Oral History of John Warnock, part 1 of 2

Interviewed by:
David C. Brock

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David C. Brock: Thank you again for joining us today, John. If my research is serving me correctly, you were born in 1940 in Utah.

John Warnock: That's correct.

Brock: And I see that you were, I think, born and raised in Holladay, [Utah], if I'm pronouncing—

Warnock: Yes.

Brock: —that correctly.

Warnock: That's correct.

Brock: A suburb of Salt Lake City.

Warnock: That's right.

Brock: Could you give us a little bit of a description of Holladay as it was when you were a youth and what it's like today?

Warnock: My parents bought a piece of land, two acres, out in Holladay in the middle of a sort of forest of cottonwoods. They built a fairly modest house; I think they paid $1600 for the land and they paid less than $10,000 for the house. We had three ponds in our backyard that we swam in. It was totally wooded and you really couldn't even see the neighbors. I had a brother, Tom, and a sister, Kevin—they were both older—and grew up as a family of five, went to elementary school, junior high school and high school in Holladay.

Brock: Was it the case that many people were commuting into Salt Lake City for work, if they were—

Warnock: Yes, my father was an attorney and he worked in downtown Salt Lake, and he would drive in to Salt Lake every day.

Brock: Could you share with us a little bit about your parents and their background?

Warnock: As I say, my father was the only one of four siblings that went to college and he got a law degree. My mother, he met in college and married her. She went to a private school in Salt Lake—a school called Rowland Hall. They both skied. My dad loved hunting and fishing—rather, he liked that way more than being a lawyer. He used to read profusely. But we were raised in a fairly straightforward manner.

Brock: Was that something that you and your siblings were able to participate in with him? Fishing and hunting?

Warnock: I think fishing goes every other generation.

<laughter>

Warnock: He loved it. I never cared for it. We did occasionally go hunting together, but not—and the hunting—my brother used to go deer hunting with him. I never did that. I used to go duck hunting sometimes in Wyoming.

Brock: Did you have extended family nearby?

Warnock: Yes. My mother had a sister and I had cousins on my mom's side and I had cousins on my dad's side. Most of the cousins were older than I was.

Brock: Okay. And they were in the general—

Warnock: Salt Lake area.

Brock: —Salt Lake area.

Warnock: Yes.

Brock: Thinking about your household growing up, sometimes for people there's almost like a dominant or pronounced theme of the household, you know? Some households it would be like an emphasis on education or art or, for some, it's politics or religion. I wonder if there was any kind of theme like that for your household?

Warnock: Yes. Everyone in the family drew and was an artist. My brother painted, I painted, my sister paints, my mom was very artistic. We were outliers in the community because we were not Mormons, and we were not religious in any way. And the Holladay community—I was one of maybe three or four non-Mormons in elementary school.

Brock: Out of—?

Warnock: Out of—

Brock: —a hundred?

Warnock: —however big elementary school is.

Brock: Right.

Warnock: The church dominated very much the community and the early life. We were fairly independent. We didn't mix too much with the community.

Brock: Interesting. Was that—I don't know how to ask this. Was this something that your parents knew they were getting when they moved to—?

Warnock: Well, they grew up in Salt Lake so they had always been like that.

Brock: Okay, okay. So, it was a kind of family tradition of—

Warnock: Yes, it was family tradition. <laughs>

Brock: Interesting. Sort of a religious minority, if you will.

Warnock: Yes. The school that my mother and my sister went to were Episcopalian and it's so funny: you're called gentiles if you're non-Mormon.

<laughter>

Warnock: Most of my friends growing up were either Jewish or Episcopalian or Catholic or—

Brock: That's fascinating.

Warnock: Yes.

Brock: I guess I never really thought about that dimension. There was almost a self-identified gentile community, if you will—

Warnock: That's right.

Brock: —in Utah. Interesting. In terms of painting, was there part of the house devoted to painting or was it happening all over the house?

Warnock: It was happening all over the house.

Brock: Was everybody doing watercolor or was it a mix—

Warnock: Of everything.

Brock: —everything. Interesting. Was your mother kind of the primary painting tutor or something?

Warnock: I just think everybody was attracted to it. I have a funny story. My third-grade teacher let me draw all day long. I've had a friend ever since the first grade who we're still very close friends with and she said, "Well, how—" she went to the teacher and said, "How come he gets to draw and not do all the rest of the work?" And the teacher said, "Don't worry. He'll catch up."

<laughter>

Brock: What do you think was behind that?

Warnock: I drew a lot. She liked what I did. She gave me all the paper I wanted. That's sort of the way I grew up.

Brock: Interesting. Could you tell us a little bit about then—you were going to the public schools—

Warnock: Yes.

Brock: —all the way through high school—

Warnock: Yes.

Brock: —in Holladay.

Warnock: Yes.

Brock: Okay. I've read some characterizations in some of the materials I was reading to prepare where I think you were describing yourself as almost like a lackluster student, if you will.

Warnock: Yes.

Brock: Is that your characterization of yourself?

Warnock: Yes. It was really interesting: I flunked ninth grade algebra. <laughs> I've always looked back and always wondered, "Why did I flunk ninth grade algebra?" My best recollection is that I never sort of learned the procedures to solve equations. I tried to solve them in my head and then I would hit a brick wall and not be able to solve them in my head—

Brock: I see.

Warnock: —by just looking at the equation. So, I did. But then I got an amazing teacher in high school who—I think out of my high school senior class I would guess 10 to 12 went on to get PhDs.

Brock: And you attribute it to this teacher?

Warnock: Oh, absolutely. He was famous. In Salt Lake, he had students in his class that went to all the best schools in the country and they were all—one of my friends in my high school trigonometry class went into mathematics and became academic vice president of the University of Utah, and went from high school to a PhD, I think, in four years.

Brock: Oh my gosh!

Warnock: Brilliant guy. Anyway—

Brock: What do you think it was for this mentor for you all? Was it sort of an eye for talent or a way to open people's passion?

Warnock: I think he op—he said, "Don't go to the assemblies. Come in and solve problems." Everybody would come in and solve problems. He had a very interesting way of approaching things. He said, "Look, here's the trigonometry book. We're going to use a college trigonometry book. How many of you can solve all the problems in the book?" A week later a guy would come in with a stack of paper and have solved all the problems in the book. He sort of challenged people, and a big part of the class would do it. I mean, just do it. He was an amazing guy and I fell in love with mathematics.

Brock: Sort of plopping a college trigonometry textbook on the table and saying, "Okay, high school kids, go and solve all the questions—" it must be—he must have had some sort of a charisma or something to get people to even entertain the notion of doing that.

Warnock: Yes. Well, both competitive spirits and things like that. There was another teacher who was in the chess club and he would say, "How many moves can you do in your head without looking at the board?" and those kinds of exercises. And the students responded.

Brock: Was it the case that once this kind of turn happened for you with the mathematics, were your other subjects easy for you, or were you the sort of person where you were very strong in math and science and less interested in language?

Warnock: No, it changed me from being a non-student to a good student.

Brock: I see. Across the board.

Warnock: Across the board.

Brock: I see. You mentioned that your father was an avid reader. Would you also characterize yourself in this time period as an avid reader?

Warnock: No, not avid; but would read, sure.

Brock: Does anything stand out in particular as the sorts of things you enjoyed reading?

Warnock: As I recall I read a fair amount of Steinbeck and—I'm trying to think—mostly non-fiction.

Brock: Hm. Mostly non-fiction. It has been interesting for me to learn that for many people, who later went on to become engaged with computing, that they were avid readers of science fiction and I wonder—

Warnock: I also read science fiction, yes.

Brock: Was there anything in particular that stood out for you there?

Warnock: I don't know whether I can recall the titles, but—no, I can't think of any particular titles.

Brock: Did you participate in sports or other hobbies like that or—

Warnock: I was on the high school tennis team and on the high school ski team.

Brock: Okay. I guess skiing must have been a big theme. <laughs>

Warnock: Well, skiing is part of Utah.

Brock: Did you have work experiences during your youth—your high school years?

Warnock: I worked in a photography shop. That was really my first job, and I was sort of the stock boy and I used all my summer's earnings to buy cameras.

<laughter>

Brock: Is that something that you've kept with, photography?

Warnock: Oh, absolutely. Yes.

Brock: Yes.

Warnock: Photoshop.

<laughter>

Brock: But I meant, you know, taking photographs yourself—

Warnock: Oh, yes.

Brock: Is there any particular kind of subject that you do with that? Is it landscape photography or—?

Warnock: Yes, I would characterize it as landscape photography. In high school I was on the year book staff and I was one of the photographers on the year book staff. I had a dark room, learned about chemicals, read the Ansel Adams books. Photography’s always been a big part of my hobbies.

Brock: Okay, I hadn’t quite realized that.

Warnock: I can’t count the number of cameras I have.

<laughter>

Brock: As your high school career was coming to a close, I understand there was a family tradition of going to the University of Utah.

Warnock: Yes.

Brock: So, that was obviously—

Warnock: That’s what people did.

Brock: —on the landscape.

Warnock: Yes.

Brock: What were you thinking of in terms of your career aspirations or ideas at that stage?

Warnock: I thought I’d probably end up being a teacher at that time. I really hadn’t thought about it much. I guess I’d thought about being a photographer or something like that, but I would say teaching or photography or something like—I really didn’t think about it much.

Brock: I guess you were graduating around 1957—?

Warnock: I graduated from high school in ’58.

Brock: ’58.

Warnock: I went through college in three years without a break and graduated in ’61.

Brock: I’m just thinking about growing up during the height of the Cold War and if you have any thoughts about how that shaped your experience or your perspectives?

Warnock: Well, that was also getting into the time of the Vietnam War.

Brock: Yes.

Warnock: I went straight through to get a bachelor's degree and I would—then I went on to get a master's degree in mathematics.

Brock: Right.

Warnock: That, I broke up in the summers and I would work in the Forest Service and fight fires in the summer.

Brock: Mm.

Warnock: But I had the most horrible job in the world. I worked at Firestone Rubber re-capping tires in hundred-degree heat <laughs> and it was awful. I one day decided, "You know, I've almost got a master's degree in mathematics. Why am I doing this?" So, I applied at IBM in 1963, and they hired me and sent me off to training in Seattle for a couple months, and then sent me to Los Angeles for big machine training, 7094 training in Los Angeles.

Came back and I had the Hercules Powder account and I had the Hill Air Force Base account and I had the University of Utah account, and I helped people with their computers. Then the draft came up for the Vietnam War, and I did not want to go to the Vietnam War. IBM had a strict policy not to ask for deferment even though I was working with defense-related people. I said, "Well, I'm going back to school."

Brock: Oh.

Warnock: So, I went back to school.

<laughter>

Warnock: I finished my master's degree in mathematics in ring theory and decided—I started working on a PhD in mathematics and went to work for the University of Utah Computer Center, and that was sort of my job. I was also a teaching assistant for a while in mathematics. In 1966—well, at the Computer Center in the University of Utah, I wrote the university first automated registration system. I think Purdue had the very first one, but the University of Utah had the second one. We used to register students by filling out cards and getting them registered. In 1966, David Evans came from Berkeley to the University of Utah and at that time Jim Fletcher, I think it was, became the president of the University of Utah and he's the one who ultimately headed NASA.

Brock: Oh, okay.

Warnock: James Fletcher.

Brock: Okay.

Warnock: He brought Dave to the University of Utah and Dave was very, very well connected with ARPA.

Brock: Sure.

Warnock: He brought an ARPA contract with him to the University of Utah. I'm sure you've had many, many, many people talk to you about ARPA and how ARPA worked at that time. It was amazing.

Brock: Well, I'd love to hear your perspective on that as well. But if I may, can I take you back a little bit?

Warnock: Sure.

Brock: When you're doing that hard work with the tires or retreading the tires, and having that realization to apply to IBM, implies that you were already—you had an interest in computers already. Could we talk a little bit about how you were exposed to them or how even the idea of "I'm going to work for IBM" comes about?

Warnock: I had zero exposure to computers.

<laughter>

I just walked in. At that time, IBM used to give you this very long test.

Brock: Yes, right.

Warnock: They'd say, "Here's a test. Take it." It would ask you mostly general knowledge questions, you know? "If you have a hand in bridge, what do you bid? What does 'shush' mean? What does—" I mean, just general awareness of the society kinds of questions. Apparently, I did very well on that test and, so I went up to Seattle and learned how to plug plug-boards—

Brock: Oh, my gosh.

Warnock: —for card machines.

Brock: Okay. <laughs> For tabulators.

Warnock: For tabulators. Yes.

Brock: Okay.

Warnock: This was—

Brock: Plug programming.

Warnock: Yes. I mean, I think the 1401 was really very new at that time when the 1610—or whatever it was. These were very—computers were just starting to get interesting. Anyway, I really learned how to do plug-boards. They taught you how to deal with customers in Phase 1 training this was called. And then as soon as I got back to Salt Lake, they said, “We’re sending you to Los Angeles.” This was very intensive course on machine language programming for 7090.

Brock: Was it kind of like a fish to water? Was it just something that really appealed to you and came easy to you? Or what was that experience like once you started using the computer?

Warnock: Well, with mathematics behind you and learning FORTRAN and things like that, it was fairly straightforward. I learned how to do that. But mostly when you came back, and you started visiting customers and solving real problems that’s when you started to learn about operating systems, how operating systems worked. As my customers would always say, “You’re here so we can train you.” <laughs>

Brock: Interesting.

Warnock: So, I learned how to program.

Brock: The customers would have a contract with IBM for essentially software services and support.

Warnock: That’s right.

Brock: And you would kind of be living there with the customer—

Warnock: Yep.

Brock: —creating those programs, creating the systems involving them—

Warnock: Yes.

Brock: Interesting. Huh.

Warnock: These were machines that filled huge rooms.

Brock: Yes, we have a 1401 downstairs.

Warnock: Well, 1401 is a teeny machine. <laughs>

Brock: Compared to these gigantic—

Warnock: Yes, Hill Air Force Base had a 7080 and, good god, a monster machine. They used to data process tons of stuff. University of Utah had banks of tapes and they had a FASTRAND—they eventually switched away from the 7040 that they had to 1108—UNIVAC 1108. They had a FASTRAND drum that weighed—I think it held five megabytes and it was the size of this—half the size of the room.

Brock: Amazing. Was it the case then that you were—IBM has such a good reputation as a company—

Warnock: Yes.

Brock: —with opportunity—

Warnock: Yes.

Brock: It's a big blue chip—big blue.

Warnock: Yes, big blue.

Brock: Okay. So, you're back at Utah. In mathematics ring theory is part of—

Warnock: Algebra.

Brock: —abstract algebra or something.

Warnock: Yes.

Brock: When you came back into the graduate program at the University of Utah in the math department, were you going to continue along that line of abstract algebra?

Warnock: This is a really interesting story. There was one ring theorist in the math department and his name was Norman Sexauer and he was my thesis advisor. As I was getting my master's degree I decided to tackle an unsolved problem in mathematics that had been stated I think in—I don't have the exact date, but it was, like, a 20-year-old problem that had been stated by Nathan Jacobson, who was sort of the supreme ring theorist at that time. I thought about that problem for about two years and solved it. My master's thesis was, I think, 25 pages—no, 35 pages—and it was eventually published in the *Transactions of the American Math Society*.[1]

Brock: It was a proof.

Warnock: It was a proof of an open question that had been around for a long time. My thesis advisor said, "Well, why don't you use this for a PhD?"

<laughter>

Warnock: You know? I was confident enough that I could solve some other problem, I guess, that I didn't do that. But anyway, the master's thesis got me into the PhD program fairly easily. I was working at the

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[1] N. E. Sexauer and J. E. Warnock, "The Radical of the Row-finite Matrices over an Arbitrary Ring," *Transactions of the American Mathematical Society,* 139 (1969): 287-295. Added by Frances Corry on July 3, 2018.

Computer Center, just maintaining computers and programming and doing stuff for the university Computer Center.

In 1966, Dave Evans came and started the ARPA contract and they started building a lab around where my office was in the engineering center, and they were going to do computer graphics. They started getting graduate students and building up the faculty. The computer science department was nothing before Dave came. I think his ARPA contract was, like, five million dollars a year, which was a huge amount of money at that time. It wasn't a big amount of money now, but it was a huge amount of money at that time. Dave had recruited Ivan Sutherland, he had recruited Tom Stockham, he had recruited Bob [Robert] Barton, and these other really, really good computer scientists.

Brock: Right.

WarnockThey were experimenting with displays and how you do three-dimensional stuff on displays. One day Gordon Romney, who was working on it, came in and he said, "I have a problem," and he sort of described the hidden surface problem to me. I was in the Computer Center. I thought about that problem and then said, "Gee, here's a way you could solve it." Gordon said, "You probably ought to talk to Dave."

I talked to Dave and I talked to Ivan and they said, "Here's the deal: your guy in the mathematics department has left. He didn't receive tenure. We hired a group theorist to replace the ring theorist," and I thought to myself, it will probably take me two years to come up to speed in group theory, which I'm not terribly interested about. Dave said, "Why don't you come to work on the ARPA project? Switch to engineering, and work on the ARPA project with us." I said, "That's a good deal." I did that and I also taught computer programming in the computer science department.

Brock: Was electrical engineering and computer science together—

Warnock: Yes.

Brock: —at that time? Okay. The hidden surfaces problem for computer graphics, could you explain for us what that problem really is? You know, what's the essence of that problem?

Warnock: The essence of that problem is you have a three-dimensional geometric model that's mathematically defined as a bunch of polygons that fit together to form a sphere, or a toroid, or triangles, or buildings, or anything—or terrain or anything else. You pretend you're shining a light on it and it's projected—the result is projected on the screen. So, how do you display the things that are in front and back, and hide the things that are obscured? In other words, if in this three-dimensional model, that post obscures the wall.

Brock: Right.

Warnock: If I'm from this point of view and I only have the geometry, how do I detect—put this in front of that and not show the stuff behind? In other words—

Brock: Okay, so, it's a realization of—

Warnock: Three-dimensional—

Brock: —perspectival—

Warnock: Yes.

Brock: It's realizing the perspective of the viewer onto a mathematical description of—

Warnock: Yes.

Brock: —a 3D object.

Warnock: Yes.

Brock: Okay.

Warnock: So, imagine this room, the camera, everything else described only geometrically in three-dimensional space. Now as you move the camera around, how do you make a two-dimensional image of what that is?

Brock: So, while it's called hidden surfaces it's actually a very fundamental question about perspective—

Warnock: That's right. You put the three-dimensional object through the same perspective transformation that your eyes have—

Brock: Right.

Warnock: —so that the two-dimensional mapping is the correct two-dimensional mapping. Now, how do you figure what shows and what doesn't show?

Brock: So, this must have been at the heart of computer graphics.

Warnock: It was. Yes.

Brock: Okay. I just wanted to ask you a question that relates to your thinking about the hidden surfaces. You know, we have you with your family doing all this visual art and painting. I know for a lot of people involved with mathematics, it's very visual. They're different, I guess, forms of mathematical creativity. I wouldn't know, I have very little—but for some people it's very visual. I know when I did an interview with Ivan Sutherland and for him it was almost entirely—

Warnock: Visual.

Brock: —visual. Was that the case for you?

Warnock: Yes, I was very comfortable with geometry.

Brock: Okay.

Warnock: I was very comfortable with three-dimensional mapping and all of that stuff and you sort of visualize how you might want to solve this, and that's sort of what happened.

Brock: When your soon-to-be-fellow-graduate-student came to talk to you about the problem in the computing center, did you continue on with the sort of line that you had first seen for the hidden surfaces problem?

Warnock: Yes. Yes.

Brock: You know, you had kind of got the nugget of your solution.

Warnock: They said, "Okay, program it." So, I programmed it. The way that it worked—it's sort of interesting. This is when computers were so infinitely slower than they are now. We had an 1108, UNIVAC 1108 that filled an entire room in the other room, and we had a wire going to a PDP-8. And the PD-8 was programmed to talk to the 1108. And then, on the PDP-8 had an oscilloscope.

Brock: Okay.

Warnock: It was a lab scope that had a green phosphor on it, and they wrote a program so that if you gave them an array of pixels, namely RG—first of all, just black and white, shades of gray—it would sweep it out on the oscilloscope. You would put a Polaroid camera in front of it, and you would open the lens, and you would let the thing sweep out an image on the oscilloscope. I think I was one of the first ones who started to do that. This was in 1968.

We started taking pictures and then we said, "Well, if we put red, green, and blue filters over the thing and take three pictures then we can make a color image." But since it was a green phosphor—I still have that picture. You get this greenish, but colored image. It may be—I'm talking with some of the guys who are trying to write a book about it—it may have been the first color image made on a color—three-dimensional image made on a computer. Anyway, it became obvious we needed a white phosphor oscilloscope.

<laughter>

Warnock: Dave bought a white phosphor oscilloscope, and then we started making real three-dimensional images that really looked right.

Brock: Were these geometric shapes?

Warnock: Yes.

Brock: The Utah teapot has famously become this test object in computer graphics.

Warnock: That's right. Yes, Martin Newell was at the University of Utah and William Newman was at Utah.

Brock: Right.

Warnock: Bob Flegal. These are all guys who ended up at PARC. And Ed Catmull and all of the Utah crowd were sort of learning this as we were going.

Brock: I was wondering for these early images that you were making—3D images on the oscilloscopes, was there a test graphic or a test model that you would put in across these experiments or were you just drawing different things?

Warnock: We would try different things. Now the unique thing about my algorithm was that most of the algorithms couldn't deal with self-intersecting objects. In other words, if I put a triangle through a rectangle—

Brock: Got it.

Warnock: —you want the intersection to show. Well, none of the other algorithms would do that. So, a lot of the tests I did would have intersecting objects so that it could make sure that all of the boundaries were done properly and all of that kind of thing.

The very first pictures were very, very dull. It was like, everything was made of felt. I figured out how to do spectral reflection. In other words, there's the white component that's reflected back and then there's the colored component that's part of the thing. I made the first spectrally reflected objects. You would experiment with lighting conditions and you would experiment with different things like that. But these were all done in 1968.

Brock: Wow. So, the lighting conditions I guess are also fundamental to that—

Warnock: Yes.

Brock: —finding a way to give perspective—

Warnock: Yes.

Brock: —to create perspective—

Warnock: That's right.

Brock: —on this model.

Warnock: Now the light source in the original ones was sort of always in the front. Then you would move the light source and then you had the shadow problem. Then that became a ray-tracing problem when ray-tracing started to be reduced into the hidden surface algorithm.

Brock: I would be interested to hear your perspective on, to hear you talk about these things from the perspective of today. It seems so natural. People have a perspect—you know, that a computer is graphical and making these sorts of images seems—

Warnock: Easy! <laughs>

Brock: And also, like, "Of course, that's what you would do with a computer."

Warnock: Right.

Brock: But I'd be interested if you could talk about how unusual and almost crazy it was to try and do this work on the computers of the late 1960s.

Warnock: Well, first of all, you had no memory. The 1108 was 32,000-word memory machine. So, you really had no memory. Tape storage was not terribly useful. The random-access storage was slow and small. It took racks and racks and racks of computers to do anything. Anyway, I proceeded along this line and finally—my thesis advisor was David Evans, Ivan Sutherland, and Tom Stockham. And I wrote my thesis and then I just started to go with a start-up in Canada.

Brock: I definitely would like to talk about that, but before we get to that, if I could, I'd like to ask you about the way in which Dave Evans and Ivan Sutherland communicated why graphics was so important, why this graphical turn in computing was going to be so important. Was there a way that the people at Utah understood why computer graphics was so important?

Warnock: Well, his charter for that ARPA contract was "Man/machine communication." It wasn't just graphics. It was "Man/machine communication." They had normal line drawing graphics. Ivan was very, very famous for doing Sketchpad, and doing sort of the first interactive program where you're interacting with the screen. There was work going along in that area, and there was work going along in sort of the visualization area. I got my degree in 1969 and I think they were just about to start Evans & Sutherland at that time.

Brock: Oh, okay.

Warnock: They said, "There's a way to commercialize this. We're going to go into the graphics business." They founded Evans & Sutherland. I'm trying to remember what my frame of mind was. I had just gotten my PhD and some people in the Computer Center had been approached by a company to start a computing service kind of company in Canada, and that sounded fun. We left—they were unhappy, I think, about me leaving—but we went up to Canada and went with a company called Computime and were there for—well, I can get into that.

But the research—Catmull came, Jim Clark, came to the University of Utah. Henry Fuchs—I mean, all the people—who's who in graphics were essentially at Utah. Just at the summer before I left, Bob Taylor came to the University of Utah. So, we had Bob Taylor, Ivan Sutherland, Ed Catmull—I mean, Jim Blinn—no, Jim Blinn wasn't at Utah. He was at Caltech. I'm just trying to think of all the people. But almost everybody—

Brock: And Alan Kay—

Warnock: Alan Kay—yes. Alan Kay and I go way, way back.

Brock: His time would have largely overlapped with yours.

Warnock: Yes.

Brock: Well, what was he like during those Utah days?

Warnock: As crazy as he always is. You know, he's very, very smart. Very advanced thinking. Just, you know, full of ideas all the time.

Brock: I think by interrupting you and asking you other questions I derailed you from talking about your thoughts about the importance of ARPA and the ARPA community and including your graduate cohort at Utah, if—

Warnock: My description of the ARPA community is—Bob [Robert] McNamara decided that—and Licklider, who really founded ARPA, had decided that it was much better, rather than give out little teeny grants to lots and lots of faculty people all over the country, to build centers of excellence and give them a lot of money. In those days, it was a lot of money. Rather than like the National Science Foundation or something like that, they would say, "University of Illinois: supercomputers; MIT: artificial intelligence; Stanford: artificial intelligence, operating systems, machine architecture." They farmed out all these centers of excellence—"communication for UCLA."

One of the best experiences I had is, they decided when Taylor took over that it would be a good idea to take the two best graduate students at all of the centers of excellence and put them together for a week or so in a room and have them all explain to each other what their work was. Alan Kay and I were picked to go to the University of Illinois to the graduate school meeting. And, god, the people who were there—[Steve] Crocker and [Paul] Rovner and all of these guys who were really, really smart—we spent morning, noon, and night talking about computers and what they were good for and what we were working on. And it was fantastic. It was really fantastic. Everybody gave their little talk about what they worked on, and Alan gave his talk and that was really great. When we came back from that I was invited to the ARPA general contractors' meeting and Alan was also invited. We were sort of guest observers and that's when Larry Roberts presented the Internet at that meeting. That was in 1968.

Brock: Right.

Warnock: He said, "We're going to put 56 kilobits," which was an amazing amount of bandwidth at that time between computers, "between the centers of excellence and we're going to build the ARPANET." That was Bolt Beranek and Newman and all those people, and that's when it started.

Brock: That ARPA community was a a dominant fraction? A majority? I mean, the overlap between that community and, essentially, the computer science and artificial intelligence communities, there was a huge overlap—

Warnock: Yes, yes.

Brock: —was it not the case? It's fascinating that you could have such an insight into the whole of the research frontier.

Warnock: That's right. When they turned it into DARPA—the cool thing was that Dave would write a one-page report on what he'd accomplished over a quarter, and he'd send that in and that was sort of his reporting responsibility. Then I think in the late '70s or something, they decided to switch it back to defense and have much more defense focus on it. I mean, nothing was classified at the ARPA community at that time. It was sort of disseminating information.

Brock: Right. There is an interesting way in which by choosing to have these centers of excellence, these big projects distributed around at just several locations—and while you may have some rivalries between Stanford and MIT—

Warnock: Yes.

Brock: —let's say, in artificial intelligence—that's a competition based on sharing all the information, all the time.

Warnock: It was great. No, it was really great. I think that's essentially sort of what launched all computing that we know today. They all talk about the very first personal computers and everything—but the work that was done at PARC sort of swamped all of that.

Brock: Thinking ahead when you were in your involvement with Adobe, are there ways in which you consciously took things that you saw that were successful from the ARPA management or approach in how you did things later in your own organization?

Warnock: Yes, I think we were highly motivated by letting people be creative and using information. I mean, it was really interesting. Bob Taylor was not a good fit at Utah. He just wasn't a good fit. He talked with George Pake at Xerox and decided to start a computer sciences lab at PARC. But he cherry-picked every good graduate student from ARPA. He really did. It was the most amazing group of people you've ever seen.

Brock: So, it's in some ways a distillation of that community.

Warnock: That's—

Brock: According to Bob Taylor's vision.

Warnock: According to Bob Taylor. He looked at that as a home where he could have a mini-ARPA community. From my perspective, that was his mental attitude.

Brock: You overlapped with him for about a year or so in Utah?

Warnock: No. Three or four months.

Brock: Okay. They had given him a faculty position there?

Warnock: I don't know what his title was. He was—

Brock: He was there. <laughs>

Warnock: He was there. In the meantime, we went to Canada. The company failed in Canada. I got a job at Computer Sciences in Toronto, worked there for about a year; moved to Washington, D.C.; to Rockville, Maryland, and worked for Computer Sciences there as primarily a contractor to the Goddard Space Flight Center.

Brock: And the start-up, was that—the name—

Warnock: Computime.

Brock: Sounds like a time-sharing company.

Warnock: It was.

Brock: Okay.

Warnock: 1108. Right.

Brock: Okay. Was that a move away from graphics work?

Warnock: Yes, I was writing programs for Rio Tinto and all kinds of things.

Brock: Okay.

Warnock: So, did this sort of two-and-a-half-year route around. Dave Evans came to see me in Washington and he had a mini-problem at Princeton that he wanted me to solve, and I helped him with that problem. I convinced Computer Sciences to lend me to Dave Evans and then he said, “Why don’t you come to California?” We hated Washington.

<laughter>

Warnock: That was during Watergate, it was during the Vietnam War—

Brock: Right.

Warnock: —riots. It was the burning of the District. I mean, it was—

Brock: Wow.

Warnock: It was not a great place to be. And my wife really, really wanted to come to Palo Alto. We came out with Evans & Sutherland. I was put on the ILLIAC IV project, which had been moved to Ames Research.

Brock: From Illinois?

Warnock: Yes. They moved the machine from Illinois and Evans & Sutherland took a subcontract with Ames Research to provide software for ILLIAC IV.

Brock: Okay. So, Computer Sciences Corporation was a computer services—

Warnock: A beltway bandit.

Brock: A beltway bandit.

<laughter>

Brock: One of the original beltway bandits, of, “We will create the software and system—”

Warnock: Yes, contracts.

Brock: The NASA work for Goddard was—

Warnock: A part of the beltway bandits.

Brock: Okay. Was there anything particularly interesting about the—was it scientific software?

Warnock: Yes, it was.

Brock: Okay. Something for the space program.

Warnock: That's right.

Brock: Then Evans & Sutherland had a contract with something at Princeton University?

Warnock: Yes, they had a Picture System, which was one of their early graphic systems at Princeton. They wanted to do a demo for a mining company in Canada to visualize the mines and how they dug in open pit mines.

Brock: Right.

Warnock: I helped them with that project.

Brock: That would be getting that simulation to—

Warnock: Yes. Well, I was just building a program to do that.

Brock: Okay. So, that's a return back to graphics with that.

Warnock: Yes.

Brock: With the ILLIAC, was that then a shift back away from graphics, to just trying to get this supercomputer to work?

Warnock: Yes, I was head of operating system development for the ILLIAC IV.

Brock: Oh, I didn't realize—okay. Because I had a bunch of questions and my question, "What is he doing at Ames?" <laughs> That's fascinating. Was that always the intention to move that computer from Illinois to Ames?

Warnock: I think that was close to the time [Daniel] Slotnick died and he—they decided that they could use the ILLIAC IV for weather prediction.

Brock: Okay.

Warnock: That was I think the motivation to move the ILLIAC IV, was to try to get it running and to do weather simulations on it.

Brock: Okay.

Warnock: Now, the ILLIAC IV was an impossible machine. I mean, it was way too big and it had way too many components in the early ‘70s—

Brock: You mean physical components.

Warnock: Physical components. These are before transistors.

Brock: Right.

Warnock: I mean, before, you know—

Brock: Integrated circuits—

Warnock: Circuits.

Brock: —are really—

Warnock: Yes. They were constantly, constantly trying to keep these machines alive and they were—it was a losing fight. There was just too much of it and there was just— you'd get one bank working and then this wouldn't work. The thing that controlled the ILLIAC IV was the PDP-10. We tried to build the operating—then they had this gigantic parallel disk that you had to figure out how to put the data spaced around the disk so you could maximize bandwidth. Part of the operating system development was to communicate with this disk and the ILLIAC IV. It was just impossible.

Brock: To get—

Warnock: To get it to run.

Brock: It sounds like some of the problems on the very earliest computers.

Warnock: Yes.

Brock: Writing things when the disc is spinning—

Warnock: That's right, exactly.

Brock: —and then you read it when it's—

Warnock: Yes. Under the head.

Brock: —spinning around.

Warnock: Yes.

Brock: Wow. Okay. So, it's very hardware specific.

Warnock: Specific. Very tough timing conditions. Very—impossible.

Brock: From the outside listening to it—getting the mining simulation to work on this machine and switching to a completely different one-off machine to do the operating system—from the outside it sounds like you're kind of whipsawing from one kind of project to another. Was there something that's common to all these problems?

Warnock: Computers.

<laughter>

Brock: I guess so.

Warnock: Computers. What they had done is they brought a lot of people from Illinois. A lot of those people worked for me inside Evans & Sutherland on the ILLIAC IV project. And Charles Simonyi worked on the ILLIAC IV project.

Brock: In your group?

Warnock: In the same group of people on the ILLIAC IV project.

Brock: I hadn't realized that.

Warnock: I got to know Charles. The head of the project was Mel Pirtle, who was also part of the ARPA group.

Brock: Right.

Warnock: He was the manager, possibly the worst manager I've ever worked for in my life, but he was the manager. He was not a people person. <laughs>

Brock: It was his interpersonal—

Warnock: Yes. He was not a people person.

Brock: Am I correct that when Ivan Sutherland was at ARPA—was he the person who funded—

Warnock: He was head of ARPA for a while.

Brock: But isn't the ILLIAC IV one of the things that he was supporting?

Warnock: He funded—yes.

Brock: Okay. So, there's a natural kind of fit then for—

Warnock: He was head of ARPA before he came to Utah.

Brock: Right. I was just thinking there's a natural Evans & Sutherland collection, because Ivan Sutherland would know all about the system—

Warnock: Well, and Mel Pirtle was one of Dave's students at Berkeley.

Brock: Oh, okay.

Warnock: The world all fits together from people who know other people and—

Brock: I suppose especially so in the '60s and early '70s.

Warnock: Yes.

Brock: The community of computer science of possible people to work on such a thing is so much—

Warnock: Very small.

Brock: —smaller compared to today, that these interconnections must have been much more frequent.

Warnock: Yes. Butler Lampson was at Berkeley and Peter Deutsch—they were all part of the Berkeley—let's see, they were—Dave had a big part of the design of the Sigma 7.

Brock: Right.

Warnock: Peter Deutsch and Butler and everybody worked on the—what was the name of the project?

Brock: Was it called Project Genie?

Warnock: Genie. Yes. Project Genie.

Brock: I had heard Dave Evans started that.

Warnock: That's right, and then went to Utah.

Brock: Okay; and they would have been a part of the ARPANET community as well.

Warnock: Yes, absolutely.

Brock: Was it your experience that when you got to the Bay Area and started this effort working at Ames with Evans & Sutherland, was the ARPANET community who you had kind of known before, did that become your natural social community when you got out here?

Warnock: No. The ILLIAC IV project was relatively isolated. It was a part of Ames and there were a whole bunch of—Computer Science was one of the contractors, and Evans & Sutherland was a contractor, and there were a bunch of little contractors that contracted in and Mel directed all of those. For—I think, what, I worked on that for maybe two years?—it was fairly isolated community.

Brock: Okay.

Warnock: It was not going to succeed. It was just very clear, this machine was way too complicated. Unless you completely redesigned it from the ground up and used better technology, it was just never going to succeed. Your phone was faster than the ILLIAC IV.

Brock: Right.

<laughter>

Warnock: It has way, way more memory than the ILLIAC IV. And Mel was very, very difficult to work for. He would berate people in public and just—management styles that just were not great. Very smart guy—very smart guy, but just not a motivational person.

Brock: It must have been difficult for a project that—

Warnock: Yes.

Brock: —was struggling for so long. Added frustration on top of whatever was—

Warnock: Dave came down and visited me and he said, "Well, I need you to—we got ourselves into a contract—"

Brock: Yes.

Warnock: "—into a contract and you've got to help me." <laughs>

Brock: Perhaps we could go through that story for this audience also.

Warnock: Okay.

Brock: So, please, the harbor piilot simulator.

Warnock: The harbor pilot simulator. Evans & Sutherland was just getting into the visual simulator business. They took a contract—oh, god, they took this contract with—as a subcontractor to Philco-Ford to build a life-size simulator for a ship to train, in the maritime academy to train pilots how to take a ship into New York Harbor. There's nothing about that that's reasonable.

<laughter>

Warnock: Absolutely nothing. Dave said to me, "I'll start an office in Mountain View, California, go find some space, hire people and help me out of this situation."

Brock: This is the offer he makes to you.

Warnock: Yes.

Brock: Okay.

Warnock: I picked a guy named John Gaffney, Paul Zima and Christine Barton who all worked for the ILLIAC IV project and said, "Do you guys want to do this?" And they said, "Yes," because they didn't like Mel any better than anybody else. We announced that we were leaving and Mel never forgave anybody for leaving the ILLIAC IV project. We bought this little—I don't know—maybe thousand-square foot office, got a PDP-11 into it in Los Altos and we started diving into this problem. The problem was the following. Do you know what and Eidophor projector is?

Brock: I don't.

Warnock: This is most improbable machine in the world. It's a circular mirror that spins around and it has a wiper blade on it and it has a film of oil.

Brock: Okay, I have heard of these. This was the same projector that was used in the mother of all demos—

Warnock: Yes.

Brock: —right? It's this very bright—

Warnock: You're shining a projector light on it and the oil is modulated by an electronic beam that makes bumps in the oil, that disturbs the refraction index of this mirror. If you shine the light onto the mirror you can paint an image. If you have three mirrors and you have three different colored lights, you can paint a colored image.

Brock: Wow.

Warnock: Yes. Wow! <laughs>

Brock: And a projector would have three of these mirrors?

Warnock: Yes.

Brock: One color projector—

Warnock: Would have three mirrors.

Brock: Three scanning electron mirrors—

Warnock: Well, I don't know—I think they might have had three separate projectors for one image.

Brock: For one image. Okay.

Warnock: Well, they have five Eidophor color—so, five sets of three to project on this screen that was gigantic. Getting one of these projectors to work is hard, getting all of them to work—impossible! But anyway.

Brock: Was it an electron gun that would—

Warnock: Yes!

Brock: So, you have fifteen electron guns in the whole thing and the idea is that you can drive those guns digitally?

Warnock: Yes. Yep.

Brock: And that's—

Warnock: That was the projector system. Then there was a full mock-up of the bridge. It had window steering things and controls to control the sort of ship.

Brock: Right.

Warnock: I tell people this and they just stare. They said, "Okay—" in those days you didn't have a framebuffer. There was not enough memory to have a framebuffer for the images.

Brock: The framebuffer would be the complete image that you're going to render.

Warnock: Yes. It would be memory that held the image that you were going to remember. You couldn't buy memory that was that large, so what you had to do is, in real time, you had to compute the image and stream it out to the projectors in real time.

Brock: Wow.

Warnock: You couldn't make an image and then project it and then make another image and then project it. You would make an image and while you were scanning that, building that image, the other image would be getting worked on and, so, frame by frame. All of this happened in real time.

Brock: And you're doing 20 or so—

Warnock: Thirty frames a second.

Brock: <laughs> Thirty frames a second.

Warnock: Well, I think it might have been 25.

Brock: Okay.

Warnock: E&S had had this contract for I think three years. I think that was the contract. It was a three-year contract. If you know Ivan, Ivan is probably one of the world's great inventors. But he would focus on a problem and he would solve that problem as a component to the system. One of the problems he tried to solve is: how do you digitize New York Harbor? There weren't any digital tablets that worked, that were that big, where you could put down a map and do anything.

Brock: Right.

Warnock: He set off one of his goals in life to build this digitizer that would hook to a PDP-11. I don't know what they did for two years. But, finally, Dave Evans, because this contract was in so much trouble he hired the two top guys out of GE, Rod Rougelot and Schumacker —Bob Schumacker. And these guys were—had built simulators for NASA, with GE. They were hardware experts and Rod Rougelot was an extremely good manager. He came in and we all sort of started with, like, about a year to go on this contract.

Brock: Wow.

Warnock: Schumacker and Rougelot started building hardware and the hardware was six racks of hardware—racks this tall, this big—six racks of hardware with just special purpose stuff on it.

Brock: Now, this is not to create the digitizing of the—

Warnock: Images.

Brock: The six racks is to digitize the—

Warnock: Images and feed the images to the Eidophor projectors.

Brock: Okay.

Warnock: Now, all of this is controlled by a PDP-11. The database is controlled by the PDP-11, the managing of what polygons you send to the image generators is managed by the PDP-11, and the position—so, you're at a position in the harbor and you say, "I'm going to take this swath of the database and feed it to the image projector."

Brock: Okay.

Warnock: We were responsible for the PDP-11 and the building of the database. So, there were I think—PJ Zima, myself, Gaffney, Christie Barton, and Dave Lewis—five guys. We were to build a database and all the software to drive this image generator. <laughs>

We get Ivan's tablet shipped down <laughs> and we have this PDP-11. We said, "Alright. We have to attack this problem in a very systematic way. Gaffney, take five cameras, rent a tug boat, drive through the Verrazano-Narrows Bridge, have all the cameras facing in all directions and take all the photographs of what it looks like—"

Brock: Right.

Warnock: "—as you drive in. You only have to go down to the Staten Island thing and come around Staten Island back to the Harbor." You didn't have to go into Manhattan, thank God.

<laughter>

Brock: Far fewer buildings.

Warnock: Far fewer—yes. The buildings that were important were the ones that you could see. We got a topographic map of the harbor and we said, "These are the buildings." We spent database day—and we went through every roll of film, identified how many stories the building was, was it a red brownstone, was it a yellow brownstone, was it a circular tank?

Brock: Wow.

Warnock: And that's what you do! You go and identify all the buildings and you mark them off on the digitizer. You put the map on the digitizer, you say, "Here's where the building is," and then you want to enter the dimensions of the building and the color. Just very simple, fundamental data about the buildings.

Brock: Right.

Warnock: Small buildings you don't care about. Big buildings that are landmarks that are useful to a navigator. That would be great, but Ivan's tablet didn't work very well. <laughs>

John Gaffney came up with a really brilliant idea. He said, “What we need to do is we need to make a little pseudo-machine in the PDP-11 that we can say, ‘Read the pen, give me the X-Y coordinates, hit this menu, generate this piece of text, and write all of this out as a line,’” in other words—“and then go to the next building.”

What you would do is you would touch where the building is. That would pick up the coordinates. You would touch the fact that this is a square building three stories. This is the orientation of the building, it’s at this angle, and this is the color of the building, and this is the building’s number.” And it would just generate a line of text.

Brock: I see. So you’re almost automating the input to this database.

Warnock: That’s right.

Brock: Okay.

Warnock: And nothing specific about the database, just the information about the database. It wasn’t specific in that there was no machine format, because we didn’t know what it was.

Brock: Okay.

Warnock: Because the hardware hadn’t been built.

Brock: Right. It’s just sort of a—

Warnock: It’s a meta-record.

Brock: I got it.

Warnock: We would sit there and on the keyboard we could program this little thing to do these various things and we would make up menus and every time you’d hit this menu, it would execute this piece of code, it would expect you to enter data in a specific order. A little tiny interpretive language; and it had registers and it had storage and it had memory and you would program it while you were sitting there.

Brock: How on the tablet would you be able to—would you put slips of paper, or something?

Warnock: Yes, just glue down slips of paper—

Brock: Okay, with a piece of tape or something?

Warnock: Yes, yes.

Brock: Okay, I got it.

Warnock: Nothing complicated here. <laughs>

Brock: Right. No, no. Because the tablet, the surface of it is just like a—

Warnock: Big coordinate system.

Brock: Okay.

Warnock: We went through and we build this sort of metadatabase. Now, the database—we didn't know what data structures the machines would want. We built this metadatabase that had the information of the database, colors, all that stuff, but it was sort of all symbolic. But this little programming language was called Joy, and it saved our lives. Because if you had to hard code that in PDP-11 language you would be coding the rest of your life. This little interpreter really worked. At the same time, we were also working on management of—if the ship is here, what part of the database can we expose to the visual system?

Brock: Yep.

Warnock: We solved that problem and we tried to—because the visual system only had a certain capacity for polygons—in other words, it could only deal with so many, only had very limited memory.

Brock: Right.

Warnock: You had to, as the ship moved, toss things out of the database and pull things into the database.

Brock: Oh, it couldn't even contain the whole—

Warnock: No.

Brock: Okay.

Warnock: Well, it did on a disk, but you had—

Brock: Right, in the active—

Warnock: —in the active part. We coded that and we put the database together and I think Gaffney and PJ went to Utah to live with the hardware guys for the last couple of months. Oh, the thing also simulated fog, because you have foggy conditions and, so, they had to build into the hardware how you simulate visibility. Things desaturate as they get further away and all of this kind of stuff. Then they had to build the interaction with the ship itself. You're taking locations from the ship, its orientation and its elevation, that kind of stuff.

Brock: Was it dealing with changing conditions of the water?

Warnock: No.

Brock: Was that part of the—no. Okay—

Warnock: That was too complicated.

Brock: —it was nice flat water.

Warnock: Yes, very flat. But it had other ships.

Brock: Okay.

Warnock: There were other ships that were moving that were part of the database, and those were driven by different controls. There was a set of controls on the thing and then there were a set of controls to drive the other things. Anyway, the system was delivered on time. I think it only stayed live for about a year and a half, because technology was changing fast enough where this was a very primitive solution. But it did work.

Brock: Wow. It sounds incredibly expensive.

Warnock: It was.

<laughter>

Warnock: It was. It was incredibly expensive and—but running ships is incredibly expensive—so, they could justify it. Dave decided he liked our work and he said, “Well, open up another office and work on our other customers’ problems.”

We liked this little toy Joy, because it worked really well. John Gaffney had an idea and he said, “Well, what if we make a full-blown machine, interpretive machine, that we can drive displays with?” In other words, if I am designing an oil refinery, can I use this, in some sense, interactive programming language to procedurally describe the oil refinery and then visualize it on Evans & Sutherland systems? Or can we build a database with it for the NASA space shuttle? That’s what we did. We called this interpretive language the Design System.

Brock: Now, for the case of the idea for, like, the oil refinery or the space shuttle, it was that you would use this approach to—was it still involving the use of the tablet and these menus and these kind of things?

Warnock: Yes.

Brock: Okay. It would be to take what you had made for the harbor pilot simulator and make it into a sort of a general—

Warnock: Model building.

Brock: Model building tool.

Warnock: That's right.

Brock: As I was listening to you describe it and trying to picture the set-up, it sounds very much like you're creating with physical objects essentially something that sounds very much like a graphical user interface, except there's a tablet, I have a pointer, I'm selecting locations, I have changeable menus that I'm also selecting with the same pointer. You know, if you flip the tablet up and turn it to the screen it's a mouse.

Warnock: Yes.

Brock: Is there a connection then to…

Warnock: The interesting thing about it is there are several ways to build databases. You can build a database as a static geometric thing, or you can build it as a procedure that builds that thing. The way this worked is we had procedures that would build cylinders. We would have procedures that would build shapes, elbow connectors, things like that. You would have this menu of procedures, and they would put things together, and then you could interactively drive through a line drawing display in three dimensions, for instance. This was before you had hidden surface removal.

PDP-11's are not big machines, so you're driving an E&S Picture System to do this. We worked with people like Fluor Corporation and people who build oil refineries, and they got interested in it. We would play around with this. It was an approach that not many people were capable of assimilating and using. You sort of had to be very technical to do this stuff.

Brock: I am having trouble understanding the distinction between a way of creating an image through—I understand I can call different procedures, and then give the parameters to the procedures, you know, cylinder, box, elbow, connect them, tell them where they are.

Warnock: Yes, sphere.

Brock: I get it. What I can't imagine is the contrast between what was the status quo.

Warnock: I believe the easiest way to build three-dimensional objects is not just to have the geometry of the object, in other words a static line with coordinates in it, but have procedures. So if I have a spheric procedure, I can say: “Here's a radius. Here's the refinement of the polygons that make it up. Go make me one.”

Brock: I get it, I get it.

Warnock: Whenever I need one I call this procedure, so it's really a set of procedure calls.

Brock: Rather than the mathematics that describe just the outline of the whole thing, like a huge list of X, Y.

Warnock: That's right.

Brock: Okay. Just defining this complicated surface and—“There it is.” A whole different set of points in space.

Warnock: That's right. Now, at any time, you can take these procedures and you can have them just generate geometry if you want to go to a visual thing. Or, you might want to have it have some other purpose, and so you change the tail end generators and they do something else. It's a very procedural-oriented thing.

We did this for a while. It became clear that E&S was changing focus, and it was building simulators, and they were not getting the kind of traction in the commercial world that they were. They invited me to come back, and be a vice president of Evans & Sutherland, back to Utah, and I didn't want to go back to Utah.

Brock: Was it that—just the attractions of the Bay Area? And what was happening here?

Warnock: We loved it here. The people here are not all Mormons. <laughs>

My wife and I just had a really long talk and said: “Okay, here are our options.” We said, you know, “The Bay Area is a really interesting place. Lots of things are happening.”

I called William Newman. William Newman called Chuck Geschke. Chuck and I went out for interview. We’re both roughly the same age, both roughly the same education. We have the same number of kids, that are the same ages. We both refereed soccer. We hit it off very well. He said, “I'm starting a new laboratory called the Imaging Sciences Laboratory. I'd like to have you interview.” I came up and did the normal PARC interview.

Brock: So it was William Newell that you knew…

Warnock: Newman.

Brock: Newman. Sorry. William Newman who wrote the book on graphics with Bob Sproull. He kind of knew that you were looking for—that you were grappling with this choice.

Warnock: Yes. We were William’s children's godparents.

Brock: Okay, so you're very close.

Warnock: Yes. I've known William forever. He was also at Utah.

Brock: Right. Is that how Chuck Geschke had known you by reputation previously?

Warnock: Yes.

Brock: William was part of…

Warnock: Well, after I did the hidden surface algorithm I sort of toured the country to the ARPA facilities and gave talks on it. I think Chuck heard of one of my talks.

Brock: At Carnegie?

Warnock: At Carnegie.

Brock: Okay. Had you been aware of the effort that he was doing with Mesa and everything at PARC?

Warnock: Not at that time. I knew a lot of people at PARC; I knew almost everybody at PARC. I came in, interviewed, was given a job in the Imaging Sciences Laboratory. Now, the interesting thing was they, at that time, this was in 1978, August 1978. I came to PARC. PARC had built the Alto with a very singular point of view on how displays would be used and driven. A display was a bitmap. Black-and-white bits the size of a printed page. They had built all kinds of special-purpose hardware to deal with bitmaps. Moving bitmaps incredibly rapidly around in memory. They had special hardware to do that so that you could update displays very, very fast.

The Alto wasn't much faster. It was a little faster than the PDP-11. It had a better address space; it had a 65K address space as opposed to a 32K address space. It had a five-megabyte hard drive that was removable. Fantastically, it had the ethernet that connected all of the machines. And it had Dover printers, and those were amazing. But at that time they were engineering the Dolphin. The Dolphin was a color machine that had grayscale capability and was a different orientation on the screen. All of the bitmap stuff could be translated as is, but it was not useful for that display because it was a very different machine. It was a color machine.

Brock: Right, I see.

Warnock: All of the software and all the display and graphics had been really, really focused on bitmaps and how you create those bitmaps. Nothing three-dimensional, nothing colored. It just was very focused. My primary responsibility was to make device-independent graphics, so that a piece of software could drive not only the bitmap display, it could drive color displays or grayscale displays, and deal with a much broader spectrum of stuff. But, also, potentially could drive high resolution printers, Dovers and color printers. They had the Puffin printer at that time.

Brock: Right. One of the first color laser printers.

Warnock: That's right.

Brock: I know this kind of saying, like, a lot of the hardware of the Alto was devoted towards the screen, but I hadn't quite realized that it was, the hardware was specifically implementing this bitmap approach to the screen. So the challenge then is, you know, how is the new computer going to address the screen?

Warnock: Yes, address the screen.

Brock: So it will either be creating a new bitmap system, if you will, or—

Warnock: That would be one approach, but if the resolution of the screen changed you're screwed.

Brock: Right, because it's burned into the hardware.

Warnock: That's right.

Brock: So this is a shift from addressing the screen through hardware to addressing it through software, in essence.

Warnock: That's right. Almost none of the geometric work that had been done at Utah sort of made it to PARC, even though William Newman was there. William Newman did a thing called Markup; Patrick Baudelaire did the curve stuff; but this was all bitmap stuff. And Bob Flegal. And all the other guys from Utah had done these implementations.

When I arrived I said well, first of all, the underlying representation of the objects can't be bits. It has to be geometry. I had started working with Mesa. I had to learn how to program in Mesa. Mesa was a very strongly typed programming language that was meant to build bug-free computer programs. It was very strict in what you do. In changing a Mesa program, you had to be very careful that everything was typed properly, that everything was bolted down properly. I found that it was just hard to experiment, it was hard to try things, it was hard to do things sort of interactively. So I re-implemented the Design System. The Design System is essentially PostScript.

Brock: Right. When you were describing it, my mind was running ahead to it, because that difference between calling procedures, defining the geometry versus specifying all of the bits from the Design System, I can see very directly the inspiration. Again, the screens change. The printer changes. The bits change. So you have to kind of have this…

Warnock: Abstract representation, just like the database. You generate different stuff out of it. The difference was the Design System didn't have anything that really directly went to a raster-styled screen. We had to put in all of the draw commands, all of the fill commands, all of the image commands, all of the graphic machinery that's inside PostScript.

I enlisted, Martin Newell's work, who was a procedural-oriented guy and he loved it. He helped implement the JaM, John and Martin. We used this, and we could generate any image in the world and any resolution and send it to the Puffin printers, or send it to the Dorado, and print stuff. We could do very imaginative transformations and display things that nobody else at PARC had ever been able to display. I thought this was a really cool thing to do.

We were sort of billboarded inside of PARC of making breakthroughs in various areas of how to use displays. How do you make grayscale characters, for instance? Use anti-aliasing to make good looking characters? How do you size characters? How you do that kind of stuff? We did that, drove the Puffin printers. A guy named Doug Wyatt became the primary maintainer and implementer of JaM. We added features and features and features, imaging features, and all kinds of things so it could take in photographs and scale photographs and do all that stuff.

Brock: To do all of these extensions and elaborations and build capacities, let's say, in it, is it a simple way to think about it, is "I'm just adding another procedure?"

Warnock: Yes.

Brock: Keep all of the stuff that I did before…

Warnock: I'm adding new operators.

Brock: Okay.

Warnock: Just adding new operators, and you type "Add it," and it's there. You see, you can experiment because you're never compiling, loading, trying. You're typing say go, seeing the results. Typing, essentially typing and say install this command, new command. Very interactive, very productive from my point of view. So we got some fans. I was in the office next to Mel Pirtle—not Mel Pirtle. The guy from Carnegie Mellon, Alan Perlis.

Brock: Oh, yes.

Warnock: He loved it. He thought it was great that we were doing this. We were going along and Chuck and I and Bo—Chuck, myself, Bob Sproull, Butler Lampson, Brian Reid and Jerry Mendelson were put onto the task of building the new Xerox printer protocol. This was to be called Interpress.

Now, what had happened is they had started to make the Star a commercial product at Xerox. They found that they had no universal printer protocol, and so they said, "Well, we've got to sell printers to these guys. Why don't we have PARC design a printer protocol for Xerox?" This was also one of the most fascinating projects in the world, because we very rarely met. We did the whole design via email, and we'd have arguments via email, and everything.

Brock: I wonder if any of those emails survive?

Warnock: I don't know. It would be nice if they did, if they've archived them. Because there were two very, very distinct approaches. I was on the sort of, “Gee, why don't we just make this a procedural thing and essentially use some of the attributes of JaM to drive the printers?” And there was the Butler crowd that said, “No, we have to be able to ensure page independence, we have to have certain static stuff, and all these have to be mashed together.”

Now, the problem, and the problem that got in the way of the procedural stuff, is that the only fonts that Xerox had at that time were bitmaps. They had outlines but they couldn't generate bitmaps from outlines and have them look good. Every letter had to be taken in front of an artist and hand-tuned so that it would look good at all sizes, and had to have one for each size of the font.

All of the printers had this library of fonts, and there was no solution to the font problem so you had to use those. So the architecture of Interpress got really ugly. It got ugly because there was sort of these static bitmaps that were in specific sizes, and you had this procedural architecture where you could rotate anything through any angle and size it at any size.

Brock: Okay. Two different idioms: bitmap and geometry.

Warnock: Interpress ended up to be a mashup of those two idioms. I didn't, in my heart of hearts, believe it could ever be implemented. I really just never thought it could be implemented but we sold it inside of Xerox, and they said, “Okay, this is the standard.” We said, well, if it's the standard we ought to announce it to the world so that the world can implement it. They said, “No, you're not going to do that until all of our printers can run it.” I thought to myself, and Chuck thought to himself, “That's never going to happen.” I don't know what he said in his interview. <laughs>

Brock: That's what he said, yes.

Warnock: It's never going to happen. So, we were depressed. I went into his office, and I said, “We can live in the world's greatest sandbox for the rest of our life, or we can do something about it.”

Brock: The idea was with Interpress, that the Star computers would be able to use Interpress to work with any variety of…

Warnock: Laser printer.

Brock: Laser printers. And, similarly, it would also allow other people using non-Xerox, non-Star equipment—people could use Interpress with whatever computer they had to use a Xerox laser printer.

Warnock: Yes.

Brock: Okay. What I don't understand is when I was talking to Chuck Geschke he said that Xerox was saying something like, “Well, our product cycle is seven years,” or something like that.

Warnock: Right. Yes.

Brock: Which is an infinity.

Warnock: That's infinity. <laughs>

Brock: Ten lifetimes or whatever it is. It's functionally never. Maybe I'm not understanding it, but it seems like laser printers were so new, how many different products could Xerox have had at the time to—

Warnock: Well, they had a color printer, the Puffin, and they had the Dover. The Dover was 240 spots to the inch, and the new Canon printers that were sort of getting announced at that time were 300 spots to the inch. Resolution was a big deal.

Now, Hewlett-Packard—so the person who had done the Press protocol for Xerox that we used with the Dover's and the Puffin was done about Bob Sproull. But those protocols were static. They were: "Start at this position, write this line of text. Start at this position, write this line of text." They were not models of a page that you could transform or do anything to. They were static descriptions.

And the HP protocols, PCL [Printer Command Language], was exactly that same way: "Use this point size of this type. Use this point size. Move up a little and put in an exponent," that kind of thing. A very static description, one for each page. You would have to go back to the generating program to change anything, to do anything differently. All printer protocols were like that.

I went into Chuck's office and I said, "Well, I need to flight back to Salt Lake and talk to Dave Evans." I flew back to Salt Lake, and I said "Here's what we want to do." And he said, "Let me introduce you to Bill Hambrecht," who he had worked with closely in Evans & Sutherland. I said well, "One thing is I reimplemented the Design System at PARC, but it is the Design System. If we need to start this company, I want to license it from you, because that's where the original work is." So we gave him a portion of the company to license the design system. We contacted Bill Hambrecht. Bill Hambrecht said, "If you can put out of business all of the financial printers, I will invest anything into you."

<laughter>

Brock: A revenge investment.

Warnock: A revenge investment. He said, "How much money do you need? Where are you going to start up?" And all of that stuff. We got a commitment for two million dollars. The first tranche was going to be one million. We said, "Okay. We'll do that." We tendered our resignation and left, and started the company December 2, 1982.

From the outset, we were going to essentially use PostScript as the framework. Now, the original company plan was to build workstations. The PC was just being announced and it was a lame machine. I mean it was really a teeny, green phosphored, lame machine. Sun Microsystems had reasonable machines.

We were going to build high end document production systems and do the software on both sides, and build the printers. But not physically build the printers, use printers and drive those printers. We borrowed a printer from Digital. They lent us a Xerox printer. We bought a PDP-10, I think, was the first printer we had. We used it in a timesharing mode. We had a Sun Microsystems machine that we built the interface to, and we started to code.

Brock: Was it at this point that you were able to, since it was, in essence, your project and Chuck Geschke's project, you could abandon the bitmapped font regime?

Warnock: Yes.

Brock: It was going to treat everything on that page as a geometry.

Warnock: But we hadn't solved that problem. <laughs>

Brock: Right. But you knew you were going to put the font problem front and center?

Warnock: That's right.

Brock: Would it be incorrect to think about, going from Interpress to PostScript, was essentially—while Interpress was a combination of these two idioms, the geometric and the bitmapped, with PostScript, you could make it all geometry.

Warnock: Yes.

Brock: That's a fair way to think about those differences?

Warnock: That's right. It's all mathematics.

Brock: Right. Then the challenge was to have a capability in the printer to be able to use this new language, and also an ability in the workstation to use that same language.

Warnock: Language, yes.

Brock: Yes, okay.

Warnock: Because the displays or sizes didn't work. Now, we hadn't solved—the bitmap problem for the printers was easier than the bitmap problem for the displays, because the displays are much lower resolution. How you pick what things to turn on and turn off is harder because you're at a low resolution.

Brock: Was your idea at the start of Adobe, when you were going to make the entire system, with the workstation, printer, screen, and everything, was that you would use the same language of PostScript to run the printer and run the screen?

Warnock: That came up later, with NeXT.

Brock: Okay.

Warnock: Now, the Macintosh— a couple of months in, so this would be, I would guess, I think it was—maybe Chuck remembers better. I sort of think it was in May of ‘83. Bob Belleville had gone from the Xerox group to Apple, and Larry Tesler had gone from the Xerox group to Apple. Larry Tesler was part of the Lisa machine. Steve Jobs called one day and he said, “Bob Belleville tells me you guys are doing great things. I would love to come talk to you.” In May, at that time, we had output. We could show stuff. The fonts were not great, but at that time I don't believe we had solved the font problem, but we could show stuff. Steve came over and, I think, he came over by himself. And he said, “This is fantastic.”

Then he brought over Bill Atkinson. Bill Atkinson had worked down, I believe, in San Diego on Evans & Sutherland machines. He had worked with the Picture System and he sort of was in tune with the procedural stuff. He gave us a high score with Steve. At that time Steve offered to buy the company. He said, “I would love to buy you guys.” We said well, we just started. Too early. We don't want to do that. But we can obviously go into a contract and build something.

He was telling us, at that time, about the Macintosh. He said, “And we also want to use the Canon machine as a printer,” because the only thing the early Macintosh had was a dot-matrix printer and no office in its right mind would use a dot-matrix printer. I think he aesthetically knew that. I think it was September we finally signed the contract, or something like that. We had been working very, very, very hard—we printed out all kinds of test pages and everything. Then, I had an idea. And Don Knuth had been trying to solve font problem for 100 years. If you talk to Don Knuth, he thinks he did, but he didn't.

<laughs>

The way he represented characters was so bad. He used complex variables. It was so hard in tech. He's a great mathematician, so no math is hard to him. But the math behind that. What I had learned from Utah in making geometry is if you want to describe curves, you use Bézier curves. You use the Frenchman's incredible work in the automotive industry to describe curves. We decided all curves are going to be Bézier curves.

Fonts at that time in the rest of the industry were using conic, conic sections. And conic sections aren't nearly as flexible or as compact or as precise as—they’re as precise, but everything has to be part of a circle. You need more than that, you need bends so you can do it. We decided early on that we were going to use Bézier curves, and so we hired a couple of people to start building fonts. We would have our kids come in and copy big copies of fonts. Then we would digitize them and then turn them into fonts.

Brock: Then match the Bézier curves to these outlines.

Warnock: Yes, digitizing tablets and everything. Actually, we had to do all of the font production. We had to sort of streamline this so that we could then—we started out with Times Roman and Helvetica. Because Xerox was so closely allied to the graphic arts and the printing industries, Chuck and I had a very strong feeling that it was worth your weight in gold if you could license the real thing. Now, you could have the same outlines, but if you couldn't call it Times Roman, and you couldn't call it Helvetica, the design community wouldn't trust it.

We went off to ITC [International Typeface Corporation] and we licensed their library, because they were in the business of licensing libraries of fonts. Then we contacted Linotype and they, "No way. No way can we do this." In the early implementations we started to show them samples. We said, "We can drive a 1000 spot to the inch typesetter, and we can drive it very effectively, and we can make these kind of images."

The head of engineering at that time loved that technology, and so did the guy in charge of marketing. They convinced [Wolfgang] Kummer, who was head of Linotype, to license us Helvetica and Times Roman. We got one of their early machines at 1000 spots to the inch. We were committed to making PostScript run on that machine. Now, no other printing protocol, none of the stuff at Linotype, none of the stuff Compugraphic, none of the stuff anywhere, was device independent.

Brock: That really shows the reach of the device independence—

Warnock: Yes.

Brock: —it can reach to the highest resolution or…

Warnock: The lowest resolution.

Brock: That dynamic range, if you will.

Warnock: The other thing, in the graphic arts, scaling things and blowing them up and rotating them and putting them around curves, in the graphic arts community all of those things are used on wax boards every day by graphic designers. They want total control over how the image is placed. If you have rules about where you can put things, it's not possible, so it's never, never, never going to address the graphic arts.

We got the license, and then we had to convince Steve to license the fonts for Apple. But he had Chicago. He had these little bitmap fonts that he had made for the Macintosh. We said, "No, Steve." <laughs> I said, "Those are cute, but they're not fonts. Get over it." We spent this long conversation from Germany convincing Steve, and said, "Steve, this is worth its weight in gold."

Brock: So, in addition to you licensing them he would have to license them, too.

Warnock: Yes. Essentially licensing the names, because the ones you use on the screen, they're close approximations.

Brock: Well, is it a copyright license?

Warnock: No, it's a trademark license.

Brock: It's a trademark. Is the trademark on the actual appearance of the text?

Warnock: It's the—"This is Times Roman." You're guaranteed to have this spacing, this shape of characters. It's like Coca-Cola. You can have Pepsi but it's not Coke.

Brock: Right. But I'm just wondering, if it were the case that you just got a standard set of one of their fonts, whatever it is, Garamond or something. Then digitize the outline, make it in Bézier so you have it as a digital font.

Warnock: You could call it "foo-foo," and that would be fine.

Brock: It would be fine. They couldn't say, "Hey, that's actually our font."

Warnock: Right, no.

Brock: So you're really licensing the names?

Warnock: That's right.

Brock: And it's because that's what everybody's familiar with.

Warnock: Well, and that was their value-add. All typesetters sold their type libraries that were specific to those type things to the printing industry. So, when you got Linotype you got Times Roman and Helvetica. When you got Compugraphic you got something else. Linotype and Monotype had these very, very valuable names—Garamond. Now, the other thing that's specific is the spacing, inter-character spacing. Technically, these are not important things, but from a marketing point of view and an aesthetics point of view, they're very important.

Brock: That's fascinating. So, the only way that these holders of these trademarks could stop you from doing something is if you actually called it by their trademark name.

Warnock: That's right.

Brock: But, in the industry, using that trademark name is a guarantee for the user that it's going to look this way, it's going to have this spacing. If I use it in this book, it's going to be the same, or this ad, it's going to be the same as the other ad. So if I'm concerned with my brand, or my book layouts, or whatever, I know it's the same thing.

Warnock: Yes.

Brock: Interesting.

Warnock: So, we licensed and digitized their fonts. The problem is if you just throw the outline at sort of the bitmap and mark the ones that are inside of the outline, it doesn't work. It really just doesn't work. What Don Knuth's approach was, "You have to look at the fixed outlined and you have to figure out what bits you want to turn on." I came up with a different idea. I said the right way to solve this problem is not to use a fixed outline but know what the resolution of the screen is, and stretch the outline, and pull the outline a little so that it lines up with the raster points.

Brock: And the raster points are—?

Warnock: Are the spots on the screen.

Brock: You're doing a transformation to move the outline so it matches up with the physical spots.

Warnock: Yes, but you're not just moving it. You're stretching it and shrinking it.

Brock: Right, do a transform—

Warnock: On it to be in harmony with the frequency of the bitmap.

Brock: Interesting.

Warnock: A very, very different approach than Don Knuth's approach. We have the X height, we have to make sure all of the outlines hit on the X height on a raster boundary, all the bases line up on a raster boundary, the top of the characters all line up on the raster boundary, the width of the characters last through on the raster boundary, the stems line up on the rasters. We figured out how to do that. Now, once you build the bitmap for that, you can move it anywhere.

Brock: Right, okay.

Warnock: You only have to do that once for each letter at each resolution and size. But you're doing it dynamically, you're doing it on the fly, and then caching the bitmap and then using the bitmap every time it occurs.

Brock: I get it.

Warnock: The first time we tried this, it just worked like a champ.

Brock: In terms of how it looked.

Warnock: Yes. It looked as good as any bitmap-tuned thing you could do. The other thing we noticed is that diagonal lines have a tendency to look higher—look fatter than they should. So, we would first shrink the outlines a little on diagonals so that, when you filled it up, it would appear smaller. We made test pages.

We showed those to Jonathan Seybold, and he couldn't believe his eyes. He said, "Really?" He said, "This—you have solved the problem," okay, "For laser printers." The first conferences we went to as part of Adobe were the Jonathan Seybold Conferences.[2] We mixed with the printing communities and the graphic arts communities. We weren't after the computer communities; we were after the graphic arts communities. Every time he saw this, when he would see test pages come out, where we could rotate type around spirals, and we could take images and shrink them and rotate them, he said, "This is revolutionary. This is going to change the world."

Brock: When you're talking about the raster points, here we're talking about for a laser printer.

Warnock: That's right.

Brock: But was it then the idea that you could also do the same mathematical transform of the geometry to also write it to—paint it to a screen?

Warnock: At that point, we couldn't, because screens were still too low of a resolution. Later on in the year, we got the contract with Apple. They announced the Macintosh in 1984. We worked on the LaserWriter, all around, until '85. One of our engineers, Dan Putman, worked very closely with the engineers at Apple to build the controller board.

Brock: To build the hardware that was going to run the PostScript.

Warnock: That's right.

Brock: In the LaserWriter.

Warnock: Yes.

Brock: And Dan Putman had been with—

Warnock: Adobe. He was at Xerox.

Brock: He was at PARC, too.

[2] Seybold Seminars. Added by Frances Corry, July 6, 2018.

Warnock: Yes. Yes, he was one the hard—

Brock: And then joined you.

Warnock: Yes. He and Bob Belleville designed the hardware board that was going to go into the LaserWriter. Now, most people don't know this, but the hardware board that went in the LaserWriter was the biggest computer Apple ever built.

<laughter>

Warnock: It's staggering. It had, I think it had a—500 megabytes of masked ROM. The code had to be burned into masked ROM.

Brock: Right.

Warnock: It had 500 megabytes. I think it was either a megabyte of masked ROM or half a megabyte, but it was the largest masked ROM outside of NASA that had ever been burned. <laughs>

We also had hired Ed Taft, who is probably one of the best programmers that ever walked the Earth. And we said, "Okay, we are going to spend all year beating up on PostScript trying to break it, doing everything we can to disrupt it. We have to put in mechanisms so that if we find a bug, we can patch it in RAM with a download or something like that." We would beat the hell out of this machine.

I was mostly the test guy, and I would build random geometric problems and throw it at it. It went through just an extensive debugging cycle. In the fall before '85, we showed it to Jonathan Seybold, and he just said, "This is going to just change the world. It's going to change the world." We've got it now. When it came to the announcement, the cost to build the machine was seven thousand dollars.

Brock: The cost to build the laser printer.

Warnock: Yes, and the controller. Steve was going to price it at seven thousand dollars. His analyzing staff said, "You are crazy." Everybody said, "Steve, you are crazy. This is total idiocy. You can't announce—" even though the printer could be shared, and it had AppleTalk between it, "This is crazy. How can you sell a printer for seven thousand dollars, that cost seven thousand dollars?"

He said, "Don't worry. The price of memory is going to come down." He pushed it through. It was announced, and he, unfortunately, hired [John] Sculley. They had the palace coup later on in that year and got rid of Steve. But because Paul Brainerd had been exposed to it early, he had written a piece of software; he had written PageMaker.

Brock: Right.

Warnock: Between PageMaker and—we didn't have any software at that time. Although it was in '86, I think, that we started to announce Illustrator. They had the normal Apple software that was interfaced into the LaserWriter. So, Paul's program took off.

Brock: Now, was it the case that for something like the Macintosh applications or the Aldus PageMaker, —in the application software, did they have to do something to it so that it could speak PostScript, or was that in a separate kind of driver that would be installed?

Warnock: They essentially had a system of QuickDraw commands that interfaced the application to QuickDraw. What we did is we wrote in PostScript QuickDraw emulators. We would write a little PostScript routine to take the QuickDraw command and turn it into its PostScript equivalent.

Brock: So, you built kind of a translator between QuickDraw into PostScript?

Warnock: Yes, and you download the translator and then just feed it QuickDraw.

Brock: Okay so, that's all that's on the person's Macintosh is this—

Warnock: Yes, QuickDraw and some interface stuff.

Brock: How would that get on somebody's computer?

Warnock: Oh, it came with the operating system.

Brock: It came with the operating system.

Warnock: As soon as the LaserWrit—yes.

Brock: Interesting—I was puzzling about that. It also strikes me that—having this very powerful computer inside the laser printer to be able to contend with this geometric language—it sounds like, it reminds me of the harbor pilot simulator in that you have these gigantic, however many, half a dozen, gigantic racks to run the projector. Then a PDP-11, or whatever it was—

Warnock: Yes.

Brock: —feeding the commands. It's the Macintosh to the laser printer is kind of like, this PDP and that—

Warnock: The first printer shipped was actually by QMS. That was shipped in '84, late '84. It was a PostScript printer. That, we could drive with Sun Microsystems machines and stuff like that. PostScript printers, from a marketing point of view, Apple wasn't the first.

Brock: I didn't realize that.

Warnock: No, QMS was the first.

Brock: Interesting, and QMS was, forgive my ignorance, they were a printer company.

Warnock: That's right. They came along. Also, at that time, obviously Linotype had—we were starting to—now, essentially, it's the same controller that can drive the Linotype. You have to buffer the bitmaps in a different way, but it's essentially one thing because it's resolution independent. It doesn't care about resolution.

Brock: Right.

Warnock: So, we also got deals with Compugraphic. Let's see, we also got a deal with Apollo, with DEC [Digital Equipment Corporation]. The various printer manufacturers and computer manufacturers for Sun and everything else were falling into line. The Macintosh came out, and the LaserWriter came out, and then we started talks with IBM. In '86, IBM signed the contract, and Hewlett Packard said, "Game's over." Then Hewlett Packard started to license PostScript.

Brock: When, let's say if we have these two kind of classes of customer, if you will, computer manufacturers, printer manufacturers. On the computer maker side, was it the case that what was involved there is they were buying software that they could integrate in their operating system so—in the same way that with the Mac it could—there was an interpreter or whatever that could take—

Warnock: No, the only people who drove it directly I think were Apollo, or Wang—maybe Wang drove printers directly. They had dot matrix printers and stuff like that. They weren't great printers. IBM, in that time, was in the printer business.

Brock: Okay.

Warnock: They licensed for the printers. And Hewlett Packard had the Boise stuff; so, they were in the printer business. The Japanese started to come on board. The world was starting to build software with PostScript drivers.

Brock: Okay. That's what they were licensing.

Warnock: Yes, and Microsoft said, "We have to have a PostScript driver." They would change Word. They would change Excel. They would change all of their software to have Post—actually, Microsoft was one of the first.

Brock: And their applications would essentially send—

Warnock: PostScript.

Brock: PostScript directly out of Word.

Warnock: Yes.

Brock: To whatever printer.

Warnock: That's right.

Brock: Interesting. That's what I couldn't figure out, if the application makers—

Warnock: We were friends with Charles Simonyi, and he was head of the Word group. The first time we sent him PostScript, he said, "We'll drive that." No, and I mean that was a really, really important thing.

Brock: Yes.

Warnock: From the PC side of the world.

Brock: I'm sure. I guess I'm wondering how in that choice, on the other side of the table, for the people who were creating application software, how big of a decision was that to code their applications so they could speak in PostScript?

Warnock: I think it was infinitely easier than doing the old printer protocols.

Brock: Okay.

Warnock: You have all the same things you had in the printer protocols, but you could place anything on the page in any order. You didn't have to have it in order. You could send any orientation you wanted whether it was landscape or—so, building PostScript drivers was really very nice.

Brock: Was that something that they would all do on their own?

Warnock: Yes, most of them.

Brock: Okay.

Warnock: They could consult. We spent an enormous amount of time in the first year documenting it, writing the first PostScript manual and saying, "Here's how you do it."

Brock: Okay.

Warnock: Taft was in there, and we—I did all the example pictures on the thing, and I did the explanations of how things work. Taft and they all proofread it, and we produced it.

Brock: I was interested recently to learn that—I had known about Tom Malloy's association with Charles Simonyi and working on Bravo, and then of course his long association with Adobe. But what I hadn't realized is that he had gone early over to Apple and been involved with Lisa and LisaWrite—

Warnock: Yes.

Brock: —and all of that. Was he in Adobe's contracting relationship with Apple? Was Tom Malloy—

Warnock: No.

Brock: That was a separate—

Warnock: A separate thing.

Brock: Okay.

Warnock: We had Doug Brotz. Doug Brotz was the one who implemented the font technology. We had Bill Paxton. Bill Paxton figured out—so, there was a very famous conference in 1989 when Apple teamed up with Microsoft to say they were going to bury us. Okay and so, Steve—not Steve. Steve was with NeXT. Whoever the guy from Apple was, it might have been Jean-Louis Gassée, but anyway, he got up with Bill Gates, and they said they're going to bring out their version of PostScript, and build their own printers, and bury us. I thought that was garbage. I didn't think that they could do that. Steve didn't think they could do that, he was with NeXT.

Brock: Right.

Warnock: We had the wars. They said, "Well, we have TrueType. Everything's going to be done in TrueType because type A fonts from—Type 1 fonts from Adobe are obsolete." What happened is, I've been quoted, I went back to Adobe, and I said, "We're going to out-invent the bastards." Bill Paxton figured out how to modify the font code to work on screens.

Brock: Okay.

Warnock: He did enormously difficult work in figuring out what bit—he did a combination of the Don Knuth approach and our approach to figure out just exactly how you shrink letters and have them contain readability. It even worked for Japanese and Chinese. Then, we came out with ATM, Adobe Type Machinery.

Brock: Right.

Warnock: I don't think Microsoft ever shipped a printer. They may have shipped one or two. But they never survived. We got all of that stuff working on the newest machines, and it worked like a champ.

Brock: In essence, that was when you really were able to use this geometric language to capture both the page and the screen.

I did want to come back to this Display PostScript idea. In one source that I was reading to prepare for today, it suggested that, unless I'm misremembering the story, a request for a Display PostScript was part of even the initial dealings between Adobe and Apple, that Steve Jobs was asking or demanding or whatever—

Warnock: Yes.

Brock: That you produce a Display PostScript.

Warnock: Yes.

Brock: And that after Steve Jobs' departure from Apple, that that project was kind of shut down or something like that.

Warnock: Jean-Louis Gassée's mentality was he wanted to have nothing to do with Steve's decisions. He wanted to be the new Steve Jobs.

Brock: Okay.

Warnock: Anything Steve had been associated with, Jean-Louis wanted it gone. Obviously, the relationship with Adobe, that was a Steve's thing. He wanted it gone. I mean he was rude. He was not terribly smart. But that was him.

Brock: Okay. Had you thought of a Display PostScript?

Warnock: Oh, yes.

Brock: Okay.

Warnock: Yes, we were saying, "This makes a natural thing to drive the displays," especially since Paxton was getting close on the display. The font problem is really a hard problem.

<laughter>

Warnock: The models for scaling and transforming, you see it in Illustrator. You can do anything in Illustrator. So, it proceeded along. PostScript essentially became a standard in the formal sense and in an international—government standard sense and in other ways. We had started to build Illustrator.

In 1989, we got exposed to Photoshop. That story is unbelievable because what Bob and John Knoll showed us was a one bit per pixel display Macintosh, 512K Macintosh, that sort of showed photographs.

There was no printing architecture behind it. What they had built, is they had built a really good virtual memory system to manage photographs. The largest hard drive you could buy for a Mac was 20 megabytes. You could hold one picture.

<laughter>

Warnock: You could hold a picture! There was no color. They sort of had the architecture in there for color, but they didn't have color. They showed us this little toy. They had been shopping Photoshop around, and nobody did it. I said, "You know, memory's going to get cheaper. Computers are going to get faster. Photographs are going to become an important part of this." There were no scanners. There was nothing. No cameras! There were no digital cameras. We licensed it from the Knoll brothers. And the world's changed.

Brock: Keeping with PostScript and Display PostScript, we could talk about how the focus of your efforts in Display PostScript shift over to NeXT, essentially follows Steve Jobs, which would be what? This is around 1986/7?

Warnock: Well, it never—I mean they had access to the code. It was never a big part of the business because NeXT never really got to the size where it was. The next huge, significant thing was, all around Adobe, the wide area networks and the local area networks were becoming prolific. Even in the early days of IBM, when I worked on 7044, 7040s, 44, the problem of document communication always came up.

The standard approach in those days was to try to use an SGML [Standard Generalized Markup Language] representation for documents. SGML said, "Gee, if you have an SGML representation, then by changing parameters, it can reconfigure itself into something else." In other words, you can reformat the document. It wasn't procedural in any way. It was sort of tagging language to tag paragraphs and tag things.

Brock: I got it, the style sheet.

Warnock: Style sheets, yes. It was a style sheet thing. In 1990, the Internet and the web were at the very beginnings. '94 was really the threshold when the web became a real thing. But in '90 and '91, we had local area networks and wide area networks. PostScript could be used, and more and more sites were using the PostScript files to communicate documents from point A to point B. From a technical point of view, that's problematic. The reason it's problematic is PostScript's a programming language, and it's really a bad idea to send programming languages around the network because of security, and especially PostScript because you can redefine operators.

Brock: And what would that—?

Warnock: You can build backdoors.

Brock: Okay. It's a security concern.

Warnock: It's a security concern. The other thing is that it just is not a great document representation because of the old Interpress concerns that there isn't page independence. In other words, one PostScript program that's this big can generate a thousand pages. That's a not great representation.

So, I had an idea. The idea was: what you should do is you should redefine the PostScript operators at the very lowest graphic levels, so that rather than doing the graphic operation, they write themselves out into a file. For instance, if I go, "10, 10, moveto," what I write to a file is "10, 10, moveto." If that's in a loop, then every time the loop goes around and it hits the move to command, it writes out, "10, 10, moveto."

What you can do is you can take all loops, and you can flatten them. You can unwind them. You can take all if/then statements and resolve them. The only thing that you're ended up with is graphic commands. Show commands, moveto commands, fill commands. You take all the graphic commands, and you write them into a long linear file. Now, if you take the font commands, and you capture the fonts, then you have one linear file that describes the document perfectly geometrically. But it has no control in it. There are no control statements in it. That's what Acrobat is. That's what PDF is.

Brock: I spent a long-time puzzling about the difference between a PostScript file and a PDF file to prepare. This was the kind of way that I came to think about it, and I wonder if it's right. It's almost that you take a PostScript program, and you, in essence, run that program.

Warnock: That's right.

Brock: And it's generating all of the operations that that program is dictating. Then you just have a list of all these steps—

Warnock: And the pages are independent. There's a list of commands for each page, and they're all independent, so if you wanted to print the other thing—

Brock: Oh, because the program is saying page one, page two, page three. And so, the commands are here's the new page.

Warnock: Yes.

Brock: Okay.

Warnock: You got page independence. Now, the other trick in it, is that architecturally—so, I wrote this Camelot paper, and I said, "This is how it's going to work." Then Bob Wulff and his team built a first prototype, which worked. I said, "Throw away all that code." We're going to take the best systems architects in the company, and they are going to define a data structure for PDF that is extensible, that you can add media types to, that you can link, that you can find out static information about the file that you need to know. Everything to make it bulletproof, to make it so that if you build a PDF file, it will live anywhere.

Peter Hibbard did this work, and Ed Taft. Oh, excuse me, also—what's his name? Cohn, Richard Cohn. Primarily, Richard Cohn and Peter Hibbard did the architectural structure. The first prototype code, I said, "Throw it away. Redo this so that this is going to be bulletproof." And then since then, because PDF is used probably by more than any other program in the world, they had to what's called sandbox it and put it under a security wrapper. We had one bad hack of Acrobat. Then we fixed that bad hack of Acrobat, and now, it's sandboxed. We haven't had a problem since.

Brock: Was it a hack of a PDF file that did something—?

Warnock: Yes, something nasty.

Brock: Malicious?

Warnock: Yes.

Brock: It was some way somebody had figured out a way to—

Warnock: Backdoor it.

Brock: Interesting.

Warnock: Well, by overusing a resource and having it crash the machine, or by overusing resources, doing stuff like that.

Brock: Okay.

Warnock: Engineers after engineers after engineers have worked on the Acrobat implementations.

Brock: It must be quite incredible to see the PDF/A format is the—for the National Archives.

Warnock: Yes. No. The early days, in 1993 I think it was when we announced it, I went to talk to IBM. They didn't get it. I would talk to all the consulting groups. And they said, "Well, what would anybody use this for?" It's evolved—I'd love to meet those people again.

<laughter>

Brock: In some ways though you had the advantage of, through the ARPA community and then through PARC, you were living in a networked computing world for longer than—

Warnock: Everybody else. Yes.

Brock: I mean it seems to me that that's really the context in which it made sense to you and then has come to predominate. <laughs>

Warnock: Yes, if you look at the proliferation in all the document manipulation… I mean, we always knew that electronic documents would become prevalent and eventually even penetrate into the legal profession and penetrate into the medical profession and penetrate into the various professions. But I don't think we had any idea of the scope that it's sort of reached.

Brock: I think I read somewhere that you had done a version of this flattening earlier on in the context of making—doing a PostScript demo or something?

Warnock: Yes.

Brock: Could you tell us about that?

Warnock: I hand-coded in PostScript a picture of an IRS—1040 IRS form. Hand-coded it. It had loops in it to make dashed lines. It had all kinds of stuff in it. I took the demo, and I said, "Steve, when you're up on stage, here's the demo." The demo took two minutes to print. Steve said, "No, can't use it." So, I went back and I redefined the operators to flatten the file, and rewrote out the file. It executed in 30 seconds. Steve said, "Oh, that's fantastic." That happened in 1985.

Brock: Wow, that early?

Warnock: Yes, well it was for the first demo of the LaserWriter.

Brock: Oh, really? And to print out an IRS form.

Warnock: To print out an IRS form. I wrote down a note that, "You really can use this trick." And that's what the Camelot paper says: you can use this trick to flatten a file and make it go much faster. It has all the right architecture. It doesn't need the same kind of rendering stuff as PostScript does. So, there are Acrobat—printers that just need Acrobat.

Brock: After doing this reading and then looking at Illustrator, it almost looks like a direct way to—

Warnock: Generate PostScript.

Brock: Yes. It's like a graphical user interface for PostScript.

Warnock: It is.

Brock: Could you talk about where the idea came from and—?

Warnock: We knew we needed a drawing program. I said what we really need to do is give the basic operations that are in PostScript to draw Bézier curves. You need to be able to draw Bézier curves and control those. You need to be able to draw squares and all that, fill it with photographs, fill it with anything you want, and take the PostScript imaging model and just expose it to a screen/user interface. Mike Schuster is the one who wrote Illustrator, brilliant programmer. It's gotten more sophisticated. I don't know that a graphic artist in the world that doesn't use it.

Brock: How long did it take to develop?

Warnock: He had a first prototype probably in a year—six to nine months? Because I remember we would take it and demonstrate it on a Mac. I made some of the early illustrations. I'll send you an early illustration I did in Illustrator.

Brock: That would be great.

Warnock: You go to a Seybold conference and you say, "Really? This came out on a computer? How in the world did that happen?"

Brock: I saw a couple of examples of sort of this very complicated geometric figure that you made. I think it was called "the Death Star for pushing on." Was that for pushing on PostScripts?

Warnock: Yes.

Brock: Was that something that you enjoyed doing, trying to—

Warnock: Yes.

Brock: Push these to the point of breaking?

Warnock: Yes. Yes, because it turns out that if you try to implement PostScript, and you use—you might be tempted to use floating-point numbers. You might be tempted to use them. But floating-point numbers have restricted precision. If you don't want bugs, you can't do that.

Brock: To avoid bugs, avoid floating-point.

Warnock: You have to use two-word integer fraction portions to drive all the mathematics. The mathematics has to be precise because when you're computing intersections of lines, it can't be off a little.

Brock: Right, for a geometric description like this.

Warnock: For geometric descriptions. You have to be very, very precise. Otherwise, you introduce bugs. Doug Brotz and I went through all of this together.

Brock: Where you might be able to get away with it in a bitmap world, right, because it has a—

Warnock: Yes, granularity to it.

Brock: What was the market reaction for Illustrator?

Warnock: It took off pretty fast. It was only on the Mac. Then we came across—this is a whole other world—I can come back for a whole other world.

<laughter>

Brock: Yes because there's the—well, there's so many applications to talk about and also so many questions about the just incredible growth of Adobe in terms of its revenues and head count in this first decade. I mean it was truly—

Warnock: The other thing were the business decisions along the way, and actually how code is written at Adobe versus, say, Microsoft or Aldus, or what the architectures are, and why we can do some of the things we can do.

END OF THE INTERVIEW

