the nature of your interaction with him on Sketchpad? Did he--

**Sutherland:** Mostly he was encouraging. I don't know that he had much interaction with-- He would come out occasionally and see what was going on. I talked quite a lot with Doug Ross about structures generally. And he was big on n-component items, which--

**Sproull:** He called them plexes, didn't he?

**Sutherland:** Yeah, something like that. I don't remember. But--

**Brock:** And how was Minsky? What was his role? Did he provide anything that you can recall that was shaping in the direction of the Sketchpad project or--?

**Sutherland:** There was very little shaping done by anyone. The biggest piece of shaping that was done was when Shannon came and had an exhibit. And I had straight lines working just fine. And he said, "This is great, Ivan." He says, "I think you should do circles." And now, straight lines are pretty straightforward. Circles are a whole other bag of wax. But Sketchpad could do straight lines and circles. That was it, no conic sections, thank heavens.

**Brock:** One fascinating thing for me in watching some of your lectures about Sketchpad is just the-- how large the space is that Sketchpad represents, what a large canvas is accessible through the small screen. And I was just interested to hear how that developed.

**Sutherland:** It's perfectly straightforward. It was eighteen bit coordinates. And it was a ten-bit screen. So, the canvas was a hundred and-- no. It was two hundred and fifty-six times the size of the screen. That's as simple as that. Eighteen bit coordinates because TX-2 could do coordinate arithmetic, could do two additions at once of half-length. It was a thirty-six-bit machine. So, two eighteen bit-- The head of the group that TX-2 was built in was Ken Olsen, who left Lincoln to form DEC.

  

**Sproull:** And the PDP-10 for example, was also a thirty-six-bit machine. This was before the byte became god.

**Sutherland:** The PDP-6 before the PDP-10.

**Sproull:** Well, fair enough. That's right. And the PDP-1 was an eighteen-bit machine.

**Sutherland:** Right.

**Sproull:** So, the whole DEC beginnings were eighteen and thirty-six.

**Sutherland:** No, it was Fred Brooks who foisted off the thirty-two-bit machine on this world. And it may actually have been Warren Hunt's father. Warren Hunt's father was the designer of Harvest, which was the bubble on Stretch that was built for cryptography. And it used eight bit characters. And between Fred Brooks and Warren Hunt, Sr., they decided that machines could have power of two number of bits in the word. My own belief is they should have power of two plus ten percent.

<laughter>

**Sproull:** So, Ivan, just to kind of fill in the gaps, so the ROTC business was at Carnegie Tech.

**Sutherland:** Yeah.

**Sproull:** And then while you were at Caltech and MIT, I presume it was all dormant. You didn't have any real obligations at that time.

**Sutherland:** No, I was in the Reserves. They allowed me to put off active duty until after I got my PhD. I think they figured having an educated officer would be better than an uneducated one. So, while I was at graduate school at MIT they said, "If you go and take a physical, we'll give you a promotion." So, they promoted me from second lieutenant to first lieutenant for having done nothing. And I went and took the physical. I asked the guy who gave me the physical what the requirements were to pass this physical. He says, "You have to have a body temperature of at least 90F."

**Sproull:** Well, so this is great because this segues directly into the next topic, which is the I guess two years in the Army.

  

**Sutherland:** Right.

**Sproull:** So, which-- first of which was in Ypsilanti. What the dickens was going on in Ypsilanti?

**Sutherland:** So, the Army sent me to the U.S. Army Liaison Group Project Michigan. Project Michigan was a thing like Lincoln Laboratory, which was run by the University of Michigan at the Ypsilanti airport, which was no longer in commission as an airport I think. But-- so, I went there. There were three military officers in the U.S. Army Liaison Group. There was a colonel, a major, and me. I was a first lieutenant. So, I got all the extra duties. I was the VD control officer. I was the morning report officer. Every head in the U.S. military is counted every day. And the information is sent up to the Pentagon as to who's there and who's not, called the Morning Report. So, I had to count the three noses and make sure we were all there and report to Fort Monmouth that yes, none of us has gone AWOL, and so on. So-- and Colonel Nickel, who was the colonel in question, said to me, "I asked for somebody who would be the gopher," he said. "And they sent me a PhD from MIT." He said, "I'm not going to use you as a gopher. So, your job is to go into the University of Michigan research thing, figure out what's going on, and give me a lesson twice a week in what the research is." And the laser had just been invented. And there was a guy called Bud Vander Lugt[4], whose name appears in lots of laser related papers, who was there using lasers for various things. One of the things that they did there was side-looking radar. You transmit out the side of an airplane chirp radar pulses. And then if you collect back the reflections that you get and then carefully process them, you can get a map of what the radar sees with amazingly good resolution for thirty miles on either side of the airplane. And it looks like an aerial photograph taken from above. But it's taken from the side with radar. And the problem is the processing is pretty tricky because you have to do an inverse Fourier transform blah, blah, blah, blah. And you can do that with coherent light, which is what Vander Lugt was doing. And so, they had these methods of taking the radar data and making these maps, which-- it was brand new stuff, hadn't been seen before. And all the laser equipment was brand new. The major was the guy who had failed to classify properly the infrared stuff, I think. He was regretting that he had failed to classify it. So, some of it was used in the civilian economy already. And I think it was a good thing it didn't get classified. But it was a very interesting experience. So, I was there for four months. Fortunately, I had made a clause in the lease that I had for my rented house that if the Army transferred me, the lease was void. So, after four months, the lease became void. And I was sent off to Fort Meade, Maryland.

**Sproull:** So, tell us about Fort Meade. You went to NSA.

**Sutherland:** Well, Fort Meade was NSA. I had gone to there as a civilian after I got my PhD. They recruited me on the basis that we have computers here. I can't tell you how many but suffice to say we measure computing power by the acre. That seemed pretty interesting. So, I said, "Yeah, I'd be interested." So, I went there. And then I went in the Army. And the Army sent me to Ypsilanti, and then

[4] Anthony "Bud" Vander Lugt.

  

NSA-- oh, while I was in Ypsilanti, I requested a transfer to Fort Meade. And the transfer went all the way up through the chain of command. Then, after I'd been transferred to Fort Meade, it came back down saying denied, which shows that Fort Meade had more influence with Army assignments than I did.

**Sproull:** It shows that there may have been parallel processing involved, too.

**Sutherland:** Not surprising. I mean--

**Sproull:** Yeah. So, what did you do at the NSA in the acres of computing?

**Sutherland:** How shall I answer that, if I told you, I'd have to kill you?

**Sproull:** Yeah, something like that.

**Sutherland:** But I don't remember, anyhow, so you're perfectly safe.

**Sproull:** No, but I know many people are interested in the Schooler display.

**Sutherland:** We built a display at NSA and put it on a computer there. And I did various things with it. I don't remember them all. It was a PDP-1. I was in a group there. Doug Hogan was the head of the group. And that's the group in which the Harvard mathematician, made famous by the songs he sang-- Tom Lehrer, Tom Lehrer had been in that group some time before and apparently had sent-- been on a travel. And he had sent back a postcard which says, "$X^n + Y^n = Z^n$ only for integer values of n not greater than 2. A fact of which I found a most interesting proof, which unfortunately, this postcard is too small to hold." That's apparently a true story that that postcard was sent by Tom Lehrer back-- So, but they had the Schooler display. They had lots of computing, of course. There was a PDP-1 there, which I made extensive use of to make pictures on the display. And I don't remember what they were of. If there was classified stuff that I did, I simply don't remember it. So, your lives are perfectly safe.

**Sproull:** Was the Schooler display eventually converted into something commercial?

**Sutherland:** It was built by DEC for NSA. I don't know whether DEC built other ones.

**Sproull:** Well, so you remember the 340s that were on the PDP-1 at Harvard. Were they similar?

**Sutherland:** They were similar, but I don't know that they were exactly the same.

**Sproull:** Okay.

**Sutherland:** Total foggy in my mind.

**Brock:** Did you meet any of the-- is it Howard Campaigne the name of the fellow from the NSA who really got them into machine methods and computers? Did you have any--?

**Sutherland:** I met some of these people. The person who was most influential in my world was Mitt Matthews. And when I went back to NSA a year or so ago, I met Mitt Matthews' son, who works there now. And his shadow was long in the thing. Campaigne is a name that I knew. But I don't remember the reference. I mean I was a lieutenant, right?

**Sproull:** Yeah. So, from NSA, you went to ARPA.

**Sutherland:** Right, so then I had arrived at NSA, and six months later, they transferred me to the Pentagon to run a part of DARPA. And I think the story is that all of the reasonable people to take the job wouldn't. It was a civil service job, which meant they'd have to take a big cut in pay. And they'd have to have conflict of interest issues, blah, blah, blah, blah, blah. And they went down the obvious list of names through the forty-five who said no. And they got to me. And I was in the Army. So, I got orders. I couldn't say no. Actually, I could have. I said no initially thinking that it was too big a job. And then somebody reasoned with me. I don't quite know how it was, but then I finally said yes, probably the best decision I ever made, for me. Now, whether it was a good decision for the country and for research, that's a question which only history will tell.

**Sproull:** So, what did you know about ARPA at the time? You mentioned that Lick had brought a group up to MIT.

**Sutherland:** Well, Lick had been the first director of the information processing office. And he had set up a super program. I mean he went around to the top names in computing and assembled them as an advisory group, basically, go them to tell him what he should support. And he did it. So, he was supporting Doug Engelbart. He was supporting a big thing at MIT called Project MAC. He was supporting some work at the System Development Corporation under Jules Schwartz. He was supporting an effort at Carnegie Mellon and an effort at Berkeley under Dave Evans and a bunch of things that were first-rate contracts. So, I basically took over. And I think that I was basically the caretaker brought in to make sure that this stuff was defended and described in the Pentagon adequately. I went one time to brief Harold Brown. Harold Brown was the--

**Sproull:** DDR and E.

  

**Sutherland:** DDR and E, right. He was the DDR and E. I went to brief Harold Brown. I came back. On my way back, I ran into Al Blue. Do you remember Al Blue? Al Blue was the administrator who made it all happen. He said, "Where have you been?" I said, "I've been having show and tell with Harold Brown." He said, "Ivan--" He said, "You *brief* Harold Brown. You don't have show and tell." I couldn't tell the difference.

**Sproull:** But Harold Brown was a civilian, after all. So, maybe you have show and tell with civilians.

**Sutherland:** I think it was a briefing.

**Sproull:** Okay. So, I think you should repeat, for the record, your story about how you dealt with a big budget. Somebody gave you advice on how to think about administering a big--

**Sutherland:** Yes, Russ Kirsch, Russ Kirsch was working at Bureau of Standards. And he was very friendly to me and helpful. And he said, "How you do you keep yourself sane when you're responsible for a fifteen-million-dollar budget?" He said, "You take the ratio of your professional budget to your personal budget." And at the time, I was being paid fifteen thousand dollars a year, roughly. So, my ratio was a thousand to one. He said, "You take any professional expenditure that you have to make, and you divide it by your ratio. And that tells you how much effort you should put into the decision because now it's dollars that you're going to understand." So, by that reference, Project MAC, which was my biggest contract, was a new car. And I had nothing that was a house because you know you never have an expenditure that's bigger than your professional budget. So, nothing had to take as much decision as a new house would have taken. And that, he explained to me, is how you stay sane. And it's a pretty good idea, actually at any level of work.

**Sproull:** So, you must have spent a fair amount of time going around and visiting these labs and meeting a whole set of people that--

**Sutherland:** Yes.

**Sproull:** Expanded your universe a good deal.

**Sutherland:** In some sense, it was a traveling fellowship that I got to go and visit all these people who were doing work for DARPA. And I got to know some of them reasonably well. And that's how I got to know Perlis and Newell basically was through that activity. One of the things I thought would be important would be to have a common character set for the DARPA contractors, that it would be important that they could communicate together. ASCII hadn't been invented yet. IBM was firmly holding onto EBCDIC as the character set and wouldn't let go of it. And ASCII hadn't been invented. And so, I thought it would be valuable to have a common character set. So, I called a bunch of the contractors together. We had a meeting about it. And Al Perlis put the whole thing in context. He said, “I’m in favor of a common character set. Ours is available.” Perlis was a very perceptive guy.

**Sproull:** So, just as a footnote to that, only a few years later, there were big arguments among the ARPA contractors about how keyboards should be laid out so that all those characters would appear in the same spot.

**Sutherland:** Is that right? I didn’t know anything about that. Perlis probably would have said, “I’m in favor of common keyboard, and ours is available.”

**Sproull:** I think he may have actually.

<laughter>

**Sproull:** So, the office was just you, or who was the office? Did you have any program managers?

**Sutherland:** Licklider’s-- no. Licklider’s office consisted of him and an Air Force colonel who was his deputy and a secretary. It was not considered appropriate for an Air Force colonel to report to a first lieutenant, probably correctly. But the fact that I was in the Army was carefully concealed. When I went there, I worked for a man named Sproull, Bob Sproull’s father. And the press release of my arrival was prepared by the Army. And it said Lieutenant Sutherland is taking over this office. I went up to Bob’s father. who crossed out L-T and wrote in D-R and sent it back down. And they crossed out D-R and wrote in L-T and sent it back up. And the press release never was released. So, the fact that I was in the Army was a carefully concealed secret. I always wore civilian clothes, never wore my uniform. I used to sit on the sofa in staff meetings next to Major General Wienecke[5] who was in the charge of the war-in-Vietnam part of the organization. And he always called me Ivan, and I always called him sir. We got along just fine. I don’t think he knew I was in the service. And I certainly wasn’t going to tell him. And it went on fine. And another office director was a man named Sam Rabinowitz. And Sam Rabinowitz explained to me that are only two places in your personal net worth that matter. I remember this distinctly. He said, “When your net worth is equal to your annual expenditure, you’re independent of any one employer because you can afford to take six months to find another one. When your individual net worth is between ten and twenty times your annual expenditure, you’re independent of any employer,” what in this part of the word they call post-economic. And I remember that distinctly that discussion I had with him.

[5] Major General R. H. Wienecke.

  

**Sproull:** So, an interesting thing about ARPA, it seems to me at the time, is it was addressing applied problems using personnel, trying to make connections with universities, and so forth where fundamental research was a cherished thing and applied problems weren't always respected. Does that resonate at all in the computer world or in other ARPA linkages?

**Sutherland:** I think the Defense Department at that time understood, in some sense, the people there understood that research was a valuable thing and required continuity. And I remember distinctly the discussion of nuclear test detection. Nuclear test detection depended on seismography. And they built a huge seismometer to detect illicit tests by-- underground tests by our opponents. And at some point, they discovered that they were supporting ninety percent of the geology research in the country. And by then, they had built this huge seismometer. And they had the problem in hand. So, they had to stop doing that. And they said, "We have to stop in a graceful way because if we just turn it all off, that brand of research will be set back substantially." And so, they were careful as to how they treated that to make sure that some continuity was provided for the researchers in question. Now, I think that kind of statesman-like behavior has largely been lost to the bean counters. If the bean counters say, "Well, these people can get other jobs. We'll just shut it off." And so, research contracts often get cancelled just at the spur of the moment. And they're typically written by DARPA, now, for a year at a time. And a graduate program is three or four years. And how, in good conscience, can I take on a graduate student if I don't see a way to support him for the next three or four years? And that's a conflict between budgetary considerations and the needs of research, which I think is not well treated in the present environment. It was quite different then. And we could write sole source contracts. I mean it was-- it became clear to me early on that the most important line in a proposal was the name of the principal investigator. The content of the proposal might change. What they actually did might be different from the proposal. I mean, for example, who was it who invented the browser, done at the University of Illinois? Right? Done under a contract which never mentioned a browser. The Internet hadn't been available when the contract was written. It was done by this graduate student, basically--

**Sproull:** Marc Andreessen.

**Sutherland:** Under this contract which had nothing-- said nothing about it. And now, you can't have the kind of fortuitous thing if you insist that you follow exactly what the details are. And research has that property that it's got to be done in a flexible way that understands that you cannot schedule a breakthrough nor even the topic of the breakthrough. These things happen if there's a base of activity going on that provides the fertile environment in which such ideas can grow. And I think that's something that's very important to understand and that accountants don't understand it because they can only count things. And research can't be counted. It's not--

**Sproull:** So you mentioned you sort of inherited the program that Lick had crafted. Were there new things you started or what kind of modulation occurred while you were there?

  

**Sutherland:** The big perturbation which I did to it was ILLIAC. A guy called Dan Slotnik came into my office. He was plainly a genius. He plainly had interesting ideas of what he wanted to do. He wanted to build the biggest computer in the world, okay, and he had an idea of how to do it. He was at Westinghouse at the time, and I basically said, “This sounds to me like a good idea. Let’s do it.” Now, Charlie Herzfeld, who was the director of DARPA, had taken over from Bob’s father, and I went to Charlie and said, “This is what we want to do,” and Charlie said, “That sounds good to me. Let’s do it.” So Slotnik moved to the University of Illinois, which had built a number of computers, and started building ILLIAC IV. And there are those who can argue that ILLIAC IV was a waste of money. Well, maybe so, but it produced useful results for 20 years, and that’s a very long lifetime for a computer, experimental or otherwise, and the reason had to do with its relation to secondary memory, that it had the very quick ability to use disc storage as a storage medium for its computations, and as a consequence there were problems that it could do that nobody else could do. Now, maybe that’s fortuitous, and maybe that could have been designed into a cheaper machine. I have no idea, but those are the facts. Now you have to decide whether I did the right thing or not. But some directors after me continued the funding, so I don’t believe it was a total mistake, and I really believe that Slotnik had good ideas.

**Sproull:** So eventually IPTO sort of became famous for annual contractor conferences and graduate student conferences and so on and sort of a community of contractors. Was that going on at the time?

**Sutherland:** Yeah, that was Licklider. And Licklider was a psychologist by training and he was very good at getting people to cooperate with each other and so on. He used to have-- at the beginning of meetings he used to have what he called entrance music, which was basically some conversations of interest but not the focus of the meeting.

**Sproull:** So did that include students as well at the time from the get-go?

**Sutherland:** I don't remember what he did. Another thing that Lick did was he set up a meeting of the funders of computing research, and this was an unofficial organization that met every two or three months. And through that organization I met the people who did research from the army, from the navy, from other government agencies, from NASA, from so on. All these information processing people met to discuss what they were doing and so on, and that was mainly a social organization which assisted the communication between those groups. And Lick set that up, knowing full well that it would be important to have them communicate without having to have a charter or any purpose other than a social purpose.

**Sproull:** That’s interesting because such things still exist. I wonder if there’s a direct lineage to that.

**Sutherland:** Maybe so, but I don’t think Lick is the only wise person that--

**Sproull:** No, no, I understand.

  

**Sutherland:** --was ever around who could do those things.

**Sproull:** Right, but things do have their origins. I mean...

**Sutherland:** Yep. I visited once with the National War Games Agency. I got to know the guy who ran that or one of the guys who was involved, and he invited me to go to a war game. And at the war game was the deputy secretary of state and the chief of staff of the army and a few other people at that sort of level, and they met to do these war games. And he said to me, "The most important part of this is that these people get to know each other so if there's an emergency they know what the other people are like and how they'll behave." And he was quite clear about the value of the war game was far less important than the social interaction of the people involved. I've complained repeatedly to the dean at Portland State that there is no place I can go on a regular basis to meet people from other parts of the university, that there is no social interaction between the physics department and the engineers, for example. Why not? Because nobody thought of it.

**Sproull:** So at the risk of treading into very murky territory, from the get-go from Licklider were notions that networking, communications, connecting machines and people together would be a big thing, and he had galactic network kinds-- you know, fairly hyperbolic ideas. And these must've been percolating at some level. We're pre-ARPANET here, so no great quantity of money is flowing yet.

**Sutherland:** Lick talked about the intergalactic network.

**Sproull:** Yup.

**Sutherland:** That's what he called it. I mean he was straightforward about it and he thought it would be an important thing to do. There were three computers at UCLA, and so I suggested to the UCLA people that they network them together, that DARPA would pay for that in the interest of promoting this idea. And I learned something important from that, is that research occurs because somebody has an idea and a funding agency agrees to fund it. And because the network was my idea and not theirs, some things happened but not with great enthusiasm, and I consider that project a failure, okay? Now, I think Larry Roberts was better able to engage people who could actually do the job and make the network happen. I had a run at it and failed.

**Sproull:** Well, Larry himself was active a bit in this area at the time, right?

**Sutherland:** I don't know. I don't know what the magic was that caused the internet to happen. It was--

**Sproull:** Well, to fast-forward just a bit, I remember when you were at Harvard he got a very fancy modem installed on the PDP-1 there to do stuff between Lincoln and Harvard.

**Sutherland:** Well, you know more about that than I do.

**Sproull:** <laughs> I wish I knew what was actually going on. All I saw--

**Sutherland:** <laughs>

**Sproull:** --was that there was a DEC guy sitting there with his soldering iron wiring in the modem. So let's see. Toward the end of your ARPA stint-- so you must've finished your military service before you left ARPA.

**Sutherland:** Yes, I did. I stayed in the same job going from a first lieutenant, 02, to a GS-13, so now I could go to the cafeteria that was reserved for majors and above which I hadn't been able to go to before, and I had 2-1/2 times the salary.

**Sproull:** Now, I was gonna say, this will change your budget ratio.

**Sutherland:** It changed my budget ratio by a factor of 2-1/2, and it took Marcia and me, oh, a month or two to learn how to spend it.

<laughter>

**Sproull:** But ultimately how did the natural course of things run out at ARPA? I mean did you set yourself a two-year window?

**Sutherland:** Yeah, I set a two-year window and I wanted to go to academia, so I said, "I'm going to leave," and then Bob Taylor took over and had to find a deputy. He had to find a permanent person. He was not the right person to run the office in the long term, and he somehow found Larry.

**Sproull:** But, actually, he was hired before you left, wasn't he?

**Sutherland:** Yes, I hired Bob Taylor.

  

**Sproull:** You hired him, yeah.

**Sutherland:** I hired Bob Taylor.

**Sproull:** Right, and you hired him essentially as a deputy.

**Sutherland:** As deputy, yes. He was my deputy.

**Sproull:** Yup. So--

**Sutherland:** As opposed to assistant. There's a distinction between deputy and assistant in my mind, at least.

**Sproull:** Uh-huh. So next step was Harvard.

**Sutherland:** Yes.

**Sproull:** Who recruited you to Harvard?

**Sutherland:** Tony Oettinger. Tony Oettinger recruited me at Harvard. Harvard offered me tenure out of the box.

**Sproull:** And Oettinger was not an ARPA contractor at the time.

**Sutherland:** No.

**Sproull:** No.

**Sutherland:** Why Harvard offered me tenure out of the box, I don't know.

<laughter>

**Sutherland:** I went to Harvard as a tenured professor out of the box, very unusual. I didn't appreciate how unusual that was or what it meant at the time. I was very naïve about these things. But it was clearly a great offer. I took it. I told Carnegie Mellon that they'd done that and Carnegie Mellon matched the offer, so I could've gone to Carnegie Mellon with tenure out of the box. I elected to go to Harvard as being the more reputable place. Besides, I knew Pittsburgh--

**Sproull:** Was too close to your mother-in-law? <laughs>

**Sutherland:** Too close to my mother-in-law, yes. One might say that.

**Sproull:** <laughs> So besides the offer, were there any other particular attractive-- did you have a plan of any sort in going to--

**Sutherland:** I had a research topic. While I was in DARPA I had gone to see the Bell Helicopter Company who had mounted an infrared camera under a helicopter to help the pilot land at night. This story is told in this little speech that I gave in Los Angeles, so I don't need to repeat it here. But so I knew that I wanted to build a head-mounted display and I went to Harvard. And after I'd been there for a few months a PDP-1 appeared. I don't know how Fred Brooks caused that off. Not Fred Brooks.

**Sproull:** Harvey, Harvey Brooks.

**Sutherland:** Harvey Brooks.

**Sproull:** Yeah.

**Sutherland:** Harvey Brooks pulled that off somehow. This PDP-1 appeared from the Air Force and was put in Cruft Hall and given to me, basically. There was magic involved in how that happened. I didn't propose it. I had very little to do with getting it, but it was clearly a very important thing to have, and it trained a generation of students including that one.[6]

**Sproull:** Forgive me, but I've always assumed that this was you and your Lincoln connections.

**Sutherland:** No, it was total magic as far as I'm concerned.

**Sproull:** <laughs>

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[6] Ivan Sutherland points at Bob Sproull.

**Sutherland:** It was complete black magic. It was the Harvard old boys' network in full swing.

**Brock:** But they knew that you needed a computer of your own for your work.

**Sutherland:** <laughs>

**Brock:** So the need was well known.

**Sutherland:** I don't know what they knew or didn't know, okay?

**Brock:** <laughs>

**Sutherland:** I mean this was above my pay grade--

**Brock:** <laughs>

**Sutherland:** --and I was a very naïve young man. I had no clue.

**Brock:** And which department were you joining? I wasn't quite sure.

**Sutherland:** I was in the DEAP, the Division of Engineering and Applied Physics, which department.

**Brock:** Oh, okay.

**Sutherland:** And Harvard was so small that engineering was the department, the DEAP. And it was so small that it kept almost losing accreditation.

**Brock:** Really?

**Sutherland:** Yes. Every year it was touch and go whether Harvard would be accredited, as it didn't have enough faculty to teach a reasonable set of courses for engineering. But, you know, the accrediting body would lose credit if it disaccredited Harvard, so I mean--

**Sproull:** <laughs>

  

**Sutherland:** --there's a certain magic associated with a school that's 300 years old. We recruited at Portland State--which started in 1946--we recruited a man named Willem Mallon and he came to Portland State and the computer science department offered him a position, and he filled out his credentials and sent them in. And they said, "Now, wait a minute. You don't have a degree in computer science." They says, "You have a degree in, what is this, mathematics and the physical sciences?" He says, "Yes." They said, "Well, what does that mean?" He says, "Well, it's the same degree that they've offered for 400 years."

<laughter>

**Sproull:** So I want to talk a little bit about the PDP-1. Its similarity to TX-2 notionally seems dramatic. You were the Wes in terms of setting up access to it, I believe. You set up the yen system for scheduling time. We don't need to go into the details, but were you channeling Wes here? Did you learn from his experience about how to allocate a scarce resource and shiny object?

**Sutherland:** No, he didn't have a yen system. But the PDP-1 that appeared had three displays on it, three separate CRTs, right, and it was clearly the right thing for online use, and I was interested in online use, so it was clear that was how the machine was gonna be used. It wasn't a question to be decided.

**Sproull:** No, I'm talking about who got access to the machine.

**Sutherland:** Oh, I decided who got access to the machine. But there was this bidding system for using it, so essentially anyone who came in would get access to the machine at a very low level. And then the more important projects got more yen so they got more access.

**Sproull:** But I suspect there were a certain number of people darkening your doorstep for access. I mean, for example, Licklider himself was there playing on that machine.

**Sutherland:** Well, I suppose I used some judgment, but I mean--

**Sproull:** <laughs>

**Sutherland:** --I don't remember specifically turning down any serious applicant, you know. There was not a person from some other part of the university that came and said, "I really wanna use that machine," that I remember turning it down and having a conflict over it.

  

**Sproull:** The other person I remember who played a memorable role was John Goodenough. Do you remember him?

**Sutherland:** Of course I remember John Goodenough. He was a good guy.

**Sproull:** Yeah. He maintained DECAL, the compiler, the ALGOLic language that--

**Sutherland:** I think he was a student of Tom Cheatham's.

**Sproull:** I think that's right.

**Sutherland:** Tom Cheatham was at Harvard at the time teaching and he was a compiler guy, and I think Goodenough was a Tom Cheatham student. He was plausibly a useful character, and so of course he got some access.

**Sproull:** Well, and he chipped in. I mean he supported everybody else, too.

**Sutherland:** That machine was used online 24 hours a day 7 days a week, holidays included, okay? And we kept a record of that. One of the conditions of its being there was we had to report utilization to the Air Force, so, what was her name, Cindy, the secretary, reported to the air force the use. And I got a call from the Air Force saying, "There's no need to falsify these records."

**Sproull:** <laughs>

**Sutherland:** "We have the machine here at AFCRL and it was used for one shift. You know, that would be fine. We're happy with it being used for one shift. You're reporting it's used 24 hours a day 7 days a week." And I said, "No falsification. That's how it's being used."

<laughter>

**Sproull:** So you also recruited Steve Coons to come join you somehow.

**Sutherland:** Steve Coons had been a professor at MIT. He got in some emotional trouble. He had a difficult divorce. So I asked him to come and be a visitor at Harvard, which he did. He had an office next to mine and he was just there as a father image and pleasant guy to have around, and he understood the mathematics of curves and he taught us many things about conic sections and how to behave with them and so on. He clearly made a contribution, but it's hard to define what the contribution was.

**Sproull:** What about William Newman? He was a post-doc? Is that right?

**Sutherland:** No.

**Sproull:** No.

**Sutherland:** No, no. William Newman was at Utah.

**Sproull:** No, no, no, he was at Harvard originally.

**Sutherland:** Was he?

**Sproull:** Yeah. Wasn't he? Yeah, he went to Utah from Harvard before you did.

**Sutherland:** William Newman.

**Sproull:** Okay.

**Sutherland:** The Brit.

**Sproull:** Yeah.

**Sutherland:** I don't think so. I think I recruited William Newman to Utah.

**Sproull:** Okay, well, maybe I just remember him as a visitor. I don't know. But the other person--

**Sutherland:** The memory is foggy once you get to--[7]

[7] In 1968, Newman's affiliation in a publication is Harvard University. In a 1971 publication, his affiliation is the University of Utah.

**Sproull:** The other person-- well, obviously mine, too. The other person we need to talk about is Danny Cohen.

**Sutherland:** Yes, I taught a course in graphics at Harvard, and Danny was an MIT student and he came and said, "I want to take your course," and I said, "No." But Danny was not one to take no as an answer, so he took the course anyhow and turned out to be very effective.

**Sproull:** Yup. So let's see. There are various questions under the "Inquiring minds want to know" here. One is, so you put together a research project based on this notion of making 3-D perspective images.

**Sutherland:** Right, the head-mounted display, what I called the head-mounted display.

**Sproull:** The head-mounted display. And you got a grant to fund it.

**Sutherland:** There were a variety of grants to fund it, but the interesting one came from the CIA. Now, the CIA had gotten in some trouble because, something or other, they had been doing some things that they shouldn't have been doing, I think, so the CIA was looking for a reputable university to whom they could give an unclassified research contract. I heard about this and so I put up my hand. We were reputable. Harvard is a reputable place. We'll take the money. It was $80,000, if I remember. So got this research contract from the CIA, unclassified, totally unclassified. But it was kind of a strange thing because progress reports were to be sent to this address somewhere in Virginia, obviously a home address of somebody. And a guy came to visit one time on a-- it was a beautiful fall day. It was 60 degrees and my leaves needed raking at home, so I was at home raking leaves. And this guy came in and talked to the secretary and said, "I'd like to see Ivan." And she said, "Well, where are you from?" And he said, "Well, you know, I just want to see Ivan," and wouldn't tell her that he was a sponsor. So she said, "Well, Ivan's not here." So he had to come back the next day when I was actually there, okay? If he'd told her I mean I'd have come in, right, but he refused to tell her. So it was a funny contract. And then the Old Mole got a hold of it. You know this story. So Old Mole was the leftist rag from Harvard Square. "Harvard University takes filthy money from the CIA." Horrors, oh, horrors, Harvard taking money from the CIA, and there was a scandal about this, and there was a big fuss about whether Harvard should or shouldn't take CIA money. So Dean Ford set up a debate amongst the faculty of pro and con, and there were to be eight speakers at this debate. I was not one of them but I attended the debate. And it is evidence of the eloquence of the Harvard faculty or the naiveté of Ivan Sutherland that my opinion changed eight times during the debate. And the way it went was against, for, against, for, against-- and Dean Ford saved the last slot for himself. And Dean Ford's argument, which I think is a sound argument, was, "There is no such thing as a filthy source of money. There are only filthy conditions of the grant." And he said, "Harvard above all should understand this since a large part of the Harvard endowment comes from the triangle trade."

  

**Sproull:** Uh-huh. <laughs>

**Sutherland:** Is that meaningful to you?

**Brock:** It is meaningful to me.

**Sutherland:** <laughs> It also happens to be a true statement, right, that wealthy Boston captains made oodles of money from the triangle trade, gave it to Harvard. But there were no strings attached, which is the only important thing.

**Sproull:** So I don't know. There are many things we could talk about about that project, but we probably don’t want to shoot the rest of the afternoon. But I remember one thing, which is you were obviously known to all of the group members as the Sketchpad guy and so on, and everybody was happy with computing and it was a transistorized computer and so on and so forth. But as part of the head-mounted display, somebody had to build deflection electronics for these little CRTs that stood up on your temple. And I recall you went away one weekend and came back with a transistorized amplifier. I think it was the design that was called the long-tailed pair. It was basically a differential amplifier, but it had to turn out something like 150 volts of swing to drive these plates. Am I even close?

**Sutherland:** Well, you’re probably close but I don't remember the details.

**Sproull:** You don’t remember?

**Sutherland:** The deflection for those CRTs was a problem.

**Sproull:** And then it was built. Somebody built it, I presume a technician, inside a beautiful lucite enclosure. The only thing I can imagine is it was clear so that when components blew up you could tell what had gone wrong.

**Sutherland:** Why it’d blown up. I have no idea. I just don’t remember that at all.

**Sproull:** <laughs> Okay.

**Sutherland:** The hardest part of that project was that, was hooking up to the CRT, and I don’t think we did it as well as we should have.

**Sproull:** But to me, my impression was that was the hardest part of the project, and the leader, the most capable guy, went away and did it.

**Sutherland:** I simply don't remember. I'm sorry.

**Sproull:** <laughs>

**Sutherland:** If that's true--I'd love that to be true--

**Sproull:** <laughs>

**Sutherland:** --but I don't remember well enough to take the credit.

**Sproull:** Maybe the final report has the story. I don't know.

**Sutherland:** Could be. Could be. The CRTs were built by a wonderful little company whose name I don't remember. They were one-inch CRTs. And I went to visit them and watched how they were built at the factory that made the CRTs, and these guys specialized in making fancy CRTs for various purposes. And I learned that the ratio of the length of a CRT to the diameter of its screen is the critical factor because it's the angle that you have to have for deflection, and making a CRT long relative to the diameter of its screen makes it much easier than making it short relative to the diameter of the screen. For a home TV you want the shortest possible thing with the biggest deflection, which is hard. Our CRTs were one-inch screens and about six inches long, which makes it relatively straightforward. But those CRTs were specially built for that head-mounted display. The head-mounted display itself had been designed by Perkin Elmer and built for Bell Helicopter for the pilot experiments that they did, and we just bought another copy, and Bell Labs supported that. There was a $25,000 a year standing agreement between Bell Labs and Harvard that Bell Labs would send 25K to the dean at Harvard every year, and I got to use that to buy the CRTs -- to buy the head-mounted display optics.

**Sproull:** Ivan, are there other memorable things you'd like to talk about about that before we move on?

**Sutherland:** Yeah, Harvey Brooks. No, there was a guy who was Harvey Brooks' deputy--maybe you remember what his name was; it may come back to me--who retired and there was a retirement party for him. And one of the mechanical engineering professors, a very eloquent guy, spoke and said, "Now, this man has been with us for seven years, and the recalcitrance of the faculty, the difficulty being the assistant dean, was so great that he finally quit in disgust and he's going off somewhere else. Harvey Brooks has been here now for nine years, which Harvey Brooks was known for going to Washington to advise the president on one thing or another," he says, "Which shows you either that Harvey Brooks has greater intestinal fortitude or else that he simply visits us less often."

<laughter>

**Sutherland:** Who was that? I've got to remember his name. It was a polysyllabic name beginning with C, I think. Anyhow...

**Sproull:** All right. Well, so, but toward the end of that project, various people started showing up with blueprints labeled "DDD." Do you remember that?

**Sutherland:** Yeah, I do. Dave Evans and I started the Evans & Sutherland Company, which was originally gonna be called the 3-D Company, or Digital Display Devices --the 3-D Company, but it turns out that there already is a 3-D Company, so that name was rejected. And Licklider suggested that we use our names. He said, "You've got good names. Use your names," which we did, and that's how I moved to Utah. I had persuaded Dave Evans to move to Boston, which is where all new start electronic companies would have the best possible chance, be a Route 128 company like many others, and he agreed. And then Joy Evans reasoned with him that they had seven children and Ivan had only two, so the company should be in Salt Lake, so that reasoning prevailed.

**Sproull:** <laughs> So I want you to tell a little bit about a Salt Lake startup in 1968. This was before startups were common spinning out of university digital projects. There were a few, but there certainly wasn't a valley pattern yet about startups and how they were done and what they were like. And so everything ranging from the kind of buildings you were in to whom you hired and the relationship with students at the university, I think all of this would be fascinating. Well, first of all, a simple question: What was your role? You had a title, chief scientist, but in a startup it's all hands on deck. Everybody is doing everything. So what did you actually--

**Sutherland:** Well, Dave Evans was the president. It was quite clear that he was the guy who understood most about business. He was 20 years older than I was. He had had experience at Bendix. He had had experience, industrial experience. He had been the leader of the DARPA project at Berkeley, which is how I first got to know him because I was paying for that project. That's where Butler Lampson cut his teeth and where Bill Joy cut his teeth and so on, at that project. So it was clear he was the boss. I was called vice president, I think.

**Sproull:** Vice president and chief scientist.

  

**Sutherland:** Vice president and chief scientist I think was my title. I was a member of the board, and that was important. Now, the best thing that happened to us was that the Rockefeller people had made an investment, and I thought initially they'll want to take 60 percent of the company so they control it, and they said, "No, we never control any company. We have found that companies are most likely to succeed if no one has a majority interest, that then you have a three-legged stool. You have at least three major shareholders, no one of which can veto, and so then the rule of reason applies in the board." And, indeed, that's the setup that we had, which was a very sound business sense. And a man named Teddy Walkowicz was their principal representative, and Teddy Walkowicz came with an accounting guy from the Rockefellers to every board meeting at their expense. They didn't charge the company for their travel or anything, and they were very statesman-like shareholders. And Teddy Walkowicz came to the house for dinner. Now, Teddy Walkowicz was the son of Polish immigrants, and Marcia served him chicken paprikash. She was from a Czechoslovakian family and she made fantastic chicken paprikash. And Teddy thought this was the finest thing he had ever had since his mother's cooking, and he just loved it. And he just kind of took me under his wing and became a big influence in my life from then on. I mean I had had Berkeley as an influence, Claude Shannon as an influence, and then at Harvard there was the general influence of the dean's office and the things that surround it. And then Teddy Walkowicz became a mentor and a major influence in my life. He had gone to MIT because the dean of boys in his high school said, you know, "You ought to get yourself some education," so he went to MIT in the thirties sometime in aeronautical engineering, and when he graduated I guess he got a Ph.D. there. He went right through and got a Ph.D. But when he left there he went in the Air Force and he was assigned to von Karman as von Karman's bag carrier, basically. So he spent his service time following von Karman around going to all of von Karman's meetings and so on and being the assistant to von Karman, a terrific job for a young MIT Ph.D., you know. He just met everybody and learned everything. And when he left the Air Force he went to Venrock and became one of their partners. So that was a very lucky break. Now, I think that kind of luck happens in part because the people to whom it happens are prepared for it, and Dave Evans and I were clearly prepared. We had an edge in graphics. We had a fairly sensible business plan. It wasn't right but it was fairly sensible and Venrock backed it, so that was a good thing.

**Brock:** What was that business plan?

**Sutherland:** I'm sorry?

**Brock:** I'm sorry. What was that business plan?

**Sutherland:** What was that business plan? Well, we were gonna do graphics for scientific purposes. And we knew how to make line drawings and three-dimensional stuff, and there were just some applications had been done to chemistry. You could see what chemical molecules looked like and so on. That was basically the business plan. That turned out not to be what made money. I mean what made money was pilot training. That got converted by some people we hired from GE into a pilot training business, which was very profitable and very successful, which I had relatively little to do with, so in some sense the Evans & Sutherland Company was successful in spite of my best efforts.

**Sproull:** <laughs> The first product was the LDS-1.

**Sutherland:** First product was the LDS-1.

**Sproull:** And were you essentially the designer of the LDS-1?

**Sutherland:** Yes. And I was also the namer of the LDS-1. I went to Dave Evans and said, "I think this is the line drawing system, first one we've made. We should call it LDS-1." Now, Dave Evans was a prominent member of the local religious organization known as the Church of Latter Day Saints, and he thought about this overnight and came back to me and said, "It's not irreverent and it may be memorable. There's no reason not to call it that." Years later somebody told me he had quizzed Dave Evans about this and asked what he thought about this naming scheme. And Dave Evans gave him a little smile and said, "I think they were testing me."

**Sproull:** <laughs> So what was it like-- so you had some colleagues designing the LDS-1, especially, for example, people like Ed Cheadle doing the digital stuff-- or, sorry, the analog stuff.

**Sutherland:** The analog stuff. Ed Cheadle was wonderful.

**Sproull:** And where did you find him?

**Sutherland:** I didn't. Dave Evans found him. I mean Dave Evans had the connections in Utah, and Cheadle was known as the best electronic engineer in the valley, meaning the Salt Lake Valley. And I don't know where he'd been before that, but he clearly knew every electron by its first name.

<laughter>

**Sproull:** So you have to understand. I mean people listening to this won't have ever seen a calligraphic display.

**Sutherland:** So I'll say something about that. In those days displays drew lines, okay? So the CRT would be deflected along the line while the electron beam was on, and then the electron beam would turn off. Magnetic deflection has some kind of momentum to it so the deflection would go on but you wouldn't see that part of it, and then it would get ready for the next line, would warm up and then start displaying and draw the line and so on. That's what you had to do to make pictures of any-- raster displays were not at that time in common use. The reason was the memory for the bits in a raster was way too expensive to even think about. You couldn't think about a raster display because it involved 1,000-- I'm sorry, 1,000 by 1,000 pixels. You couldn't afford that much memory. Memory was way too expensive. So calligraphic displays--calligraphic means calligraphy, like handwriting--they traced out the picture line by line by line by line. So Ed Cheadle did a very beautiful analog design which had highly precise analog to digital converters and warmed up the deflection system so the line got going and then it turned on and drew them. The lines were beautiful. The ends matched perfectly. It was a masterpiece of design to the extent that the A to D converters had to work at frequency, and so you had to have not only the right resistors in the A to D converter to it, but the capacitance had to be right as well. And so the final tuning was a set of capacitors made of a pair of wires twisted together, which were then twisted or untwisted to get the capacitance exactly right--

**Brock:** Oh, my gosh.

**Sutherland:** --to give this perfect A to D[8] action. And Marcia, bless her soul, was my first wife, and we went to see this display, demonstration of this display, and Ed Cheadle was very proudly showing this off and there was a picture of an F4 that was tumbling on the screen, and every line was perfectly straight.

**Sproull:** And there were thousands of lines.

**Sutherland:** What's that?

**Sproull:** Thousands of lines.

**Sutherland:** Yeah, every line perfectly straight, beautifully all the same intensity and so on. It was absolutely the prettiest thing you ever saw. And Marcia knew what this was all about and the young engineers were standing around being very proud of Ed Cheadle for having done this. And Marcia, bless her soul, said, "You know, Ed," she said, "This would really be a great picture if you could ever get it to stand still.

<laughter>

**Sproull:** The displays were exquisite.

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[8] Bob Sproull notes that Cheadle's system was a digital-to-analog, or D to A, device.

  

**Sutherland:** They were exquisite.

**Sproull:** Yeah.

**Sutherland:** Cheadle later on was the guy who helped Alan Kay make the Dynabook stuff, and so he got involved with Alan to try and help Alan with the engineering of that whole set of portable machines, basically.

**Sproull:** So let's talk a little bit. You mentioned Rougelot and Schumacher and the GE experience, and that went toward now video, although not frame buffer displays, and pilot training. Were you involved in any of that?

**Sutherland:** Not very, not very.

**Sproull:** But you did have other E&S projects.

**Sutherland:** I was a third time at E&S and two-thirds time at the university. No, the other way around, two-thirds at E&S; one-third time at the university. Now, I was a one-third time tenured professor at University of Utah. And the question is, what does a one-third time tenured professor mean, right? It means if I'm not guilty of some heinous crime they'll pay a third of my salary for life, right? I guess that's what it means. But Jim Fletcher, who was the president of the university, reported to Dave Evans, he said, "I'd rather have Ivan a third time than not have him at all," so that was the deal. And I think working two jobs like that is very hard because each side thought I was full time. And it's hard to split yourself between two masters.

**Brock:** Did you have a laboratory in both locations?

**Sutherland:** Well, I had an office at the university and I had an office and a laboratory at E&S, but there was laboratory work going on at the university. Dave Evans was also split, but there was laboratory work going on at the university, and sure enough, there were students working on stuff. Now, some years later-- the University of Utah, there was a flowering of computer graphics at the University of Utah. There's no question about it. It had a huge impact. It trained the next generation of graphics people. And the question of why that happened has been asked repeatedly, basically with the question of, how could you reproduce it? That's the important question. How could you reproduce that singular event? And I've thought about that seriously. The Harvard Business School wanted to do a study of that, which they subsequently published. But my take on it is that a research project of that type needs three things. It needs money to support the research, and that came from DARPA. Clearly at the university it came from DARPA. It needs a worthy project, and the project at the university, the real project at the university was how do we make realistic looking pictures. That was the project. Computing was not up to that. There was not enough computing in the world to do that easily, so the challenge was how do we marshal the computing that we have well enough to do that reasonably well. And sort of all of the work that went on had to do with computing efficiency. How do we get the most bang for the computing buck that we have? That was the worthy technical opponent. I've come to call that a worthy technical opponent. And the third thing you need is leadership, and it was perfectly clear at the University of Utah the leader was Dave Evans, and he was a great leader. Why was he a great leader? Well, that's a mystery. I mean if I knew that maybe I'd be able to teach leadership, okay, but I think it's an unteachable subject. It's something that a few people have for the reason I described earlier. Now, one of the reasons that Dave Evans was great is people trusted him. Dave Evans was as honest as the day is long. I mean if he said he'd do something he'd do it, and people simply trusted him. Now, everybody called me Ivan, okay? I have this unusual first name. I've made the best use of it I can. Students call me Ivan. Some of the foreign students take a week or two to get comfortable with that idea, but...

**Sproull:** <laughs> Yeah, I can imagine.

**Sutherland:** And one time Dave and I were standing in the hall and Ace Erdahl came by and said, "Hello, Ivan. Hello, Dr. Evans," and then he went on down the hall. And Dave turned to me and says, "What do you got that I don't got?"

<laughter>

**Sproull:** So, Ivan, this is a perfect opportunity to comment on another thing that you've attributed to Dave that echoes later, which is the willingness or hutzpah or whatever you like to focus the department on a single topic.

**Sutherland:** Yeah. When I went to Caltech Dave Evans said to me, "You won't be big enough to do everything. Pick one thing and do it well." That was very good advice, very, very sound advice. And I think he understood that and he focused the Utah work on that problem, how do we make realistic looking pictures. That was the focus and it was a clear focus. Everybody could understand that's what we were doing. I don't think it was ever written down as a statement of work or goal. It may've been in his proposals. I don't know.

**Sproull:** Well, and he certainly wouldn't have told anybody how to go about it.

**Sutherland:** Oh, of course not. I mean you figure--

**Sproull:** It was not a plan. It was a focus or a--

  

**Sutherland:** It was a goal.

**Sproull:** Yeah, a goal.

**Sutherland:** It was a goal. And there were many different ways to approach it and they approached it in many ways. The task of understanding how the human brain works is such a goal. I mean everybody can understand that's the goal. Nobody has the slightest idea how to do it, okay, but there are various approaches. But it's clearly a worthy goal. So the magic there I think was Dave Evans, and he recruited wonderful people. He recruited Tom Stockham. He recruited me. He recruited Bob Barton, who was a strange guy. Bob Barton is the guy who persuaded Burroughs to build the B-5000, which was a stack machine. And why would a banking company produce a stack machine? Well, it used Algol, right? Well, but Bob Barton...

**Brock:** May I ask a quick question?

**Sutherland:** Sure, yeah.

**Brock:** I was interested in for you personally making that decision to leave this tenured post at Harvard for both an entrepreneurial startup and also a different university. Was this a difficult decision for you? I could imagine that it would be something that you would have to wrestle with.

**Sutherland:** No. You see, you're much more sophisticated than I was, okay? It should have been a very difficult decision, okay? It should have been a very difficult decision. It was a big decision. I mean leaving tenure at Harvard is a big deal, okay?

**Brock:** Yeah.

**Sutherland:** I simply didn't understand what a big deal it was, okay? You know, you'd have a great deal of courage if you walk on ice if you know it's ice and you know it's thin. Well, if you have no idea it's ice and you think it's concrete and it's thick, no courage involved, okay? I was simply too naïve to realize it was a big decision. I'm sorry about that but it's true.

**Sproull:** Well, but it's also an ironic story associated with your being promoted.

**Sutherland:** Oh, yeah. <laughs> So I went to Harvard as an associate professor with tenure, okay? I'm wondering how many stories I should tell about this.

  

**Sproull:** <laughs>

**Sutherland:** There's some juicy stories, but never mind.

<laughter>

**Sutherland:** So Harvard decided in its wisdom that associate professors could be either with or without tenure, and so any associate professor who had tenure should be promoted to be full professor. So I got a wonderful letter that size which says, "The President and Fellows of Harvard College, Harvard College, voted in meeting today to promote Ivan Sutherland to full professor," nice big letter like that. So I quit. I went off to University of Utah. So I got another letter only that size, okay, which said, "Voted in a meeting of the President and Fellows of Harvard College to accept the resignation of Ivan Sutherland." Then a few weeks later I got a third letter, small, right, and it said, "Voted by the meeting of the President and Fellows of Harvard College to rescind the promotion of Ivan Sutherland to full professor."

<laughter>

**Sutherland:** I thought these three letters were worth framing--

<laughter>

**Sutherland:** --so somewhere I have the three letters framed.

**Sproull:** Which order? <laughs>

**Sutherland:** In the order--

**Brock:** Chronological?

**Sutherland:** --the order of receipt, yeah.

<laughter>

**Sutherland:** I don't know where they are. They're somewhere in storage, but when I find them I'm going to put them up in my office.

  

**Brock:** <laughs> That seems peculiar, the third, especially.

**Sutherland:** No, come on. You can't quit Harvard as a full professor. Don't be ridiculous. I mean it's 300 years old, right? You can't just walk out.

**Sproull:** <laughs> So, Ivan, I'm gonna try a little harder to get you to talk more about being a startup. I remember I think even you and Marcia occasionally going on trips to customers to try to fix problems. You had problems with creeping crud on ICs and so on.

**Sutherland:** Oh, yeah, we had our share of problems, right.

**Sproull:** Well, but the chief scientist was out there trying to figure out what was wrong with the way the PC boards were being cleaned to make sure--

**Sutherland:** Well, I never did figure it out, but I did find the problem. I identified the problem and pinned it down to a particular pin on a particular IC. That was all done in Cleveland at the installation in Cleveland, which was in the hospital or near the hospital in Cleveland in a part of Cleveland where gunshots are sometimes heard at night and so on. Anyhow, I was there late at night seeking to find this problem. Someone was there with me. I don't know who he was but I had somebody there with me, and it was one of these two in the morning deals. We found a contact on a 20-pin integrated circuit which would have so many ohms in one direction and a different number of ohms in the other direction. We actually got it down to one contact, which had this particular property, and so we carefully took the integrated circuit and the socket out and sent it home for diagnostics, and it was identified as a problem with using the wrong cleaner on connections that were soldered, okay? But for this purpose I needed a microscope. Well, we're in a hospital, so I called up the hospital laboratory and said, "This is Dr. Sutherland. I wonder if I could borrow one of your microscopes?"

<laughter>

**Sutherland:** I didn't tell them what kind of doctor I was.

**Sproull:** This always works in hospitals, by the way. So were there other stories? That's the only one I remember. You must've had many other experiences of trying to get all this stuff going. This was a complicated gadget. The levels of integration and the integrated circuits weren't that high.

**Sutherland:** Well, and there was the issue of the back panels, which were wire wrapped back panels. In those days it was boards. We had boards. We plugged the boards into sockets that were in a panel, and then there was all wires. And behind that they were wire wrapped by hand, so it wasn't clear that the wires were all correct. I had to somehow correct that. So I designed a set of boards that you could plug in, which would test the wires, and that was near when I left, shortly after I left the Evans & Sutherland Company, and the manufacturing people were not interested in my set of boards that would test the wires. And two or three years later I went back and found that they had actually built them and actually had them in use because they figured out, yes, that that was the right thing to do. But there were a bunch of things of this sort. Another thing we found was when a printed circuit board was finished and stuffed it then went into test and you ran a test on it, which was an individual board test to make sure that it did all the things that it was supposed to do. And somebody had written a program that exercised the board in this way to find out that, yes, it added when it was supposed to add, et cetera. And the main thing that you learned in the first testing of a board was whether the bugs were in the board or in the test code.

<laughter>

**Sutherland:** And I came to understand that in computerology the testing process, the confirmation process is the same process that you use for double-entry bookkeeping. Double-entry bookkeeping was invented, to find arithmetic bugs, that one column has to add up to be the same value as the other column. If there's any arithmetic error you catch it. That's what double-entry bookkeeping is for. This was double-entry bookkeeping. One of them is hardware; the other is software. They are supposed to be the same algorithm, so when you bring them together you find bugs--they don't match--but you don't know whether the bugs are on this side or that side. And, you know, is a word spelled correctly? You would do a spelling checker and it tells you, no, it's not spelled correctly. All that means is that that spelling is not in its dictionary, so you don't know whether that means the word is spelled incorrectly or the spelling checker doesn't know it. And sometimes it's one and sometimes it's the other. It's all just double-entry bookkeeping, and the correctness of programs, the correctness of anything in computerology, what does correct mean? You have to have a reference that says this is what correct means. And all the formal verification stuff is basically double-entry bookkeeping. It's comparing what you've got to some reference that you believe is correct and saying they match. And so you can never say that something is right. You can say that it matches something which I believe to be right, and that's a view that's important. And I got that view from the first time we brought together the hardware definition as represented in the hardware and the software definition as represented in the test code. And you always found bugs, but they could be on either side. And it is often valuable to do things twice in different ways because you have a different set of bugs.

**Sproull:** Well, is it time to move on? So what about the university? You were on some committees. There were some great students. Some of the students kind of worked between the university and the company. There were some that were exclusively at the university, Henri Gouraud, for example.

**Sutherland:** Well, Henri Gouraud was strictly at the university.

  

**Sproull:** Right.

**Sutherland:** There were a bunch of Frenchmen at the university, and what had happened is Jean-Yves Leclerc had come to Berkeley as a graduate student knowing no English, essentially, and he had learned English and got himself a Ph.D. at Berkeley. Stayed in correspondence with Dave Evans, and Dave Evans had a rule for admitting graduate students that Jean-Yves sent him. He said, "I know Jean-Yves, and anytime Jean-Yves sends me a student I'll say yes until he sends me a bad one. Then I'll carefully look and see whether I should have," and that seemed like a good rule. If you get a reference from somebody you know and trust, say yes until you get a bad one. And HenrI Gouraud was such a student. He came from France. Jean-Yves had recommended him--I don't know why--and he came and was clearly a first-rate student, and there were a number of those.

**Sproull:** Well, Patrick Baudelaire.

**Sutherland:** Patrick Baudelaire was one of them.

**Sproull:** Wasn't Bui Tong Phong also a Jean-Yves--

**Sutherland:** I don't know.

**Sproull:** He was Vietnamese, but I think he was French.

**Sutherland:** I know. He may have come through the French connection. That may well be. So there were a number of students that came through that route, and Jean-Yves was clearly a brilliant, brilliant guy.

**Sproull:** Well, so we could move on from Utah. You've said that one of the reasons you decided it was time to leave E&S is you didn't know everybody by their first name.

**Sutherland:** Well, something like that. The Evans & Sutherland Company got too big for me to be comfortable, you know. I'm clearly a small organization person, and now that I understand that about myself I try and behave that way, but I didn't understand that initially. And I had done all the things in Salt Lake that I could do. My children were now advancing in grade school, and it was quite clear that the Salt Lake environment in the junior high school was not as good for a non-LDS person as it might've been, and so I was eager to have a more cosmopolitan-- and I had met a guy called Glen Fleck, who was the number two man to Charles Eames. Glen Fleck was a designer. He and I started a company, which we called the Electric Picture Company, whose purpose was to make movies using the computer graphics techniques. And we were 10 years too soon. That company failed for a good reason. It was 10 years too soon. But I moved to L.A. in order to be closer to the center of that business and also to get a more cosmopolitan environment for my children. We moved to Santa Monica, one block away from the beach in Santa Monica. And Marcia's uncle, Uncle Ivan, who lived in Bel Air, said, "My God, you're gonna take your children to that environment? Why, there's bums on the beach and there's prostitutes who walk around down there." And I said to him, "I'd much rather my children were exposed to prostitutes when I'm around to provide them some guidance than-- whereas your children are down there all the time with no guidance." "Oh, well, okay," so we moved to L.A. It was a fine move. We bought a house right near the beach, which I owned for the next 35 years, and it was a fine thing to do.

**Sproull:** So while we're talking about the children you can talk about your deal with Dean[9] about that house.

**Sutherland:** Yes. When we moved to that house Dean and I agreed that I would do the snow if he would mow the lawn, okay? It turns out the house had no lawn. It was concrete all around. It was near the beach and there's only sand available. But it was a nice house and it served us well. We had parties there for the people that I had met at Caltech. Carver Mead was there often, and I have some photographs of Carver Mead carving the watermelon at the big party.

**Sproull:** So leaving Utah was also coincident with another thing, which is you claim that after we did the 10 hidden surfaces paper you decided that graphics was never going to be faster than sorting and so maybe it--

**Sutherland:** Yeah, well, two things happened. I met Carver Mead. That's why I went to Caltech.

**Sproull:** So how did you meet Carver Mead?

**Sutherland:** I don't remember, but I got to *know* Carver Mead because DARPA sponsored a report, and I think this happened through RAND. I think it was actually a RAND report. I had been at RAND. When Electric Picture Company failed I walked up the beach of the RAND Corporation and went in to see the head of their computer department. There was a man named Peter Weiner. I said, "I'm out of work. Basically I need a job." He said, "You're hired." And then we had a discussion about salary and he paid me too much, so I said, "Okay, I'll only work for you 4-1/2 days a week."

<laughter>

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[9] Ivan Sutherland's son.

  

**Sutherland:** And so I had a half a day to myself. And I used to walk up the beach with Juliet and she would turn to Santa Monica High School and I would turn to RAND Corporation, which was right across the street from each other, and I got to know Juliet better than I'd ever known her before because we had this period, father/daughter, a little bit each day, you see. It was a great environment. It was really lovely, and RAND Corporation was very good to me and I think I was good to them. I appeared in their annual report about reports. It had reports that people had written, and the two years I was there I was in that each year for something or other. And DARPA commissioned us to do a study about integrated circuit, the future of integrated circuit technology. What could they be investing in to help the integrated circuit technology? And it turns out the key to that was the brightness of the cathode in an electron microscope. And I don't know if you know what the brightness of a cathode means, but a bright source is a lot of electrons coming from a very small point. And what we discovered is that field emission cathodes, the point of a field emission cathode has one atom on it. It's hard to imagine making a needle that's sharper than one that has one atom on the end, okay? And so every finger-- we went around asking, "So who makes these," and every finger in the country pointed to the Oregon Graduate Research Institute, which is somewhere--

**Brock:** South Portland, right?

**Sutherland:** --on the west side of Portland---so I went there, went to see them. I said, "DARPA just wants to foster this thing." And I found there, I found one Ph.D. and one technician who were essentially the world's supply of field emission cathodes with one atom on the end. So how do you make them? Well, you take an oriented tungsten piece of wire, which has the crystal structure pointing in the right direction, and you dip it in an etchant and you run electrons through it and in through the etchant. And for reasons that I don't understand it etches preferentially at the surface of liquid, so the etching then gradually pinches it narrower and narrower, and finally the bottom falls off and then you have your needle, and that's how they did it. And how long do you have to turn the juice off? Well, a microsecond or something, I don't know, not very long, but they had equipment that would do that. And so I said to them on behalf of DARPA, "DARPA would like to invest in this. We have 250K a year or something that we could help boost your productivity." Well, they couldn't figure out how to spend it. They said, "Well, we can take 50K or 100K you know, that's all we could figure out how to spend." And I thought-- that became my definition of high tech, okay? High tech is when two guys, one Ph.D. and one technician, provide the world's supply. That's high tech. And it's precious because if one of them dies or they forget how to do it or something or they quit, okay, you've lost that whole field of technology. And many fields of technology start at that level of high tech and then they spread. Knowledge spreads somehow and you get more people who can do it, and getting that spread of knowledge is an important thing to do. Anyhow, so DARPA commissioned a study for sort of what was the future of microelectronics, how could they help support the future. And Tom Everhart and I and Carver Mead went all over the country and talked to people and asked this question, how to do it, and a report was written about that. There's a RAND report about it which says what to do. And out of that study came a couple of things. The integrated circuit manufacturing service, MOSIS, was set up at USC to let universities send their-- meanwhile, Xerox had made this multi-chip project, multi-project chip.

  

**Sproull:** Aren't you getting a little ahead of the story, well, because--

**Sutherland:** Maybe so. I don't remember.

**Sutherland:** The timescale is not clear in my head.

**Sproull:** Yeah, so the RAND report predates your going to Caltech.

**Sutherland:** Does it? I didn't know.

**Sproull:** Yep, yep.

**Sutherland:** Is that true?

**Sproull:** Yep.

**Sutherland:** Okay.

**Sproull:** And then at Caltech, Carver had already been doing the multi-project chip idea--

**Sutherland:** Yes.

**Sproull:** --with essentially buddy foundry services from the people he knew or consulted for. And then after that was first the PARC multi-project chip and then finally MOSIS.

**Sutherland:** I think that's right. I think you've got the order better than I have.

**Sproull:** Well, so, anyway, but let's go back. So the RAND study was essentially how you met Carver.

**Sutherland:** That's how I got to *know* Carver well. I had met Carver through some mechanism. I don't know what it was. But that's how I got to know him.

**Sproull:** --did that lead directly, then, to going to Caltech, or what was the--

Sutherland: No.

**Sproull:** --segue there?

**Sutherland:** No. I would be happy to go to Caltech as a faculty member. The question is, would Caltech be happy to hire me? It's important that they provide the offer, right? And John Pierce was in charge of a search committee at Caltech to find out how to get into this field. And apparently he and Dave Evans had a conversation about this, and I think Dave Evans said, "Make no mistake. You gotta get this guy." I believe that's how Caltech decided to offer me the job. I never asked John Pierce about that. I should have, but too late now. But I think that's what happened, and he recommended that, and sure enough Caltech offered me a position and I took it. After I'd been there a little while they gave me the Fletcher Jones chair, so I was an endowed chair with Caltech. And leaving that was a decision that should've been a big decision, but, again, I didn't treat it as a big decision.

**Sproull:** So Caltech had some computing types at the time, but it sounds like you were encouraged or invited to really try to do something new.

**Sutherland:** Yeah, the charter I had when I went there, I think the dean was already Bob Cannon. Bob Cannon was the dean of engineering up there, and I went there and Cannon said, "We want you to build a computer science department," essentially, and so I set about doing that. And one thing we set up, the Caltech Development Office-- that's the part of the university that collects money, okay? Caltech Development Office is highly efficient, wonderful place, skilled at its job, terrific. They do a great job. And so I worked with them to set up a thing we called the Silicon Structures Project, and it was their idea of how to structure it, but it was a place that industry could put money in. The deal was industry puts 100K a year per company plus a person. A person has to stay for a year and be acceptable to the company and Caltech. So we got six sponsors. They were Burroughs, Xerox, IBM, DEC--

**Sproull:** Intel?

**Sutherland:** I don't remember the other one.

**Sproull:** Was it Intel?

**Sutherland:** Hewlett Packard. Hewlett Packard and somebody else. We got six sponsors to do that, so the six industry guys appeared on campus, so I had an instant computer science department. There they were, right? Six guys who could have been faculty members but were paid by industry and were there. And I had myself and I had Fred Thompson, Fred Thompson. I think it's Fred Thompson--

  

**Sproull:** Yes.

**Sutherland:** --and somebody else, language guy. Per Brinch Hansen.

**Sproull:** The systems guy.

**Sutherland:** And Brinch Hansen left shortly thereafter, and Caver said-- no, Dave Evans said, “You’ve got to focus on one thing,” so I said, “We’re gonna focus on integrated circuits.” Carver knew how to do that. I was deeply interested in it--that’s what I went there for--so that’s what we focused on. And I tried to hire a number of people including Bob Sproull, and they got turned down, one after the other. And one of them that was turned down by the faculty as not good enough was a man named Al Perlis, whom I couldn’t get an appointment at Caltech for, okay? And the argument that I was given was he doesn’t have an adequate publication record. And I was too stupid to say, “Would you believe 70 Ph.D.s as a publication record?” You know, I didn’t recognize that that was what I should’ve answered, okay, but I didn’t, all right? And sure enough, Perlis’ publication record is a bit thin. No question about it. What he published was students, most important thing to publish, right?

**Brock:** Uh-huh.

**Sutherland:** So after a while I got fed up and quit, and that was probably a mistake, but I was totally frustrated because I was asked to set up a department, then I couldn’t do it, okay? I subsequently thought about that very carefully and realized that I was not politically savvy enough to know how to achieve that in the Caltech environment. When I finally resigned I got a call from the president, who said, “Well, why don’t you take six months’ leave with pay instead of resigning?” Now, he hadn’t done his homework, because by then the Evans & Sutherland Company had gone public. And essentially I said to him, “If $40,000...” which was the amount of six months’ pay, “... is gonna pass from me to you, between us, it’s gonna pass from me to you and not the other way around.” So he hadn’t done his homework and that annoyed me, and it just was a very unpleasant sort of-- I was very unhappy about that and so I quit. And I’d been very successful. I’d raised a lot of money. I’d started a great research project. Carver Mead’s book was published, and that period of time at Caltech was hugely productive. A whole bunch of students, including some people who are at lunch here, and those people had a huge impact on the integrated circuit world. I believe that the Caltech activity fueled the integrated circuit revolution by providing the means to train the engineers that were needed to fuel it, but it felt totally unsuccessful to me.

**Sproull:** So let’s go back a little bit to while it was still on the upswing and you weren’t yet discouraged, because there must’ve been a lot to getting all that going, and it wasn’t just Caltech. There was ARPA support. There was galvanizing other people. There was, the Xerox and Lynn Conway connections.

  

**Sutherland:** Yeah, Lynn Conway worked for my older brother at Xerox, and that's how she and Carver met, was that they met because Bert knew Carver through me and hired him as a consultant and encouraged the-- the Mead Conway book is dedicated to Bert because he paid for it. You know, it's perfectly straightforward. But that period was very productive in terms of educating people about integrated circuits. Carver and I published an article in the Scientific American, which said essentially it's the wires that are the problem. You shouldn't count the transistors. They hide underneath the wires. The limitation is how many wires you have, and I think that's as absolutely true today as it ever was, maybe more so.

**Sproull:** So since you mentioned that, let's go back a bit because you and Don Oestreicher wrote a paper at Utah. Do you remember that paper?

**Sutherland:** That's right.

**Sproull:** So this is a paper I think called "How Big Should a Printed Circuit Board Be?"

**Sutherland:** Yes.

**Sproull:** So this problem of wires was not new to you.

**Sutherland:** <laughs> That's absolutely true.

<laughter>

**Sutherland:** So I had laid out a fair number of printed circuit boards, and it was clear that getting the wires in place was the trick. And the title of that paper was patterned after the question that was asked Abraham Lincoln, I think, which is, "How long should a man's legs be?" The answer is long enough to reach the ground.

<laughter>

**Sutherland:** Now, you know, how big should a printed circuit board be? The wire is the worst component on an integrated circuit, and it's also the most prevalent. Every transistor has at least one wire, so wires are the most prevalent thing. And wires are bad in two ways. First of all, charges diffuse down the wire through massive capacitance, stray capacitance, and massive resistance. So your model of how electrons get from here to there should not be current flowing. It should be smoke in a chamber or heat diffusing down a silver bar. Equations are the same. The time it takes is the square of the distance, not linear with the distance. That's important. So they're bad as means for getting information from here to there. They're also bad because as the integrated circuit gets bigger the number of components that you have grows with the area, but the space for vertical wires grows only linearly with the size of the thing and, therefore, at the square root of the area. And so as the integrated circuit gets bigger, fitting the increased number of wires into the available space becomes harder and harder and harder. This is also evidenced in cities. As cities get bigger providing room for the traffic, that is roads, gets harder and harder, and so every big city gets traffic congestion, which small towns simply don't have, and that's inevitable because of the growth laws of how many trips there are and the fact that in big cities the trips are further. There are more trips according to population, but the trips are also further, and so you've got a compounded problem. It's a fundamental growth law issue. And that's what's hard about integrated circuit designs. You've got to fit all those wires. So that was clear, and Carver and I had written a paper in Scientific American about this saying that the computer science community misses the point. They talk about operations as if they were important, and they're not important. It's communication that's important. And I think it's widely recognized now that the communication costs in computing are the limiting factor, not the transistors.

**Sproull:** So say a little bit more about the focus aspect of the Caltech stuff on integrated circuits.

**Sutherland:** Yeah, well, there was a wonderful student named Ron Ayres who wanted to write a compiler so bad he could taste it. And I said, "How are you gonna write a compiler that's relevant to integrated circuits?" Well, okay, we compromised. He wrote a compiler that knew about X and Y, knew about geography so it could compile stuff that had geographic intent, and that was relevant to the integrated circuit problem in some, perhaps farfetched, but some appropriate way.

**Sproull:** Well, and eventually the whole term silicon compiler was one that Dave Johanssen--

**Sutherland:** Yes.

**Sproull:** It was his thesis ultimately I think that put that term on the map.

**Sutherland:** Well, I don't quite know what that meant but never mind. I mean the point was we tried to focus all of the things, and Brinch Hansen left so I didn't have to solve the problem of how to fit him into the community.

**Sproull:** So Chuck Seitz was at Caltech.

**Sutherland:** Chuck Seitz was at Caltech. I induced Chuck to come. Chuck had helped us build the head-mounted display at Harvard. In fact, he taught us how to do the design.

**Sproull:** He really did.

**Sutherland:** He worked in Utah for a while. He had been at Utah and helped the Evans & Sutherland Company in various ways, and I persuaded him to come to Caltech. He came to Caltech and became a keystone in the operation.

**Sproull:** Well, and another thing, the big pieces of the head-mounted display were asynchronous and used a self-timed interface.

**Sutherland:** Yes.

**Sproull:** And that was Chuck who introduced us to how to do that.

**Sutherland:** We didn't know how to do it. We actually did it badly. But we didn't understand the glitch phenomenon and we got bitten by it rather badly.

**Brock:** What is the glitch phenomenon? Forgive my ignorance.

**Sutherland:** Well if you have a Gulf of Mexico and if you have a Pacific Ocean and you know there's a mountain range in between, you know that there's a continental divide. You may not know where it is but you know for sure there is one. Turns out flip-flops can be flipped, Gulf of Mexico, or flopped, Pacific Ocean. In between there's a place where they're not stable, where they'll go downhill to one side or the other, so there must be a continental divide, so there must be a place where flip-flop might be metastable, neither flipped nor flopped. This phenomenon was discovered and observed and measured and analyzed by Charlie Molnar and Tom Cheney at Washington University Saint Louis. It's now widely understood that when you take a signal that is not clocked into a clocked domain you have to synchronize it, and synchronizers may take an unknown time to settle because they hang metastable on this continental divide, just as a marble at the top of a mountain may take a long time to decide whether it's gonna go east or west, and that phenomenon is by now well understood in the computer industry but was not understood at all in the eighties when Cheney and Molnar published their paper. And we got bitten by it in all of the stuff that we did asynchronously in the early days, got bitten by that problem also. But we didn't have a handle on it, Bob. We thought we did but we didn't.

**Sproull:** This is where I don't remember this at all. We were doing everything--it was so slow.

**Sutherland:** Well, but we kept adding delay to make it reliable.

  

<laughter>

**Sproull:** I suppose.

**Brock:** Well, I just had a couple questions that would be-- to move backward.

**Sproull:** Okay, that's fine. Let's do that.

**Brock:** Just interested in the Picture Design Group story again, just the idea of using computers to make film. If you could just expand upon what your ambition was at that time, what your thoughts were and the business story of that. Was it Venrock again or--

**Sutherland:** No, we never satisfactorily got an investment, thank goodness, okay? So the company went broke without losing anybody's money.

<laughter>

**Sutherland:** No, the idea, it was fairly obvious that computer graphics could be used to make movies, and so in L.A. we went to visit Disney and told Disney about it. And Disney, the big technical advance that Disney had had was xerography to make the outlines of the successive frames that they would have in their movies so that the colorists could fill in the colors and trace the outline, and that was as far as technology they were willing to deal with. So it was just premature, but it seemed fairly obvious that you could make movies using computer graphics, which I think is widely accepted that that's a good technique now, but we were premature.

**Brock:** Was your idea to partner with to provide special effects or to develop your own--

**Sutherland:** It was pretty vague. I mean I've told you essentially what the idea was, okay? And the Picture Design Group actually did a number of designs. We did the design of the Museum of Economics in L.A., which was paid for by the various economic-- the savings and loan companies and the banks, and some investment firms put up some money for this Museum of Economics. And Glen Fleck was a designer of stuff including museums, so I contributed some things to it, and that's how we tried to keep body and soul together but it was not successful.

**Brock:** Thank you.

  

**Sutherland:** So that's why I went to RAND.

**Brock:** And let's see. I was just wondering in terms of the Caltech era, were you then-- was there still the same DARPA/ARPA community? How had that evolved and how did Caltech fit into this?

**Sutherland:** We got some DARPA support at Caltech, but the bulk of support came from the six companies. There was a very funny conversation that took place in my office. It was a conversation between Hewlett Packard and Intel. Intel must've been a sponsor. No, maybe they weren't. They weren't. I think they weren't. But one of the-- IBM. It was a conversation between the Hewlett Packard guy and the IBM guy talking about their manufacturing lines of integrated circuits. Each manufactured integrated circuits, and the Hewlett Packard guy said, "Well, you know, we're doing 100 wafer starts a month," or something, and the IBM guy said, "Well, when are you gonna get up to full production?" And he said, "We are at full production. I mean we need a few specialized integrated circuits for our instruments and two wafer runs is the entire lifetime supply that's needed." And the IBM guy said, "Well--" It may not have been IBM. It may have been somebody else who-- it may've been TI, I don't know, who manufactured integrated circuits en masse, right? And so that conversation went on and their respective needs for integrated circuits were clearly very different. Another conversation that went on was between Gordon Bell, who DEC was a sponsor, and George Pake, who Xerox PARC was a sponsor. And George Pake at Xerox PARC had built a machine called MAXC, which was essentially a carbon copy of the PDP-10. They wanted a PDP-10 so bad they could taste it, but because Xerox had a timesharing system of its own they couldn't buy one, so they built one instead. And Gordon Bell said to George Pake, "We would've been happy to sell you a machine." And George Pake said, "We'd have been happy to buy one if we'd have been allowed. It would've been cheaper."

<laughter>

**Sproull:** So I have a question related to the silicon structures project. So as you mentioned, people came and spent time with you. How did you get good people from those companies? I would think there'd be a problem, that they wouldn't want to give up their best and yet you really wanted their best.

**Sutherland:** And, the other hard part was that assignment was hard on a person's career--

**Sproull:** Fair enough.

**Sutherland:** --because they were then out of sight and out of mind for promotion and so on. I don't know. It was magic. I mean the IBM guy that we got stayed for three years, and he was really good.

**Sproull:** Really good, yes.

**Sutherland:** He was a senior guy who wanted to do this and was-- he was kind of the principal advisor that I had. He was a wise head with a lot of experience. And we got a very good guy from DEC whose name was Craig Mudge. And because he was a good guy, he took a whole bunch of graduate students back to him and they ended up working at DEC. We got a very good guy from Burroughs whose name I don't remember, but he was a very techy tech guy who was there and contributed enormously to the tech situation. Some places we got less good people from and they profited far less from the experience because they didn't take the students back with them. The students basically went-- students voted with their feet, and that's a very effective vote.

**Sproull:** <laughs> Yes.

**Sutherland:** But I couldn't get Al Perlis an appointment at Caltech, and I don't think that's the fault of Caltech. I think it was my fault. I didn't understand how to do it. I was-- I mean you've seen this now three times in this conversation of where I simply was not sophisticated enough to know that decisions were big, or in this case how to work within the system.

**Brock:** Caltech does seem to be a very particular case, however, I mean in terms of an intellectual community, you know. I could see that being a harder needle to thread than in another place.

**Sutherland:** No.

<laughter>

**Sutherland:** No, that's not so.

**Brock:** <laughs> Okay.

**Sutherland:** What was wrong at Caltech was that the faculty hiring process was done by a committee of the whole. That is to say the entire engineering faculty thought they had a say in every engineering appointment, so there were aeronautics people, there were heat transfer people who thought they had opinions about what computing should be, okay? And I saw another one at Sun is the promotion process to distinguished engineer at Sun was run by the distinguished engineers, a committee of the whole. And the condition that applies to a committee of the whole is that the candidate has to be as good as we think we are. This is a very hard standard to meet. A better process has a committee of the part. The military promotion process in the U.S. Military is done by a committee of colonels who decide who shall become a colonel and a committee of generals who decides who shall become a general, and at every level there's that process that's gone through. In a committee of the part the condition is the candidate has to be as good as we think our colleagues are, and that's a standard that people can meet, okay? And the problem at Caltech was the committee of the whole problem, and the same problem applied to the distinguished engineers at Sun. It was the committee of the whole problem, and it resulted in some very bad decisions, mostly in terms of turning down people who should never have been turned down. This question of how to do promotions is a tough question, and I think a large part of the answer lies in what I've just said. I think that's an observation which I stand on, and I think it's an important observation.

**Brock:** I guess one final question I would have at this juncture would be about the Caltech and the Xerox PARC connection with two Sutherlands deeply embedded in both organizations. We already have talked about some of the connections between Mead and Conway and that VLSI design revolution, if you will, that is a result of that mixture of the Caltech and PARC contacts. I wonder if it was broader or there were more dimensions to it, just that PARC/Caltech relationship in this period.

**Sutherland:** Well, I think PARC recognized that Caltech people were unusual, and there were many summer interns from Caltech that went to PARC, so there were a lot of connections at various levels between Caltech and PARC, but those connections weren't unique to Caltech. There were connections between PARC and Berkeley and connections between PARC and Stanford, and it went on and on and on.

**Sproull:** And for example, I mean another thing that Caltech I think should get credit for is inaugurating the VLSI conferences. Chuck Seitz and John Gray organized the first one, I think, and they became annual affairs. And the Xerox people were clearly part of that, but so were all the other university groups.

END OF THE INTERVIEW

  