David Cochran Oral History

Interviewer: Charles House

Recorded: November 19, 2010
Mountain View, California

CHM Reference number: X5992.2011

Charles (Chuck) House: I'm Chuck House. I'm with the Computer History Museum. I've been on the board here for quite a while and we're putting together the computing timeline, 2,000 years of history. Going to start with the abacus and things like that. I've got Dave Cochran here from Hewlett Packard, the key inventor on the HP-9100 and the HP-35 and we're going to have a discussion today about the [HP-]35, probably one of the seminal products of American ingenuity, I think, in all of computing history. And Dave, we're delighted to have you with us today.

David (Dave) Cochran: Thank you. I like being here.

House: What I'd like to do, just to frame the discussion, we'll talk for probably an hour and a half. I've got a series of questions. I think you've seen most of them ahead of time, but what I'd like to do to begin is just get a quick sense of how you got into engineering, got into electronics, why you joined HP, and a couple of the projects that led up to when you joined the HP-35 project.

Cochran: Well, I'd known about Hewlett Packard Company for some time, as I grew up in Palo Alto. I had actually driven David Packard's car. I don't know if he knew it at the time, but he had donated his car to get out the school board vote and loaned it to my father who said, "Hey, you want to drive?" At 15? "Hey, yeah, sure." So my father was on the loudspeaker and I drove. And then about a year or so later, I was working during high school, during the summer, on a construction crew as a laborer and spent a couple of days, I was assigned to work on David Packard's house. It was his first move, I think, from the Addison address and moving up to Los Altos hills.

House: Was that the Taaffe place?

Cochran: Yes. But Hewlett Packard Company was pretty well known and so I thought, "Well, gee, if I needed a job, maybe work part time there while going to Stanford or something like that." Instead of going to Stanford;; although I had registered or indicated my intent to go to Stanford, growing up in Palo Alto, the Korean War started. I said, "Hey, this is my chance. I missed the big one." So I joined the Navy. And when I took the exam at the recruiting station, they said, "Oh, you did pretty good in electronics. Do you want to go into electronics? Do you want to go to electronics school? You want to be an ET?" And I said, "No, what's that?" They said, "Well, that's where you fix radios and stuff like that." And I said, "Well, gee, I had difficulty getting my crystal set working when I was a boy scout." But they said, "Well, it's nine months' duty here at Treasure Island, 30 miles from your home." I said, "Okay, I'm in."

House: I like that.

Cochran: And up till that time, I had been very interested in mechanical things, particularly cars. I had rebuilt a '29 Chevy, my first car, and I learned a lot. But I really enjoyed working on mechanical [things]. And then after going to the naval school, then I got very interested in electromechanical [things] and then when I got out of the Navy and started Stanford again, I started from scratch, but I already had a leg up in electronics, so I said 'electrical engineering.' They gave me some advanced credit and I combined my mechanical interests with the electronics and what I'd learned in the Navy and four years of training and actual practice. But at the end of the first year, I'd run out of money. I already had a family by then, and so my hat in my hand, I go over to Hewlett Packard Company. It was down on Page Mill Road, 395 Page Mill Road, as I remember. The old saw-tooth building, and I applied there for a summer job, and I got hired. It was about a couple of hundred employees, maybe 300 or 400.

House: This would have been ’55, ’54?

Cochran: That was in 1956, because I started Stanford in ’55.

House: Yeah, I think they built that building in ’54.

Cochran: I think so. Yeah, it had been there for a while. I started out on a production line, testing wave analyzers, the 300A. Hewlett Packard, at that time, they were the most ethical company, already had a tremendous reputation, and we were doing hand-calibrated dials. You didn’t just stamp them out and put them on and try to tune them up. You hand calibrated all of the fiduciary marks for each of the frequency settings. So we would tune a frequency, do a pencil line, tune another and do a pencil line, tune another. And then we would send those dials, we’d put the serial number of the equipment on the backside, send those dials to the engraving shop, which would then put [on] the straight lines.

House: So every dial was independently calibrated.

Cochran: Every dial on that 300A wave analyzer was independently calibrated.

House: For crying out loud, I had not heard that story.

Cochran: And the wave analyzer actually had Hewlett’s oscillator in it. Not at the time, the impact didn’t really hit me, but it did later when I tried to transistorize his oscillator to the 204B.

House: Did you do the 204B?

Cochran: Yes, I did.

House: Hey, boy you did some nice projects.

Cochran: Well, but I was in the right place at the right time. So then, working summers, that first summer, then I was going to go back to school. I asked them, “Is there a way that you can let me work half-time?” And Hewlett Packard, even in the early days, it was kind of a mom and pop shop. They said, and I forget who I asked, but they said, “Oh yeah. We can schedule the work so that you just work and do this type of production, and the rate of that production seems to fit a half-time schedule.” And I’d draw half-time pay, so that was fine. So they accommodated the individual. You’ve talked in your book about the value of the individual at Hewlett and Packard, to them personally.

House: So there's living proof it worked.

Cochran: Absolutely.

House: You had a family. That was a godsend almost.

Cochran: It was. My brother, my younger brother, had already been at Stanford for a couple of years, and he helped me plan out my program so that I took all of my labs my first year. And actually, my third quarter, I took my sophomore courses in my prerequisites for engineering, so at the end of my first year, I had more than 60 units of credit. I only needed 180 to graduate. I averaged 20 units per quarter. I had to get special permission and so on, but from then on, I only had to go to school in the mornings, so now I had the afternoons free and I would work from 1:00 to 5:00. So four hours and it just fit, and it was perfect. Then after three or four months, somebody in the lab-- and it was just one laboratory at the time-- had recognized my work, or had come out and seen me, and knew I was working towards my degree in electrical engineering, and asked if I wanted to be a lab technician, kind of a junior engineer in the lab. Boy yeah, sure. Why not?

House: Who was that, do you remember?

Cochran: Bruce Wholey and Ralph Lee were involved, and so was Jack Petrak. And then I was assigned to Ted Anderson and that's a different story. Actually, there was a new fellow also, joined the lab about the same time I did as a junior engineer to, and that was Len Cutler. I think by that time he was getting his advanced degree, but he could only work part-time. I was assigned to a digital voltmeter. Not the 3440. I think it was the 205 digital voltmeter-- 405.

House: Yeah, 405 AR.

Cochran: Yes.

House: Was the first one we did. Ted wrote the journal article on it.

Cochran: Right, right. It was the 405.

House: It didn't do very well. It didn't sell very well.

Cochran: The design architecture was probably antiquated________ -- there wasn't a "gotcha." There wasn't a step forward in that. But it did train me for later, doing the 3440, which was the fastest--

House: Oh, that blew the doors off.

Cochran: Because there, I learned on that first project how to-- there was an easy way to design. You just take what's done or do it the easy way, and whatever fits. Or there's stretching, and if you reach out, and I'd like to talk about that later with the HP-35, everything we reached out. What was the hardest thing on the HP-35?

House: Everything.

Cochran: Everything. So my first project really, at that time we were just feeling our way, and I really didn't understand the concept of 'stretch goals' and so on and so forth.

House: That's an interesting point you make. HP, I think, never succeeded when it didn't stretch.

Cochran: Exactly.

House: And what the company learned relatively early seemed to me, was that stretching was always the way to do it.

Cochran: But unfortunately, the company learned it and learned it, and learned it.

House: It's one of those things you tend to forget or hope you don't have to do.

Cochran: Well, and there would be new people in place, and HP was in constant flux, for the most part. I was there 25 years and it was always a new bunch of people who would come in and it was re-organized. There was a lot of re-organization, and unfortunately, Hewlett and Packard, the epitome of their personalities, could not be rubber-stamped into the various divisions. And when they got involved, things did happen. I remember a note, we were doing oscilloscopes then in the saw-tooth building and somebody walked through on a Sunday and wrote a note on an oscilloscope and said, "We're not going to build prototypes. You can twist up with one hand."

House: I remember, that was that Clement package, wasn't it? And Packard just twisted it in half?

Cochran: Yeah, that was Packard, that was à la Packard, yes, because when he'd get involved, he would say things, or Hewlett too. It was wise to listen, because they could look at something, and they were both very, very different. I knew them both personally and I even carpooled occasionally with Hewlett. I lived across the street from him for a while.

House: Say a little bit about each of them, because you knew them probably better than almost anyone alive.

Cochran: Well, it's very interesting. Hewlett would have never really had to work. He was born with a silver spoon in his mouth. His father was head of the Stanford medical school, and they lived in San Francisco. Then his father died when Hewlett was about 16 and his mother took him to Europe for a year or so, he came back and then started at Stanford, and as I understand it, really struggled because he was dyslexic. But you never knew that when talking to him, because he was an engineer's engineer, and he could look at your work and he could talk to you about it, and you could reason with him. You could tell him why you did things a certain way, quite a bit different than our vice president of R&D, Barney Oliver, who usually spent an hour lecturing to you on first principles on what you should have done. Now Packard, Packard was just a tremendous guy, a tremendous personality and it was interesting. Packard could walk the length of the building and in half an hour's time, tell you everything that was wrong and tell you what you were doing right. But he could tell you, "Hey, you've got too much inventory, you've got too much work in process, you've got this. This machine is out of tolerance." He would just listen and talk a few minutes to one person, the next and so on. He had that ability, the business sense, and we got a chance to see the differences when David Packard went off to be deputy secretary of defense under Laird, with Nixon. So he had to divorce himself totally from the company and I've got a little story to tell you. He came back for a visit, and even though he divorced himself, he brought this admiral back and was visiting. It was late at night at the Cupertino Building and we were assembling our first production run of calculators. There was a turn-on problem with the calculator. One of the problems with semiconductors is you do all this logic. Any logic, sometimes they don't turn on in a right state, and you have to design them so that they do sequence into the proper state. These didn't, so we had to put in a pull up resistor to make sure it would turn on in the right state. I was soldering these resistors. We had about 30 of these calculators and I was soldering these inside there. And here comes Packard with this admiral, and since I'd been in the Navy, I didn't know whether to salute or shake hands or what.

House: Oh, Dave!

Cochran: He's introducing him to me and saying, "This is Dave Cochran. He's the inventor of this." I felt so humble and everything. But anyhow, after Packard had been in Washington for a couple of years, Hewlett Packard, the company, there was a recession. All of a sudden, Hewlett Packard was thinking about going out and borrowing money from the Swiss banks, or something, floating some bond. Hewlett Packard had never done that. And then sales were slipping, growth and so on. That's when Hewlett grabbed something that should have gone down in history as momentous. He says, "Okay, we've got to cut production by 10 percent." Now one way to do that, lay off 10 percent of the people. Instead, he says, "Hey, everybody's going to take every other Friday off, and we're not going to pay you for that." That's fair, isn't it? "We're going to do that from the board room all the way down."

House: That was Bill, not Dave.

Cochran: That was Bill. Bill made that decision. It was just a different approach to do things.

House: What was the mood of people to that idea?

Cochran: From my perspective, it was welcomed.

House: Nobody has to worry about their job.

Cochran: Nobody had to worry about their job and the belt tightening. For the guy that loses his job, he's got to tighten his belt 100 percent, whereas you take 10 percent, and particularly since Hewlett and all the vice presidents were taking the same cut, they might have even taken more, I forget, but it was a shared thing. That was the family. I remember before HP-- I'm sorry for this aside-- before HP had any health insurance, there was no health insurance when I joined in 1956. One of the fellas got tuberculosis, one of the people on the line. He went to a sanatorium and his paycheck kept being sent to his home.

House: Is that right?

Cochran: While he was-- yes. And he's still alive today. I saw--

House: Is that right? Living, breathing proof of the HP Way, huh?

Cochran: It really was. And you know, Hewlett and Packard's secretary was the head of HR at the time too, I think.

House: Is that Anne Laudell.

Cochran: Ann Laudell, yeah. So she was everything. I remember the discussion that Hewlett Packard is going to have a health insurance program. Well, and that must have been 1957, '58, '59, something like that. So it was the early days.

House: That's a nice digression. I appreciate that. Let's come back to the 3440, now. Was that your next project after the 405?

Cochran: I don't think so. I think I did the 204B.

House: Okay, sure.

Cochran: So I think Jack Petrak was my boss at the time and said, "Hey, Dave, I'd like you to take the light bulb out of Hewlett's oscillator, and see if you can transistorize it." Because transistors are the coming things, so we were using discrete transistors. I remember taking a class from Irwin Wunderman in the basement of the 395 Page Mill Road on semiconductor theory. Now this wasn't even being taught at Stanford yet.

House: Yeah, '58, '59, it wouldn't be.

Cochran: Yeah, that was in ’56, ’57. It was just when I started, ’57, yeah. So he’s describing all this, and then I started trying to take some courses at Stanford, but I was still an undergraduate. Anyhow, but I didn’t start on the 204 until I had gotten my degree. So now, hey, 1958 I had a degree. Now I could design things. I think it was the first project after I got my degree. I worked on the 405 digital voltmeter as a technician, as an assistant to Ted Anderson. But then transistorizing the voltmeter, I was trying to duplicate the characteristics of Hewlett’s light bulb, and the more I researched that and read about it, the more astounded I was that it was so simple, but it was so exactly the functionality you wanted. It would have been hard to have said, “These are the characteristics I want: I want the negative resistance, I want this, I want that,” and so on. And it all worked at the amplitude levels and so on of the whole oscillator. And to try to duplicate that, oh, I tried to use different light bulbs, you know, grain of wheat light bulbs and so on, to duplicate that characteristic. And finally, I ended up by making some soft diodes that actually performed a clamping action in the feedback loop. And when I say soft diodes, I added resistance to make them--

House: Were they zeners [a special type of diode] in your break points?

Cochran: No, I just put--

House: Regular diodes.

Cochran: Discrete resistors on regular diodes.

House: So you used them as shaping diodes.

Cochran: A little bit. And I had a choice between if I made the hard clamp diode, I’d get much more stable, but then if you looked at the wave form on an oscilloscope, you’d see this little tick.

House: Click, yeah.

Cochran: Little blip out of it, little notch out of it. So I balanced that against the distortion. But I was able to do it, I think, five transistors of the whole thing. And doing that, I learned a lot.

House: I’m just sitting here in amazement, because I know some of the creativity that you put into the HP-35, and the question is, have you always been this inventive sucker? And the answer is, it developed.

Cochran: It developed. And what I used to tell people, if your circuit works the first time, you didn’t learn anything.

House: Yep. Isn’t that the truth?

Cochran: And I remember one poor fellah, he wasn't in the lab very long, but anyhow, he built this circuit and it used to be kind of haywire. We'd solder resistors and transistors and capacitors together. You'd built it up and it didn't work, so he pulled out a hammer and just smashed it flat and started all over again.

House: Is that right? Yeah, he wouldn't last long.

Cochran: One of the things that I found out was how I drew a circuit schematically was how it might lay out on a printed circuit board. What I had to do, when I first realized that, the transistor had, you know, the emitter gate and source-- what was it? A collector, a base and an emitter, that's right. I got mixed up now with MOS, which had two sources. Anyhow, and they were in a certain triangle pattern. When you laid out the printed circuit board, you didn't want that trace.

House: Yeah, exactly.

Cochran: And that trace, you didn't want it to have to go through those legs, because then it might hit one of the others. So what I did was I had to turn my circuits upside down and have ground at the top and the power supply down at the bottom.

House: So you're a graphical, spatial thinker.

Cochran: That's right. And actually, somebody wrote a paper on that, on me. From Princeton, they did a study. I think I sent you a copy. My thinking ability after I'd been in a few publications, they wanted to know, and I need to visualize it. So it was along the way that I learned things. You don't learn how to invent. You invent, like I said earlier, by stretching, by "I have a goal." So anyhow, on the HP-204B, the oscillator, that was really good to teach me how to use transistors, how to lay out printed circuit boards. I got very involved in that. I got involved in every aspect of the design.

One of the problems, I wanted to make the tool for, the whole purpose of making a transistorized oscillator was to make it smaller than the big one with the large tunable capacitor. So HP had a division, or one of the departments, that made these variable resistors. And so I replaced the tunable capacitor with a variable resistor. At first it looked like the resistor would chatter a little bit. As you rotated the frequencies, you'd get a variation in the amplitude, but we smoothed that out. But then I had a linear resistor. If you look at the design of a variable capacitor, just because of how it's a place in gauge, it's nonlinear. And remember, I'm making an RC oscillator with a fixed capacitor, so different equations. The other is an LC oscillator with a variable capacitor. Hewlett's oscillator had a fixed R and a variable C. So what I had to do was non-linearize the resistor motion. So I went to one of the mechanical engineers, and he says-- his name was Knut Scarpus . He says, "Why don't you try this exponential spiral?" and I said, "What's that?" And so what he did, he drew an exponential spiral and then he drew another one. Then he laced it with some tuner wire that was just a phosphor bronze rope. It was very small wire but it had strands, 15, 20 strands and it was covered with plastic. We could wrap it around, and so as you moved one, the other one moved. So it kept the centers the same, but yet had the action was transferred between these two exponential spirals.

House: Elegant.

Cochran: It really was. It was just super. We did that.   First we tried it, he says, “Oh look it, there’s gears that do this.” I said, “Gears? Gosh.” He said, “We can replace it with this little wire rope,” and make it with this dial cord essentially. So we did that, and then linearized the dial of the 204B. We made the first one with a nonlinear dial; it was just useless. We said, “That would have been the easier way.” Remember I said earlier? So how do you accomplish it?

House: That’s a great combination of your mechanical and your electromechanical and your electrical background.

Cochran: But I also go to others and ask advice. I beg, borrow and steal, like crazy.

House: Nothing wrong with that.

Cochran: No, there’s not. And you know, he led me to some research and some articles on that, and so on. The next thing you know, we’ve got this thing going. It was funny, and again, I won’t mention the name of the fellah, because I still see him at the HP retirees thing, but he told me, to get these dials to calibrate, because I wanted to use now not an engraved dial that I mentioned on the 300A, but a dial that was pre-stamped. I wanted to have something like plus or minus 2 percent accuracy on the dial and so on and so forth. That meant rocking it in. If you remember ever setting up an FM tuner and having to rock the dial.

House: Okay, sure. God, I haven’t-- yeah, in a long time I haven’t thought about that.

Cochran: You’re right. You had to do it. I’ve done a little bit of everything. He looked at the design of this when we made the first 25 on a production line. He says, “I can’t do this.” I said, “Look it, I took the manual dexterity test here at HP and I’m in the lowest 15th percentile. And if I can do it, everybody can do it.” I shamed him into running it on the production line. That was interesting. We did a gold plated one and tried to present it to Walt Disney.

House: Was that what we sent to Disney, was the 204B?

Cochran: Yeah.

House: I think Kirby got Hewlett to go down and it was kind of embarrassing.

Cochran: Yeah, yeah.

House: Dave always tells the story that it was just a little mockup, but it was actually a 204B--

Cochran: Oh yes. We gold plated it--

House: Oh, I love it. I love it.

Cochran: "Hey, here it is, and now--"

House: I'm glad to get that story.

Cochran: We've miniaturized it.

House: I'm very glad to get that story on tape.

Cochran: But then after that, we finished up that, then it was funny. There was an ancillary story to 204B. That was one of the products that went to Loveland [Colorado]. Loveland was one of the first divisions, and how I met Ray King was, they were having problems with manufacturing the 204B out there. It wasn't meeting the output. I had made a transformer that would go from a single sided to a floating output, because I needed the ground and so on from the input, it was transistor driven and such. I had designed this transformer with number of turns and with certain thickness of insulation. Ray King was the production engineer on that product and he's still alive. But anyhow, they had decided to make the transformer a little bit cheaper and had dropped the capacitance between the windings, which made the output not quite symmetrically floating. So I said, "Hey, you can't do this." And again, that was one of those trivial things that I researched and I tried to do the best to meet the requirements, and the requirement was that it have a balanced output.

House: Great story. Now on the 204B, I'm just curious, since Hewlett had done the 200A, did he have any interest in the 204B?

Cochran: I was afraid to show him what I was doing because I couldn't use his light bulb. He kind of had a passing interest and he said, "That's fine." Every time I would see him about it, then I would say, "You know, what you did with the light bulb was really terrific and I'm afraid I can't find the transistor equivalent." So I was really with my hat in my hand when I talked to him about it. But he recognized that we were moving to the transistor age.

House: I guess there's a corollary question. You said up front, how could he imagine that? Do you think he was lucky or do you think he knew what he was doing when he did the negative resistance element? Or a little bit of both?

Cochran: I think that he was looking for something with that characteristic, and I don't know what led him into a light bulb that fat. All I can guess--

House: Inspired.

Cochran: He fell into it. He knew the characteristics he was looking for.

House: This is a great prelude. We probably ought to move to our main topic.

Cochran: Sorry.

House: To do that, I think the thing that I felt was interesting about the 3440, is it became the linchpin for HP's digital voltmeter business.

Cochran: And I was just about to move to there, because my next project, it was suggested that we kind of follow on from the 405B digital voltmeter and do one that was now several years later. There was more technical architecture available. And could we use some of the products that were already coming out of the other divisions? For example, the frequency counters and so on. Don Schultz was the program manager on that, and myself and Chuck Near worked on the 3440. So here it was kind of a top down. I certainly didn't go to Don Schultz and say, "Hey, I've got some great ideas on digital voltmeters." It was, I was assigned to it and saying, "HP wants to do a digital voltmeter." We did some research, but gathered up all of the resources that HP had. They were already working on the Nixie tube for counters, and a transistorized counter. They were doing some of the work on that. That was coming out of the frequency and time division. But the biggest challenge for the 3440, and I used to tell people that I really did an integrated circuit way back, but I got Horace Overacker to make me a dual diode. That was a diode with two anodes. It was on the same substrate. Wow, an integrated circuit, but it was only diodes. The reason is, I made a dual-ramp digital voltmeter. That was the technology.

House: That was the breakthrough, yeah. That was the first dual-ramp voltmeter, wasn't it?

Cochran: Yes. There had been some discussion in articles in magazines about it, using that technique, but I needed temperature compensation. I needed those ramps to track each other. I think I'd taken a solid state physics course by that time, at Stanford, where it talked about transistors and it talked about band gap energy and those kinds of things. We did it with two different diodes and it was just terrible. So then I went to the solid state lab and Horace Overacker. I said, "Could you do this?" He said, "Sure." I was the first one that had ever asked him to do it. Then we had a reference ramp against the input and it really worked very, very well.

House: That's how you got the fourth digit of accuracy?

Cochran: Yes, exactly.

House: And got it cheaply.

Cochran: It was free. It was two and a half dollars or something like that.

House: Now we have a $1,000 four- digit voltmeter and no one else did.

Cochran: Exactly. But we had some other things. We had a range of how to get to 1,000 volts. I'd had some experience, and I forget whether I did a selectable or a programmable-- no, it wasn't programmable. It was by push button, a digital oscillator. The pushbutton switches, I couldn't figure how to get the very high impedance I needed so that I would have no leakage. So one of the things I did on the digital voltmeter was I made a Teflon insulator. I had never worked with Teflon before and so we had a problem. This Teflon insulator was to isolate the switch that you would use to disconnect and connect the [reference] standard to. There was an internal standard, so you could calibrate the digital voltmeter. I bought this Teflon, these washers from a sales rep. I called him up and I said, "When I tighten these down, then I come back the next day and I find that I can still apply some pressure, and I torque it down to so many inch ounces or whatever, 12 inch ounces. The next day I come back and it's relaxed only six. So then I tighten it down, and this stuff just squeezing out." What I learned from that was, you decide on your final torque and you tighten it down at something greater than that, and then it relaxes to that final torque. Either that, or you have to capture the whole thing.

House: It's like half the distance to the goal line always.

Cochran: Exactly, yes. And then upon other switches, I remember immersing them in silicone, silicone fluid, a printed circuit board. But the printed circuit board was made out of special absorbent paper that would absorb the silicone. I could get 10^{12} resistance. Why I cite these things is that I ran up against things at every step in the design usually. Things were not easy. If they were easy, I'd say anybody could do it?

House: What comes to my mind as I'm listening, is that the instrument business had that characteristic. This wasn't like building radios or televisions. This was pretty much black art. Every box was a new idea.

Cochran: Right.

House: And everyone is at the edge of the state of the art. So the problems you have, perforce, aren't in the books.

Cochran: But the more successful the product, the further you expressed, I feel, looking back at it.

House: Yeah. I guess what I'm trying to say is that there's almost like a double end gate structure. The problem is deliciously interesting and the solutions to stretch are even more so. You put the two together and you are a constant learner, is how it's coming across to me. In field after field, element after element, so you've just developed this tremendous resourcefulness, kind of a can-do attitude, for whatever comes your way.

Cochran: Yeah, it was.

House: Was that true for most engineers there? How unique were you in that approach to engineering? I guess it's hard to say, probably.

Cochran: Seventy percent of my projects at HP labs, after the original HP laboratories were split into division labs and HP lab, 70 percent of my projects were successful.

House: That's phenomenal.

Cochran: That's right. The average was about 25 or 30 percent. Now there's two reasons for that. One is me and the other is--

House: Luck.

Cochran: If I didn't believe in it, I would kill it.

House: That's right. The ones that are going to be good.

Cochran: Ones that I was interested in or believed in. Now some of this was forced on me, and I'll give you another example, Don Schultz. On the 3440, we'd gotten to the prototype stage and we'd tried it. We sent it to Heat and Beat the environmental chambers. And it came back with it wouldn't work when you stacked them. And Don Schultz, when he was upset, like a thermometer, he would get red in the face.

House: He would, I remember that.

Cochran: And he said, "Dave, I told you months ago to check this out. Now here we are, already in our prototype, and the damn thing's not working." And I said, "Okay. Give me a little time to think about how to fix this." Well, Chuck Near and I, we looked at this thing, and we had the covers off. And we said, "Okay, we can't put holes in it because if we put holes in the top cover, the heat from this machine will just heat up the one above. So the only way we can get heat out is through the back, the back panel." And we'd already done one thing unique, and that was, we took the cover off the transformer, bolted the transformer onto the back panel, and put the cover on the outside of the back panel so that the heat transferred. We thought, "Okay, now how about the rest?" And the number AC-4A rings a bell, and I think that was the frequency counters, the stack for each digit with a nixie tube. And I said to Chuck, I said, "You know, if we drill some holes up front here and we get and we take the chassis and we don't have it go all the way back." Now, I had taken the thermal flow and so on that required a sophomore or junior engineering course from Bernard at Stanford. And all those things, and I tell people, "Don't skip your fundamentals."

House: Isn't that the truth, yeah?

Cochran: Your material science, your fluid dynamics, your physics, your chemistry. Because I said to Chuck, I said, "Okay, where is the heat coming from? It's coming from these array of transistors here. Okay, if we can get that heat coming up to the top and then it'll move towards the back because the back is where things are cool." And so without a fan--

House: It's almost a little convection in there.

Cochran: Without a fan.

House: Yeah.

Cochran: We can do this without a fan. And we tried it. We got a 15 degree drop

House: Did you really?

Cochran: We did. It dropped--

House: Just built a gradient in there--

Cochran: We were about 60.

House: Oh, I love it.

Cochran: We got it down to 45 degrees. It was tremendous. Because it doesn't take a lot of airflow. And it saved my butt with Don Schulz. And we changed the chassis, so a bunch of holes. And Chuck was my sounding board. And at one time, Paul Stoft was looking at, you know, "How are you guys doing," and so on. Any question you had, Chuck could answer it because he had filled up two lab notebooks on that 3440. I had two pages. And Chuck wrote things down and just really was a really good documenter. And it was a super team.

House: Did you go from that directly then to the 9100?

Cochran: Probably not directly, because I would work on, there were some other things. There was a pulse oximeter that I was lending some help to. But I was available at the time when Malcolm McMillan and Tom Osborne came to HP with their various, two different calculator architectures. One was the Athena with the transcendental functions. But it was fixed point. And the other was the floating point four-function machine of Tom Osborne. And Barney called us all in. And it was about 20 people in the room.

And he says, "Bill and I have been talking, and we think that we could combine these two architectures maybe and see if we can make a scientific calculator for engineers." And that was the whole purpose. He says, "HP is not interested in making an adding machine or anything point-of-sale, or any of that kind of stuff." He says, "But, something that is an adjunct to our instrumentation where you can take your reading from your instruments." Now, we weren't talking about connecting it electronically, we were talking about just taking the data and entering it in and operating on it and slicing and dicing it until it would be a nice compliment for the rest of our product line.

House: This would have been maybe early '65?

Cochran: Yes.

House: The 2116, what was the status of that at that time?

Cochran: As I remember, I think that they were still discussing whether it should be 8-bit or 16-bit with the machine back from Detroit, Sam-- I forget his name. But there was some interest--

House: The Union Carbide thing that we picked up earlier?

Cochran: Yeah, yeah, that was part of it, yeah.

House: But Kay Magleby that was at the labs, right?

Cochran: He was at the labs, but he was also an adjunct professor at Stanford.

House: That's right.

Cochran: So he was doing some research on 16-bit machines at Stanford. HP didn't really have a direction at the time as far as the computers go.

House: So neither one was started as an adjunct for digital voltmeters. They were independent projects altogether. And then somewhere along the way, somebody conceived the idea of, would it have been Hewlett or Barney, that maybe we could couple these things together? Or Dave Ricci?

Cochran: Through the HPIB [Hewlett Packard Interface Bus].

House: Yeah.

Cochran: Yeah.

House: Did all that come around in that same timeframe?

Cochran: Don Loughry out of Dymac.

House: Okay.

Cochran: I think that they were the guys that were trying to automate. That was the automation.

House: Well remember they had that Swedish Air Force thing. And they had a data logger that was 2,000 electromechanical switches. And you remember that?

Cochran: Yeah, vaguely, yeah.

House: I bet they were trying to get rid of that pig. Okay, that makes some sense. So the 9100 was done independently of any of that thinking.

Cochran: And it was just, nobody had any idea of whether or not we could do it. And so we were given 30 days to determine, and about 20 of us were gathered in a room and each of us were given different assignments. And at the end of 30 days, we were supposed to come back to Barney and Hewlett to give our assessment, could this be done? And I was looking at Osborne's architecture and trying to figure out what an algorithm was. And I even I think, I don't know if I did it during that 30-day period, I went down and talked with Jack Volder personally, and he was down in Newport Beach somewhere. And I just flew down there for the day and talked to him for about an hour. And he just referred me to the original papers by Meggitt where he'd gotten the transcendental, the pseudo division, pseudo multiplication. So what my job was to determine how many digits and what the operation time was and what the architecture that would fit that. How many digits, how many registers did we need, what would it take? And so I was able to do that in the 30 days and come back. And the other people were coming back with their inputs on cathode ray tubes, keyboards [and so on]. I was looking at the architecture as well, but there were other people that were looking at should we use transistors? Should we use small-scale integration? Where was large-scale integration at that time? Or no, there was no large-scale integration, it was called MSI if there was any medium-scale integration, which meant more than maybe 10 transistors in a chip or something like that.

House: But instead of ferrite cores and instead of semiconductor memory, how about a printed circuit board memory?

Cochran: Well, and that wasn't even thought of at that time. We said we needed a ROM, read-only memory. And I remember Chuck Near and myself going down to a conference in Las Vegas. And we heard the first use ever documented. And that was Lew Terman, who later became president of the IEEE. And his father was Fred Terman, that introduced Hewlett and Packard.

House: Well, Lew's the guy that gave us the award for the HP-35, right?

Cochran: That's right.

House: The Millennium Award.

Cochran: But anyway, he was standing up there at this conference in, I guess it was 1965, and he defined the term ROM. He says, "ROM, read-only memory." And they had some other things already. GE had a Capacitrix, where you would put a punch card just into a static reader, and if there was a punch out, that meant there was no capacity there, because the dielectric of the card wasn't there.

House: So they essentially plated capacitors to match a pattern, okay.

Cochran: It was like ROM. Because you could then read across and it would be one, zero, and so on and so forth. And so he was defining what IBM was doing in read-only memories and so on. So then Chuck and I came back and then I'm not sure whether Chuck had-- somebody had the idea of doing a printed circuit board.

House: Using the cross-bars of all the wires.

Cochran: Yes. And if it aligned with it, then you would get a-- and somebody said, "God, that's crazy as hell." Now you're going to be reading those pulses. I mean, you've got so much-- and the fear was, electromagnetic coupling, because now you've got this stuff flying all over and everything. And people say, "Well, what are your impediments?" And when somebody says, "Well gee, if you do that, it's going to have this and this effect, and you're never going to be able to control the electromagnetic [fields] and you'll never see anything on a CRT because it'll be all jagged all over and it'll look like noise," and so on. And if you stop there, rather than say, "Well, let's evaluate it, let's go and make a mockup and so on and then proceed."

House: So let me just kind of stop you here and let's just gather our thoughts. This is an important story. These two guys, have two guys stumble in the front door--

Cochran: And talk to different people.

House: Basically with the notion of an algorithm that wasn't taught anywhere in America, I don't think, hardly. Right?

Cochran: Right.

House: And one guy said, "I can do floating point stuff for arithmetic functions." And the other guy's saying, "I can do transcendental functions," and wasn't worried about floating point.

Cochran: Right.

House: But I can do sine, cosine, all that stuff. And Barney and Bill somehow are able to have an inspired moment and saying that would combine into a box that might be interesting for engineers. And then they in turn, at a coffee break, pulled 20 people in a room and said, "I'd like all of you to consider for the next 30 days how to screw around and figure out whether something like this might make sense."

Cochran: Right.

House: Did I hear that right?

Cochran: Yeah, you summarized it very well.

House: That is so ballsy compared to anything I can imagine, huh? These two guys just loved gadgets.

Cochran: Well, but it also meant they could grab 30 people, 20 or 30 people, 20 people or so, grab them and say, "Hey, I want you to study this for 30 days." Now that's a hell of a slice out of your R and D budget.

House: And the company at the time was $150 million in sales, maybe?

Cochran: Yeah, yeah.

House: Probably had 150 engineers total. So they grabbed 20 percent of the R and D staff for a month.

Cochran: No, that was probably 50 percent of HP labs.

House: Well, I'm thinking even with the outlying divisions and everything.

Cochran: Right, exactly.

House: Jiminy. What a bold thing to do. For a field that the company is not in.

Cochran: Exactly, yeah. But we came back.

House: It's audacious.

Cochran: Everybody came back enthusiastic and already had ideas on how to do it all.

House: Yeah. And then you pulled it off, relatively quickly.

Cochran: Yep. I forget the length of time. And that was probably a really good forerunner of the HP-35.

House: Well that's what I thought. The reason I wanted to spend some time on all of this is because to my mind, at one level the HP-35 was sort of the shrunken epitome of what that was. That was the great prototype, if you will.

Cochran: You could look at it that way. Because it took a myriad of disciplines. But because we had the same heat problem that I discussed with the 3440 and the 9100, and did something similar. No fan, we didn't want a fan. And so we had this tilted casting. And it's got louvers across the front. And then it comes out in the exhaust in the front.

House: So how big was the team for the 9100?

Cochran: The 9100 was a more succinct team than the HP-35, because we were touching on so much extra stuff. The 9100 used small-scale integration. The printed circuit board technique was all done out of Loveland, 16 layers or 15 layers, I forget. I always forget, do I count the ones on the outside as a layer, and so on. And the algorithms, we purchased the CRT. I think we purchased that, although we were making CRTs for the oscilloscope.

House: Kruger was making CRTs at the labs there.

Cochran: Yeah, Don Hammond was making--

House: I guess Don was maybe making them. But Bill Kruger had designed all the stuff for the scope lab.

Cochran: Right.

House: And then we went to Colorado Springs. But you didn't buy it from the Springs, I know that.

Cochran: No. I think we got the CRT--

House: Was it electromagnetic or electrostatic?

Cochran: It was electrostatic, as I remember. It was just a small two and a half inch tube or three inch tube, something like that.

House: Dick Monnier was on that project?

Cochran: Dick Monnier, yes.

House: Was he the program manager, or what did he do?

Cochran: Yes, he was the program manager. So my job was the algorithms and working with Tom Osborne to tweak the hardware to make it fit. Because I had never done the algorithms before, so I didn't know how many guard digits. So it took a while to get into the algorithms and to figure out how--

House: So you became a mathematician on that stuff.

Cochran: Well.

House: Huh?

Cochran: I wouldn't...

House: Well, I mean, you had to learn a lot about mathematics.

Cochran: I had to learn a lot. And I found--

House: And how to marry that with electronics. And there weren't 10 people in the world that knew how to do that.

Cochran: Well, yeah, but then after we got it all finished, then Willie Kahn up at Berkeley, a professor up there, said, "I noticed some bias in your algorithm." I said, "What's that?" He said, "Well, if you do a whole bunch of random numbers, the error does not center around zero. It's about two tenths of a digit off."

House: Is that right? Did he? I love it.

Cochran: Yeah, I wish the camera had focused on your face when he said that. That's the way Willie Kahn wrote.

House: Oh, that is a great story.

Cochran: And he wrote a paper about it. And I went in and tweaked the constants.

House: And got it to center around zero?

Cochran: Yes, yes, yes. So again, somebody pushing and stretching. I mean, you could just say, "Well that's the way it is."

House: Now later sometime, and I think it probably was on the HP-35, Chris Clare wrote a little book on how to do algorithmic state design.

Cochran: Yes, yes.

House: That came out of the HP-35, not out of the HP-9100?

Cochran: Yeah. It was primarily out of the 35.

House: Was he even on the 9100? Probably not.

Cochran: I'm not sure. And he and Jim Dooley, you know, Jim Dooley did some simulation. And he wrote the simulator that we used for the HP-35. And I was trying to think of the state machine concept. I took a course from Dave, I forget his name, at Stanford. And he taught me a lot about flowcharting. And it was logic design. And Dave Huffman. And Huffman-Mealy tables, and how did minimum and states, and so on.

House: Yeah, the Kline-McCluskey stuff was happening then and all that.

Cochran: Absolutely, yes, yes.

House: Oh my God. Yeah, but you guys did more elegant work than that actually. But nobody knew. I mean, everybody had all this happening at once, right?

Cochran: You have to learn the first principles.

House: So a couple questions on the 9100 and then we'll move to the HP-35. So was it expected to be a big seller? What were the marketing-- because we're going to get to the HP-35, and Bill went out to SRI and all that. I'll bet they didn't even have a clue how the 9100 would sell.

Cochran: They didn't know the market for it.

House: That wasn’t even a question that occurred to them, probably. Let's just build it and see what happens.

Cochran: Yes. And it wasn't a great expense, because we were using for the most part off-the-shelf materials.

House: But not that big case.

Cochran: Well, the case. Yeah, but remember, HP was vertically integrated.

House: Well we had our own die cast shop, and yeah, that's right.

Cochran: Anything we wanted, yeah.

House: Sure, yeah, what am I thinking?

Cochran: Yeah.

House: Jesus, Charlie.

Cochran: You could make the tool for $25,000.

House: Yeah, you're right.

Cochran: And you could stamp out three a day.

House: A thousand of them and be done, yeah. That's right. That's right.

Cochran: Then if you wanted multi dies, then if you went into mass production, you wanted more than three a day or whatever. Because you had the cycle time of the machine. So everything else though was pretty much off the shelf, except for the printed circuit board. But we had a printed circuit board shop. So from the PC shop, and one of the big challenges of the PC shop-- Chuck Near went out and really, he shepherded that. The big challenge was, we didn't know we could get the density. And the challenge was the accuracy of the registration of those layers.

House: Oh, I'll bet.

Cochran: Because you're depending upon the coupling from one level to another.

House: Absolutely.

Cochran: And we're talking about a five thousandth of an inch thickness of the board.

House: For ICs, that's nothing. But for fiberglass, that was a big deal.

Cochran: Exactly. Can you do it? Yeah. And then the registration of each of those against each other, and that sandwiching up 15 layers, 16 layers. And so that coupling, and we did a whole bunch of tests and determined what the requirements needed to be. Chuck Near made it happen on that, the printed circuit board shop. And we did have one later, and Clyde Coombs wrote a book on printed circuits and board fabrication. But the one out at Loveland really did a very precision job.

House: Do you think that's why the 9100 was sent there to be built?

Cochran: No. They were just going to be the division that received it. Remember, HP Labs had no manufacturing. And there wasn't a division, and the Loveland division was kind of the catch all for audio, video, instruments.

House: And this was low frequency, and so why not?

Cochran: This was low frequency and so on and so forth.

House: So it wasn't yet the thought that you'd tie it to the voltmeters.

Cochran: No, no.

House: So Bagley wanted the 9100 badly, is what he told me.

Cochran: Yeah.

House: And he made the point with Hewlett that we're the digital division. And Hewlett said, "No, no. Everybody's going to be a digital division. That isn't a good excuse." And I'm told Negrete and Schulz got together. And I don't know whether Marco had the idea or where it came from, but it was, "We're having a lot of trouble with these voltmeters being used in multi-nodal data acquisition environments. And this would be a great tool to be able to tie--" And didn't Jerry Nelson, wasn't he out there?

Cochran: I don't know about Nelson.

House: I remember Nelson hooked up with Loughry and that's where the HPIB, that's why that's centered in Loveland too.

Cochran: Yeah, Marco Negrete, and Don Schulz really kind of pulled that 9100 out there.

House: So there were a couple issues. I was in the Springs by then. And the issue was will that thing sell? And who would want it?

Cochran: Exactly.

House: And I got my hands on one. I did some very nice modeling of emphysema death rates for the nation by borrowing one of these things and using it on the Colorado Department of Health statistics. And I had to go back and learn some statistics at night and all that stuff. But it was my own personal computer at home. You could do anything. It was so brilliant. But the thing took off. It started selling. Do you have any sense of how well it sold?

Cochran: No. Because by that time, let's see, I was working on some other things. And from my perspective, I had always been on the engineering side. And occasionally, I'd go out with a dog and pony show.

House: If you were smart enough to stay out of marketing, yeah.

Cochran: That would pull me in and, "Dave, say a few words about our new product." And I always loved going to Westcon, which was either in Los Angeles or San Francisco in alternate years, and see all the new products. But aside from that, no, I just loved the R and D environment. And then there was some medical instrumentation that Barney asked me about to work on, there were some other things. And my memory of the time when the 9100 hit-- oh, I spent a lot of time up back and forth to Loveland. And I remember having to teach microcoding-- I forget his name. But I taught how to microcode to people, because they said, "Hey, we're going to start the follow-on products to the 9100."

House: Would it have been Bob Watson or somebody like that?

Cochran: No, it was somebody that worked for Bob Watson. I'll remember it.

House: Was it Freddie Winninger?

Cochran: No. No, Freddie and I were good. But I taught...

House: There was a Jack Walden?

Cochran: No.

House: Let's not go down that path.

Cochran: I know all of those people, and I did hold classes on--

House: Where my question is coming from is, somehow-- so I'm going to posit something and you can react.

Cochran: Sure.

House: So the 9100 goes into production. The bet is that it's going to sell a few but not very many. I think with Dave and Bill, there was almost a private bet going on. And Bill thought it would be a lot better than Dave thought it would be. And then Dave takes off for the Defense Department, okay? And this thing starts selling. And the next thing you know, it's selling like 50 a month of these things. And to stage that, Wang had a new one coming out that they had shown and in nine months they had taken seven orders. And Packard knew An Wang. And they'd discussed even getting together, and Dave said, "No, we don't want to be in a business that's that small." And Bill was saying, I think it'll do better than that, right?

Cochran: Yeah.

House: Well then this thing, all of a sudden it's selling. Remember the cover, we had a picture of the 9100?

Cochran: Yes, right.

House: And it's a production line?

Cochran: Yes.

House: I think that was the first mass-produced computer in the history of the world. No one ever built 50 at once.

Cochran: Right, right. Yes.

House: We built 50.

Cochran: We built that whole line, yes.

House: But the point was, they start selling. So where I'm going with this thinking is, when Hewlett asked for it in a shirt pocket, I think he already sensed from the success of the 9100 for the first year that this thing has real value. I mean, that it's not just a toy I like, I mean, it was selling for what, 5,000 bucks? Pretty close.

Cochran: Right, right. Hewlett did and he didn't.

House: Well, that's what I wanted to ask you. Because he was almost like you. He really never got out of the lab either.

Cochran: Well, and he would second guess himself.

House: Okay.

Cochran: He would bug me personally. And I know he also talked to Tom Osborne about it, what do you think, and so on. But he would come into the lab and he'd look for me and he'd say, "You know, hey, how are you coming with putting the 9100 in my shirt pocket?"

House: It was his idea, "I want it in the shirt pocket."

Cochran: Yep.

House: You're clear on that.

Cochran: Yeah.

House: Everything you've written says that. I've never heard anybody else say otherwise.

Cochran: No.

House: This was Bill Hewlett's crowning achievement. "I want that sucker in my shirt pocket." Then you guys go buy Hawaiian shirts, that was cheeky.

Cochran: At first, I said, "Hey, come on. That's crazy. It won't fit." He says, "Dave, integrated circuits are coming and so on." And I said, "You know, integrated circuits are coming, yeah." I don't know that Moore had even formulated his law at the time. Because we're talking about in the late '60s.[1]

House: No, I don't think he had.

Cochran: Yeah, because all they had was the 4004.

House: Four thousand four came out in '71.

Cochran: Yeah.

House: Late '70.

Cochran: No, no, that's the 4040. Are you sure? I think it was the 8080.

House: Well, they had the thing they did for Busicom earlier.

Cochran: Yeah, yeah. Right.

House: Well, they may have had sample stuff on the 4004.

Cochran: Let me back up for just a minute.

House: Yeah.

Cochran: You mentioned An Wang and Wang Labs. And one of the products was the products was the LOCI-2. And I grabbed one.

<break in audio>

House: Describe the An Wang story.

Cochran: Yeah, we had purchased a LOCI-2, I think it was, and recognized that they used the same algorithm to do square root and they were also doing log and exponential. And so in my research on

[1] [Interviewer's note] While Gordon wrote the paper in 1965 for Electronics, it wasn't until l1975 that Carver Mead publicly called it "Moore's Law".

algorithms, I had found some prior art dating back to 1624. And it was written in Latin, but I could tell mathematically that it was the same algorithm. So we did get a letter, our legal department got a letter from Wang Laboratory saying that we had infringed on their patent. And I just sent a note back with that reference to 1624 and it said, "It looks like prior art to me." We never heard another word.

House: Never heard another word, I love that. That's a great story. <laughs> Your homework has been exceptional. So let's move to the HP-35. It's apocryphal that you guys bought Hawaiian shirts for Hewlett to try and get a bigger pocket.

Cochran: We were talking about finding out who his tailor was to see if we could get some custom made for him, fudge it a little bit. The HP 35, yeah, it was absolutely all Hewlett. And he was so enthusiastic about it that he went to the industrial design department and had them design this calculator before we knew what was going to go inside. He had them design--

House: The industrial design?

Cochran: The industrial design did the shape, the key layout.

House: The key layout?

Cochran: The key layout.

House: He knew what keys he wanted?

Cochran: Not really. But he knew there was going to be multiplies and divides, there was going to be trig. There would be sine, cosine. Those are all the functions. They took the keys that were on the 9100 and said, "Okay, we need all of these keys, and how to put them on there." And so they spaced them out. And so they had already solved a whole bunch of problems.

House: Wow. Now was this Ed Liljenwall and John?

Cochran: Ed Liljenwall and Wong [ph?], yes.

House: Okay.

Cochran: And his team there. They had solved the problem of when you press a key, the calculators all to that time, had keys like typewriters that they were adjacent. In other words, there was no space between them. And then they suggested-- Barney Oliver, it was a very fortuitous time, Barney was off working on project SETI, the Search for Extraterrestrial Intelligence. And so he wasn't bugging us about anything. And so the industrial design or the physical, began to take on a shape that Hewlett and the industrial design group envisioned, and we never got involved. But they were thinking about such things as when you press a key, how do you prevent from pressing an adjacent key? And they figured, oh, if we use smaller keys and not next to each other, in other words, separated by space, then you have less chance, and so on. And they were starting to sort out where keys should go.

House: Almost the Audi brake pedal problem.

Cochran: Exactly, exactly. Yes, yes. And so they were solving problems and determining the shape and so on, and making sure it fit in his pocket before--

House: Long before.

Cochran: Long before.

House: I didn't realize that. So this actually had some nice gestation time.

Cochran: Well, and it had legs. I mean, it was already moving before. But the pressure was mounting on us in the labs to come up with an architecture. And Hewlett would come by and he'd say, "Hey, industrial design looks really good."

House: My part's coming along, huh?

Cochran: And the other aspect of that was that Hewlett was talking to the light emitting diode group, the LED group, which was a kind of a joint venture with HP Labs and the HP Associates, I think they had--

House: Yeah.

Cochran: And so they were already working on a light emitting diode and how to get more light with less power. Because it already had tentative specs.

House: So where did those specs come from do you think?

Cochran: Well, when he'd come and talk to us, when Hewlett would come and talk to us, he'd say, "Well..."

House: This is what I want done.

Cochran: It's got to work a minimum of four hours on batteries. "You're right, Bill. Yeah, we're going to have to find a technology that won't consume too much power." So bipolar was out, it wasn't dense enough. So bipolar used way too much power. So he was already working with those specs. And it had to have the same number of digits we had on the 9100.

House: Okay, so that was fixed.

Cochran: So that was already in there. Because what it was supposed to be, you just said it a few minutes ago. It was supposed to be a 9100 that fits in your pocket. We weren't going to have three registers, you only got to see the answer.

House: Okay, sure. But otherwise...

Cochran: So we had defined some things. So the requirements were being formulated, and like I said, it had legs. It was moving along and people were thinking about it. So it was mostly Hewlett and Tom Whitney and I would talk about, well, if we really did this thing what it had to have, and so on. So things were already in there, like battery life, visible in direct sunlight. You had to be able to demonstrate it to somebody, so two people had to look at the display at one time. So the light emitting diode group, they were working with magnifiers.

House: That's right, that had a little magnifying lens in it.

Cochran: They had a magnifying-- because you don't need a 90-degree viewing angle. You could use a smaller viewing angle. And so they were looking at some driver circuits as well. And then they talked about things like superlinearity. And I said, "What's superlinearity?" Well, if you double the current, the light output would a little bit more than double. And so you've got a little bit exponential, because there was leakage current. So those things were going on, and then it was again, an accident. We talked about the light bulb with Hewlett. Well, Fairchild Semiconductor invited Tom Whitney, or I don't know how they sent the invitation, but Tom Whitney and I went down to Fairchild Semiconductor on Ellis Street, Mountain View, and they wanted to show us a calculator architecture that they were planning to provide to various companies that wanted to build calculators and semiconductors. So we went down to look at it. And I looked at it, and oh, this could do the algorithms. See, I knew. By this time, I had already fit the algorithms in a small-scale integrated, the 9100. So I knew exactly what architecture I needed, the capabilities of the architecture. I didn't know what it was going to look like, but I knew what its capabilities had to be.

House: So frame this time wise for me.

Cochran: It was I think September of 1970.

House: Okay. So Intel had spun out of Fairchild in '69, and they had bid the Busicom deal in like January of '70, right?

Cochran: Right.

House: And HPA bid the light emitting diodes for them for that. And that's what the 4004 actually was invented for.

Cochran: Right, right, yeah.

House: And then Busicom said no, told us no at the LED guys, then told Intel, "You can buy back the design." And sure as hell, Fairchild heard about it, and now they say, "Well, if they're going to do something like that, we ought to do something like that." Do you suppose?

Cochran: I don't think it was related. It's interesting.

House: Or just great minds think alike? Or that's where the stuff was progressing?

Cochran: I don't know. Because what happened was, I saw a design that was different than anything else. It was not a computer architecture. It was not your classic computer architecture as taught at the universities. And it was all shift register. It was designed for the technology at the time.

House: Oh, whereas Ted Hoff put a computer architecture on a chip.

Cochran: Yeah.

House: Yeah, okay.

Cochran: He actually did a classic computer architecture on a chip.

House: That's an important distinction then.

Cochran: It was very much.

House: Yeah.

Cochran: And I'm talking to the people at Fairchild. And one fellow, Rich Whicker , who later came to work at HP. And I said, "God, this design, did you think of this?" He says, "No. We got it from Sweda, the cash register company." And Sweda at the time was trying to make an electronic cash register and they were using shift registers.

House: I'll be damned.

Cochran: Now, shift registers were the most dense form of integration.

House: Oh yeah, they were.

Cochran: Of integrated circuits at the time.

House: There was some stuff going on for T1 and T5 carriers and all that using shift registers.

Cochran: Oh yeah, yes.

House: That's how we did all the pattern triggers for the logic analyzers.

Cochran: Yeah, yeah. Because shift registers-- but you had to keep the clock moving and so on.

House: Oh yeah. Yeah, that's true.

Cochran: It had no static memory and such, exactly. So here was a design and it used the shift registers. And they had, oh I forget how many, they had this 20-digit-- they said they were designing a chipset that could satisfy anybody making a four-function machine. Add, subtract, multiply, and divide. It could give you the numbers as big as this, but it was all fixed point. I mean, it was 20 digits. So they had 20 digits, should be more than enough for anybody. Because then you could have the decimal point anywhere in that stream.

House: So there's a brand new book out, Christophe Lécuyer just got access to a lot of Fairchild documents and published the documents. He didn't do much editorial writing, he just published the documents. It came out from MIT Press three weeks ago. [Makers of the Microchip: A Documentary History].

Cochran: I'd be interested.

House: It would be interesting to know if that's in it.

Cochran: Well, I do have the original papers that Rich Whicker, who was the engineer that was working on it at Fairchild, I have his notes, a copy of his notes.

House: Do you?

Cochran: And the way that that came about, I was an expert witness in some litigation between TI and Dell. And TI had challenged Dell that they wanted 50 cents for every one of the Intel keyboard chips that used a processor, because TI had the microprocessor patent. Well, I saw some early notes on that patent application from TI. And the early notes are the same as what I saw at Fairchild. So the guy, and there was a record of Gary Boone, who worked for TI, visiting Fairchild in the 1970 time frame. But I didn't have Fairchild documentation at the time. But anyhow, that litigation was thrown out. They awarded Gary Boone a patent. We used to kid around saying, "Well, he says, "Yes Your Honor, I know I said hotel, but I really meant microprocessor." Because what he described originally was the racetrack architecture, or the shift register architecture. And what he finally, in the revisions of the patent over ten years, finally the application looks like the classic computer, fetch and you're sending each, and you do it BCD and so on and so forth.

House: So you know obviously the stories of later when TI stole all our patents for the HP-35.

Cochran: No, I don't.

House: Don't you?

Cochran: No, I don't.

House: Oh yeah. They just infringed to beat hell when they built the 51 and 52. And I was on the team, I had the logic analyzer, we just did the back trace of all the code. Then they just flat stole them. And we had a team of five go down to fight them. And they said, "Well we thought you wanted memory for your HP 3000s." They were sole source at the time for all the TTL memory logic. We stole away in the night and they went ahead and used them. I was back at the Smithsonian when they put the four-function calculators in there. Then I talked to the guys and they said, "Well, we got behind the power curve. We sold the rights to the four-function to Canon," I think it was.

Cochran: Yeah, right, yeah.

House: And then HP makes these damned calculators work and we had to get in the business. So yeah, we just borrowed the patents.

Cochran: But they always had the equals sign. And so you had to use parenthesis or you had to work the thing outside-in and so on.

House: Yeah, they didn't want to do Reverse Polish Notation (RPN).

Cochran: Yeah. And at that time, the Stanford bookstore was selling t-shirts for $395 that said, "Enter is greater than equals," and they throw in an HP calculator, you see.

House: Is that right?

Cochran: Yeah.

House: I love it. Well, I digress there. So sorry.

Cochran: No, that's all right. So seeing that architecture at Fairchild, and I got really cranked up about it. I got very excited. And I'm whispering in Tom Whitney's ear, "God, this is great." And I'm trying not to be too excited while I'm there.

House: Yeah, right.

Cochran: And then we drive away from there and I said, "God, that's exactly-- you know, I can tweak that architecture just a little bit. We don't need the full 20 digits, we can do this and this and this. And gosh, yes, I can do it, I can do it, I can do it." And so then we started a dialog with Fairchild and then after a couple of weeks, they decided they didn't want to make the calculator chips for HP. They didn't want to modify anything. And it wouldn't fit as it was, because I needed subroutine calls, they didn't have that. I needed really some actually trivial architectural changes, but were significant to make the thing work. They were just changing the structure just a little bit. And so then I said, "Oh, okay, they don't want to do that."

House: But now you knew it could be done.

Cochran: Yeah. I said, "They don't want to do it, but we've got some friends, right?" And we got AMI that we've worked with before. We've got Mostek trying to sell us a bill of goods that they can do ROMs, they can do this and that. Why don't we go to them? Well, that's going to take some money. So then Tom Whitney, Paul Stoft and I go to Hewlett. And I lay out, so I have fleshed--

House: You're ready now.

Cochran: I have fleshed out all the design. I've got the new architecture, I did it in two weeks, wrote it all out. And I've submitted those papers to the museum here.

House: Here? Have you?

Cochran: Yes, yeah.

House: Oh great.

Cochran: With dates on them, the few things that I wrote out. And I have some flow charts. Then I can do this and this and this and I can do subroutine calls and so on. So I'm really getting excited. So we go to Hewlett. And I said, "Hey, we can do it. We can fit it--" and so on. "Hey, and here's the project authorization sheet. Just sign this." He says, "Well..." Now he's starting to second guess himself. He says, "How much is this going to cost?" "Oh, about a million dollars." "Oh." And he's there all alone, Packard's off at Department of Defense.

House: What month is this? This is probably like October?

Cochran: This is October/November of 1970.

House: And we're on every second Friday off.

Cochran: Yeah.

House: Right?

Cochran: Yeah.

House: We're in the middle of a big recession.

Cochran: Oh yeah.

House: And the word in Seattle is, "Last person out, turn out the lights."

Cochran: Yeah, yeah.

House: And the word in LA is all the engineers are driving taxicabs. And you walk in and say, "I'm ready, I need a million bucks."

Cochran: Yeah. "And it's what you've been asking for two years."

House: I love it. Your timing was impeccable.

Cochran: And he says, "Well, look, I've got some friends at SRI, and I want to turn it over to them and ask them to do a focus group and do a study and see what we could sell this for. Because it doesn't look like it's going to be under a hundred bucks." I described the architecture, it's going to take five chips and this and that and the three ROMs and such, and LEDs and all of this.

House: Well now wait a minute. So you just said another important thing. So he had been an advocate all along.

Cochran: Yes.

House: Did he hold in his mind that it would be a hundred bucks?

Cochran: Now when the rubber meets the road.

House: Okay.

Cochran: And now, he's saying, "Oh."

House: This is Hewlett the pessimist. We know that side of Bill.

Cochran: Yeah. So now he comes back and says, "Oh, wow. Oh." Actually he wanted the thing, but he never gave it a thought, I don't think, of how much this was going to--

House: Yeah.

Cochran: Or whether anybody would buy them. He wanted it. He wanted it.

House: That explains so much.

Cochran: But remember that he was the next bench engineer. He was the epitome.

House: Oh always, always.

Cochran: Of the next bench engineer. And if the next bench engineer wanted something, you knew it was going to be successful.

House: Yep.

Cochran: So anyhow.

House: Oh, I have never made the equation of asking for the money and it being higher than he thought right in the middle of the recession. How perfect. What a great story Dave. So who was it? You and Whitney and Stoft?

Cochran: And Stoft, yeah.

House: Help me a little bit with Tom Whitney. Position him for me. Because I knew him later, but I didn't know him at the start of that project. Where did he come from, and why was he on it?

Cochran: Oh, well Tom Whitney, he was the negotiator. The lab essentially had probably two or three program managers. And he was a program manager.

House: Kind of like Monnier had been for the HP-9100?

Cochran: Exactly. Exactly.

House: Okay.

Cochran: Yeah.

House: So he was kind of like a super project lead.

Cochran: He has a Ph.D.

House: I thought he did, yeah.

Cochran: From University of Iowa. Or it was Iowa State. Ames, I guess.

House: Ames, yeah.

Cochran: Okay.

House: Yeah. I'm from 20 miles from Ames. And I knew Tom for a long time. But I never knew how he got to HP. So he hired into the Labs?

Cochran: Right.

House: As a Ph.D.

Cochran: As a Ph.D. And as a program manager. And his role in this was really whatever was needed on-- I did the architecture and the programming. And he drove the other aspects of it. So he was the one that signed up Mostek and AMI. He was the one that would get the machine shop to do special things.

House: But it was your architecture and your chip designs that AMI and Mostek were going to do.

Cochran: Well, it wasn't my chip design. I just took the architecture, I just laid out the schematic--

House: Requirement, yeah, sure.

Cochran: Essentially, okay, it needed shift registers, but I didn't put the little individual cells in.

House: Oh no, no. I didn't mean to imply that.

Cochran: No, no. But Francé Rodé and....

House: Chung Tung?

Cochran: Chung Tung were the guys that did the individual chip designs. But they did the detail architecture down at the transistor level and then turned that over to Mostek and AMI, who did the layout.

House: Okay. So they actually did the chip design?

Cochran: Yes.

House: I'll be. Okay.

Cochran: Yeah. And then Francé also did part of the bipolar driver too. Because one of the things that I've thought about the HP 35, and people have asked how many people were on it? Well Whitney was the orchestra leader, although I've written the script, but he was conducting the whole thing. So then there were the key design aspects of the chips, the keyboard. What was the toughest? There was a myriad of tough things that had to be done. How do we get that feel on a keyboard with no cost? With no space?

House: That little oil can digital thing.

Cochran: The little cricket.

House: Oh God, that was clever. And free. Once they came up with it.

Cochran: Well, it was just some strips that were welded on. But there were a couple of guys, Bill Misson and Don Lobdell, that were working on that. And the exact shape of that was a challenge to design.

House: Oh, I'm sure it was. I'm sure it was.

Cochran: And to figure out the tolerances again. And so on. So every little aspect was.... So Whitney was going around talking to this group, "How are coming? What kind of resources do you need?" And so on. And whether they were inside the company or outside going to external semiconductor.

House: So was he the guy that had the million dollar number for Bill? Or did you have it?

Cochran: No, we kind of, we threw something up on the wall and see what stuck.

House: But he blanched.

Cochran: He what?

House: He blanched. Bill. He didn't like the number.

Cochran: Oh, Hewlett did, yeah, yeah.

House: Then what?

Cochran: Well, so then we went back and Stoft said, "Well look, I've got an R&D budget. We'll just start it under our day-to-day lab budget."

House: To hell with him.

Cochran: No, not just. Because he figured they'd come back and he'd get it. Sooner or later, he'd get reimbursed or whatever, in the thing. But then word started getting out that this was Hewlett's project. So there were about 10 or 12 key people on the thing that were working, like I said, there was an industrial design, a couple of guys there. A couple of guys on the keyboard. There was Francé, Chung, Chu Yen on the DC-to-DC converter power supply. So now we knew the technology. It was MOS, it was PMOS technology. So now a lot of things were cemented down. And we now started getting estimates on the power usage, okay, then we figured it out, okay. Decisions had to be made. It probably took us two weeks to decide on the battery size. We needed a rechargeable battery, a NiCad, where do we get them from? I even visited the manufacturer, and I forget who it is right now. But visited them to determine the number of recycles we could do, how fast we could recharge the batteries, what the battery life was, could they stretch it, what size, da-da-da, da-da-da. We settled on I think it was AA size. And it had to be three cells. And these decisions, how do you make that decision? Well, we knew what voltages we needed to supply. We had a bipolar voltage and we had PMOS voltages. So I think it was a plus six, minus twelve, minus eighteen, and a plus three for the bipolar or something like that to drive the LEDs. And we were going to have to use an inductive driver for the LEDs to store energy and to get the current. And part of it too, we discovered that, I mentioned superlinearity before, that as you increase the current, you get more light output than just proportional. So I talked to the LED guys at HP Associates, and I said, "What happens if you pulse these? Can I pulse them with 1,000 amps?" "Oh, no, no, no, oh, 1,000? No, no, no." No, we're talking about milliamps." "Oh, well, okay." Well the average current on these LED segments was something like three or four milliamps. And I said, "Well, suppose we hit them with 30 milliamps, but 10 percent bridge cycle?" "Oh, well, that might work." We ended up with a one percent duty cycle.

House: Really?

Cochran: Really. And we got about three times the light output than we would have if we'd just applied the three milliamps. We put 300 milliamps through it, on one percent duty cycle. I got three times the light output. Now that's a freebie.

House: That is a freebie.

Cochran: That is.

House: But it's something they wouldn't have thought of. Something that you walked in with. It's a classic combination of multiple minds.

Cochran: Exactly. And asking the question. And then they said, "Well, there's a reliability issue." So on the side I set up and I did some constant three milliamp displays in a set that pulsed at a 0.1 percent duty cycle, ten times more. And I ran those for six months. And then I looked at the comparable light output over time. They were the same. So I had to answer these questions.

House: Sure, sure.

Cochran: But those were the types of things that would come up. But we had to make the decisions fast and still keeping the constraints of the size, the functionality. There were other ways-- one of my fears was doing an arc hyperbolic tangent and having to wait 20 seconds.

House: Oh yeah, right.

Cochran: And no, we sized out. And it was interesting, I had scoped out, I knew how many cycles in the average because I'm doing a pseudo division, pseudo multiplication. It's essentially shifts and adds and so on. And so how many of those would I be doing? And one of the things that probably is not known is the sine is never calculated directly or the cosine. There's a secanting error in the algorithm. The algorithm for the trigonometric functions is a little bit more than pseudo-division, pseudo-multiplication. It's a coordinate shift. And it gives you a stretching error, secanting error at each rotation when you rotate it by the arced hand of 1.0 or 0.1 or .01, and so on. And it's variable. So you'd have to keep track of that. Well, I said if I do just a rotation and I'm calculating the sine, if I calculate the sine and cosine because one register will hold the sine, the other register will hold the cosine, each with a secanting error. If I divide the sine by the cosine, that's the tangent.

House: Sure.

Cochran: And the secanting error disappears, drops out. Then I reconstitute the sine by the square root of the tangent divided by the square root of one plus the tangent squared. And the reason I do that is that it was a lot easier than trying to calculate a running secanting error. And secondly, I preserved the small-angle accuracy, because the tangent and the sine approach each other at small angles. See you remember that.

House: Clever, clever.

Cochran: Well, but every time we faced something, then we attacked it. And I'm talking about some of the things I did with the algorithms, but the same thing was approached on the DC-to-DC converter or the keyboard field. You notice that the keys in the calculator are not just a little stamp put on top of a key. This is a double shot molded. Those kind of things, just because somebody asked the question. Well, in many calculators, I see that the plus key gets worn off because it gets used more. Well, because they hot stamp. And they say, "Well, let's a double-shot mold." Then as it wears, it just goes to the same level you always see.

House: Yeah, exactly. It's so elegant.

Cochran: It's those kind of things, they kept approaching it always from what are the requirements and how do we meet those requirements? Not how can we do the requirements?

House: So when you say you stretched every single-- every one of you made the decisions that pushed that into that superb quality level, yeah.

Cochran: And so we had constant communication. I don't remember formal meetings, but constant. And that's where Tom Whitney was a great leader in that, "What are the objectives?" And each area was stretched, everything. So there were 10 or 12 key people that were making those decisions and working on the thing. But then about probably another 100 contributed in other departments, in machining and the light emitting diode people and the transistor design, the integrated circuit design down in Santa Clara that were making the bipolar drivers. And there were some mistakes made along the way. Some things didn't work quite right and we had to--

House: Oh well.

Cochran: Yeah. But we always were pushing and pushing.

House: So October, you see Hewlett and ask for the money.

Cochran: Yeah, October, November, it’s something in there.

House: Okay. Now when does he get the SRI report back?

Cochran: Oh, it wasn't until March or April or something.

House: And it's a negative.

Cochran: Well, a name's been reported, but my memory says it was somebody Calhoun who was on this team or headed up this team at SRI. He comes back, "Well, we did our focus group. And they all say if it's going to be a four-function machine, it's got to cost under $100. But what you're planning, we have no idea." And so Hewlett, I don't know whether he told us that directly, but we said, "Well, we're just continuing on." And he says, "Well, okay." And so the budget got straightened out.

House: So when did the machine come out?

Cochran: Well then in September, we got our first prototypes.

House: So 11 months from go you've got prototypes in hand.

Cochran: Yes, yes.

House: And they worked?

Cochran: Oh, well.

House: Here's another story.

Cochran: Here's another story. And we got about six or eight of them, and we were just excited as hell. Oh God. And we played around with them for about 30 minutes before Hewlett was grabbing them. And he was really excited and grabbing them and taking them off to see his buddies. Like Charlie Townes, the Nobel Prize winner in physics.

House: Yeah, sure.

Cochran: Yeah. Wolfgang Panofsky, who looked at the thing and says, "Are you going to give this to me?" He didn't want to buy it. There was another Nobel Prize winner at Stanford, Hofstadter, that he showed it to. Then he showed it to Terman, Fred Terman. And Fred looks at it, and I'm there. And he's looking at it. And he's saying, "Where's the cable for this? How can you do this? How can you do this?" And he's just beside himself. And then, wouldn’t you know it? He presses 90 degrees and hits sine, I guess he hit sine. Well.

House: He divided by zero.

Cochran: Yeah. The tangent of 90 degrees. And so it blinks at him with an overflow condition. It doesn't give back one. And I say, "Oh. Uh-oh." And I knew immediately what I had done. I hadn't checked that out.

House: In the limit, as they say.

Cochran: Well, I was so interested in finding obscure, random numbers. And 90 degrees was not a random number. And so I would do 46.32162 and then I would find the sine of that, and then I would go over, we called them the big red books. It was a National Bureau of Standard tables of mathematical results and so on. And so I would look up the sine of that and I would check in the 11th and 12th place and so on. And then I could go and peek at the extra digits and see what my errors were and so on and so forth. So then we started testing and testing and checking and so on, everything. And we went back for a ROM turn. So I had to re-program some of it. And since always with programming, you program to fit the size. And so I always had to then re-program quite a bit so I could get more ROM states.

House: Trying to write the essay to 1,000 words, right?

Cochran: Yes.

House: And you're at 1,200 now.

Cochran: Exactly. Had to pull it down. Hewlett was pleased. So we got the final parts and so on. And I went up with Hewlett to a presentation at the Fairmont where it was being shown to the press and such. And there was quite a bit of excitement.

House: This would be December?

Cochran: In December.

House: January?

Cochran: Yeah.

House: December.

Cochran: Yes.

House: Came out before Christmas.

Cochran: Yes. Yeah, about December 15, something like that. And so it went into then official production I think January or February. I'm not sure if it was against Hewlett's wishes, but it was optimistically thought well, let's do 100,000 buy of sets for the chips for the circuits. There were some sales estimates.

House: A hundred thousand.

Cochran: A hundred thousand.

House: Okay. That's higher than I would have imagined.

Cochran: Well, but see Mostek and AMI weren't going to crank up their production. I mean, 100,000, we're only talking about 50 wafers or whatever.

House: Sure, yeah.

Cochran: Yeah. So we're talking about just a run of wafers. And I'm not sure if I-- we were probably on four-inch wafers at the time.

House: So you could buy 100,000 die without committing to 100,000 calculators actually.

Cochran: Right.

House: Yeah, okay.

Cochran: Yeah.

House: But if you didn't commit to 100,000 die, they're not going to play.

Cochran: Exactly, yeah. We kind of went into it with them and such. They're going out on a limb a little bit too.

House: Sure.

Cochran: And the reason we chose two vendors, AMI and Mostek, [was] because those of us working on the thing felt that this was really going to be a super deal. We were getting really enthusiastic that we can do this, we could accomplish this. And there was nobody else out there, that we could do it that we were afraid somebody else would find out. And so we split the circuits up.

House: Oh, okay. So if anybody got a hold of one, they didn't have the complete machine.

Cochran: They never had the complete set. AMI and Mostek.

House: Oh, I didn't realize that. So there were chips from both vendors in every machine.

Cochran: Yes. Yes.

House: Oh, I didn't know that.

Cochran: Yes. We later then let them each supply both chips, but not until after production started.

House: Okay.

Cochran: That's why we went to two vendors.

House: So it wasn't like you had two vendors.

Cochran: Not a back up, no.

House: You had a pair of vendors, not two vendors.

Cochran: That's right. We had a pair of vendors.

House: Wow.

Cochran: And we had set the frequency--

House: So you really had no redundancy capability.

Cochran: No. And one of the things that we did also, well, I had timed the whole thing out, and I said it's all going to run with a 200 kilohertz clock rate. And they questioned that. And the reason for that specific clock rate, that it couldn't be less than that because I couldn't complete the most esoteric transcendental function in less than a second. And that's what dictated that. And they said, why do you need 200 kilohertz? It's only going to be a four-function machine. And I said, "Oh, we're going to make it do some other things too."

House: They didn't know it wasn't a four function?

Cochran: No.

House: Okay. Either vendor.

Cochran: Mostek we were in bed a little bit more because they got to see the ROM. And they were wondering what we-- they were doing the ROMs. And so they asked questions and they had an idea that we were doing some fancy calculator. But AMI had no idea.

House: That's an interesting sidebar, yeah.

Cochran: So yeah. The 100,000 production, that lasted about two months only. The sales on that thing really took off. Now you talked about the desktop calculator before. The desktop calculator was sold through a number of HP channels. When the HP-35 came out, it stood HP on its head. Because at first, the salesmen, they all got excited about it when they saw these things. And then they went around to their customers. And the first thing you knew, the salesmen were spending more time taking orders for HP-35s than they were their standard product line. And so then-- and I remember Jim Treybig who started Tandem, he was, in trying to explain marketing strategy to Hewlett in the boardroom and there was a bunch of us in attendance there. And this was early on, sales are just starting. And Jim Treybig is now subscribing to Women's Wear Daily to see how to sell this thing through department stores. And he's trying to explain to Hewlett on a big blackboard, I think it was a blackboard at that time, or a whiteboard. And Hewlett, after about 20 minutes, says, "Hey, it looks like a battle plan for World War III. I don't know what you're talking about," and walked out of the room.

House: Really?

Cochran: Yes.

House: I'll be damned.

Cochran: Yeah.

House: So Treybig was the marketing manager for the HP-35.

Cochran: Well...

House: Okay.

Cochran: Chuck Comiso later took over.

House: Who?

Cochran: Chuck Comiso.

House: Oh yeah, right. Sure.

Cochran: But Treybig was there. And this was in the early days. This was the January-February time frame. So how are we going to sell this, da-da-da, da-da-da? HP, like I said, it stood on its head. So pretty soon it was, "Hey, we don't want our salesmen taking orders because it's really detracting from the rest of the business." So next thing you know, it's on the main floor at Macy's and people are gathering. HP is becoming with familiar with things they never thought about like what is the average sale per square foot at Stanford Shopping Center? Well, if it's on the first floor it's $3,000 a year per square foot. Now these are the numbers from 20, 30 years ago. And the higher you go in the floor the less the sale per square foot. So HP now got into to it.

House: That was not our game.

Cochran: Exactly. But the salesmen were really excited about selling it. The HP-35, it was better at a party than playing a piano.

House: Oh, yeah.

Cochran: Used to be if there was piano player at a party, everybody would cluster around him. Well, if a guy had an HP-35, all the men would cluster around and the women are standing off somewhere saying, "What are those guys talking about?" The word of mouth and the ability to do calculations that were just, the desktop calculator, you could do it in your office. But now you could do real ones. Hey, you're just walking along and somebody asks a question, dial up and say, "Well, gee. Yeah, what's a gusset on this bridge across a river in Minnesota need, the thickness." Maybe if they'd had an HP calculator on it, it wouldn't have fallen down.

House: Well, there you go, yeah.

Cochran: But you could make the design, it took the place of slide rules. And Dietzgen has put out a--

House: And almost overnight, right?

Cochran: One year, Dietzgen was put out of business.

House: K&E [Keuffel & Esser, maker of slide rules] went out too, didn't they?

Cochran: Pardon?

House: Did K&E survive?

Cochran: No, no. K&E survived because it had the paper business and other things too.

House: Oh, that's right. Yeah.

Cochran: But you were able to do the exact calculation that you wanted and not have to estimate the power of ten like a slide rule. And you could do it to the high precision--

House: And you could do it to 15 digits, yeah.

Cochran: Exactly.

House: Jesus, yeah. Well what, the Pony Express went out of business the day they finished the railway.

Cochran: Yeah, yeah.

House: I mean the day.

Cochran: Exactly.

House: They pounded the stake and the train chugged and they stopped the horses.

Cochran: Yeah, yeah, right.

House: So you stopped slide rules in their tracks. Do you remember any of the sales stats? How well did this thing really take off?

Cochran: Well, like I said, the 100,000 production order, which at minimum was supposed to last six months, only lasted two months. And another order was placed.

House: Really?

Cochran: Really.

House: Wow.

Cochran: I think the HP-35 overall sales were something around more than 400,000.

House: The first year?

Cochran: No, the lifetime, because of the replacement, the HP-45 and the follow-ons.

House: So say a little about those additional machines. Had you always imagined it would be the first of a series? You couldn't have been thinking that way. You were building a machine.

Cochran: We were building a machine specific, with never a thought about an extension for it or greater capability. It had a store and recall, but it had no programming or anything like that. But then as soon as we got that out, then there were other, you know, people would say, "Oh, gee. Can we put a clock in it? I'd like to do financial calculations?" "Oh, how many years would you like to--" "Well, could we start at the birth of Christ and maybe go out another 4,000 years or 2,000 years?" And we did that. It goes to the year 4096. None of this stuff where the Y2K, where nothing would work after the year 2000. I wanted it to last at least my lifetime.

House: And you were thinking big.

Cochran: And some of these calculations, we wanted to know where the business days fall. And so Saturdays and Sundays. So you have to calculate what day of the week is this? This note comes due, and so on and so forth. And so some of these things, now you could do the what ifs.

House: So did you work on all of those machines? What did you do after the HP-35?

Cochran: I worked on putting the clock in on the HP-45. I led a team that did the static RAM, that did the CMOS RAM, the CMOS development. I did the HP-65 card reader. Because I wanted to do a bipolar chip. So I designed the motor chip and amplifier and read chip for the HP-65. Worked with Bob Taggert on that. He did the mechanics. Then I did some work on some of the financial, the HP-80 and then-- and I forget his name that was pushing for that.

House: Bill Crowley and--

Cochran: Bill Crowley , yeah.

House: And Francé Rodé did a lot of the work on bipolar drivers.

Cochran: Right. But I would always be called in or I would carve out a little chunk of it for myself. That looks interesting, I want to do that.

House: In some ways, I think the HP-35 is the quintessential product, no question. But I think the HP-80, in terms of a surprise from a company like an HP, was more surprising.

Cochran: Probably, because we went off charter.

House: Because that was not our forte at all.

Cochran: Yeah, we went off charter and into banking.

House: Yeah, I mean, what are we doing in banking and real estate and all this stuff? And it worked.

Cochran: But that was pushed by Crowley, yeah.

House: Oh, was it? Because Hewlett told me, and this was a long time ago and I may not remember it perfectly, but apparently he took a bunch of the HP-35s to Wall Street.

Cochran: Oh yes, I've heard that too.

House: Do you know that story?

Cochran: Yeah.

House: And nobody could figure out what an E to the X did and stuff like that.

Cochran: Yeah, right, right.

House: And on the plane back he's saying, "Well they don't know much about math. We're going to have to do it different."

Cochran: Well, and I think Crowley had Hewlett's ear too.

House: That could be. I never knew Crowley very well. You knew him?

Cochran: Yeah. His cubicle was right near Hewlett's. And he would go over and blow in Hewlett's ear and say, "Hey, we could do this, we could do that."

House: Is he still alive, do you think?

Cochran: Yeah, I think so.

House: Crowley?

Cochran: Yeah.

House: I ought to actually meet him. It'd be fun to get him in and do an interview.

Cochran: Hewlett, even when we were in pretty much full production, he was still a little bit funny, a little bit stingy. He used to be down in the cafeteria.

House: A little bit stingy? Bill? Did you hear the story at his funeral about the binoculars?

Cochran: No.

House: That the chairman of the Hewlett Foundation told?

Cochran: No.

House: Oh my God. So the question, one Christmas I guess, was Walter or somebody wanted binoculars for one of their kids. And he gives him $100. And he says, "Well that won't buy a really good pair of binoculars." And Bill said it's good enough for him.

Cochran: He was eating lunch one time and I sat down with a tray across from him, or I was eating lunch and he came down and sat down. But I said, "Hey, we got an RFQ from GE for 10,000 calculators." He says, "Oh, there must be some mistake." I said, "No." I said, "Suppose they want to buy a calculator for every one of their engineers?" And he said, "Oh, they can buy fewer of them and let them share." And that's an absolute quote, and that was his.

House: You put that in this article that you gave me a copy of.

Cochran: Yeah.

House: I want to thank you for that article. Did you give the museum a copy of that as well?

Cochran: Yes. But I've updated it and I will-

House: Okay. You've written up several things about this, and they're just priceless. And Dave, I want to thank you enormously for this chance. And I know that we could go on for a long time.

Cochran: I want to end with one thing though. Or two things, I'm sorry.

House: Sure. One is, it changed the world. You mentioned that before. It changed the world. And I saw that. I used to go down to University of New Mexico and New Mexico State for college recruiting. And so I would give a little talk about the HP-35 and so on. And these students were so enthusiastic. But the professors would say, "You know, you've really screwed me up because now what do I do? Do I let them use a calculator? They all can't afford it. Do I have to buy them for everybody?" The universities really loved it because now they could do real problems. They would not have to have a problem that ended with an even number or a round number or something like that. They could do real problems in any order of magnitude. A real design of a bridge, electronic circuits, whatever. The universe, the size of a planet and do it all in a calculator. So it really changed the world to put that power in everybody's hand. The second thing, I want to say the HP-35 development didn't change HP. But it was the epitome of the HP Way, the HP company. It enabled people to have freedom, to think outside the box. It brought resources together quickly. Everybody knew that Mr. Hewlett wanted this. And people were anxious to work on it. And we put the brightest minds and accomplished a hell of a lot.

House: Do you remember the cover stories we got, and the one in particular I remember said that America beats Japan?

Cochran: Yeah. Made in the USA, finally.

House: Made in the USA.

Cochran: Yeah.

House: I mean, the pride factor that that provided in the middle of the recession.

Cochran: Right, right.

House: For American electronics. We'd lost stereo systems, we'd lost the televisions, we'd lost so much. And that came out, and I remember that as a real pick-me-up for the engineering discipline in America at the time. So I think that was a change.

Cochran: It was, yes.

House: I would actually suggest that the HP-35 changed a lot about HP in some maybe indirect ways. One is, that was the first time that we really had to go to a different sales channel.

Cochran: Exactly. Yes.

House: Okay. But as importantly, it was the first time we had to deal with high volumes.

Cochran: True.

House: Everything else we did, we built 200 a month. We had nothing that was high volume. Not even the 3440 or stuff like that. They're all in the ten-a-day kind of range. This thing was 1,000 or 2,000 a day.

Cochran: Exactly, yeah.

House: I mean, it was just a different mindset that that team had to learn. And we did that with LEDs and stuff like that. But we drop shipped them to 10 customers. Here, it's 1,000 a day going to 1,000 people.

Cochran: Right, right.

House: Right? And in particular, Dick Hackborn, when he has the peripherals and is looking at Thinkjets and Laserjets as a possible dealer channel kind of thing, he went back and studied the learning from the HP-35 and said, "If it weren't for what we learned there," he said, "I would never have had the courage to go to the channel." Because if you remember there, all the peripherals for computers were tied to computers.

Cochran: Exactly, yeah.

House: We built an open systems model for computing that came I think as a clear legacy from the HP 35.

Cochran: Yeah, probably yeah.

House: Now another one. Now, wasn't the HP-65 the reason that Apollo 13 came home?

Cochran: I had heard that they used that as their backup computer.

House: Well, but the corollary is, every computer on the spacecraft failed.

Cochran: Yeah. Well, they had to use it, yes.

House: So it was the only thing they had left.

Cochran: I don't know whether they had permission to take it. But the astronauts wanted that, essentially demanded it as a backup system. It was one that they could control. And they were a little bit worried about things on the bus. And so yes.

House: So I think we have a few people on Earth that are here because we built that. Well I want to thank you again. This has just been such a delight for me.

Cochran: Well, I've enjoyed it, yeah, reliving it again, yes.

House: I think it's going to be great, and this will be a very nice contribution for the museum.

Cochran: Well, it was an exciting time.

House: What a privilege you had and what a contribution you made.

Cochran: Well, thank you. Thank you.

House: Thank you.

Cochran: Thank you.

House: Terrific.

END OF INTERVIEW

