Computer History Museum

Oral History of Alan Bagley

Interviewed by:
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Charles (Chuck) House: Good morning, Al.

Alan (Al) Bagley: Good morning, Charles.

House: Chuck House here, interviewing Al Bagley for the Computer History Museum Timeline. We want to talk about the HP way and some of the experiences you had over a very long and illustrious career at Hewlett-Packard.

Bagley: All right. What's today, Chuck?

House: Today is February 18, 2010, and we're pleased to really have your time and effort for this endeavor. Maybe you could start by just telling us a little bit about yourself, where you grew up and where you went to school, and kind of made you into the kid that found HP.

Bagley: Born in Pasadena, 1924. And my dad had health problems with the climate there, so we moved to the desert, to Twentynine Palms, a very small town, in 1927. And being about the only place in the middle of town with our homestead, we started a very small store to make a living, during the Depression. And that's where I learned that you can start some things from scratch and make something. We used to brag that we had homesteaded in the center of town, got the town built up around our little store. My parents were really quite sharp. They had the store and then next to it managed to get the post office, which was a good thing to bring in customers, and then a little restaurant-- on our homestead-- and another little garage for car repair we started. And finally people saw, "Hey, this is a place if I want to go into business, I ought to have building here." So they made a shopping center, way back when shopping centers were not known, and they became publicized for doing it. And it did become the center of town.

But early in my days out there, our customers came in from sometimes 30 or 50 miles away from mines. There was a mining activity-- gold mining, mainly, and prospecting. And those guys would come in every weekend to get supplies for their mine. And first thing they did when they got into town, however, was go to Jay's Bar. And so we got very used to being awakened Sunday morning by some guy pounding on the door of our home-slash-store saying he needed a week's supply of groceries. So my dad got pretty tired of that, and he said one day, "Why don't you learn what these radio amateurs are doing, and we can get a radio out at the mine to transmit the shopping list so we don't have to spend all day making it up." So I said, "That sounds good." It was interesting, and I started to think about it. I had had an earlier failure in that regard because one of the miners one day, talking to my dad, showing him all the things he had found-- it included a rock he called "galena." And my dad said, "What's that?" He said, "Well, it's got a crystalline structure and they use it in crystal radios today." And I thought, "Hey, that's great." I remembered in my Cub Scout handbook that it showed how to make a radio out of crystal. And so I got the big oat box with the wire around it and I got the galena thing, and just like the Cub Scout manual said, I got a cat's whisker, from my cat. And I thought if a rock in the desert is going to do the magic, so can a cat's whisker be magic. I learned later that that was not the thing to do. But after I became a little more knowledgeable and did some radio amateur work, it was a little bit late for my dad's desire, but I did get to learn some things about radio there.

House: That's an interesting start for your electronics career. Did you know Cal Tech? You left when you were three years old. How did you decide on Cal Tech?

Bagley: My parents-- living in Pasadena, you become very used to hearing about great things at Cal Tech. And my mother said, "I watched you when you were a baby, and you could as a baby pick up a little stick and put it through the hole in the spool. I said, 'He's going to go to Cal Tech someday.'" But I had lots of fun trying to go up in the high school out there, and fooled around a little bit too much. But we didn't have any physics course, so I went into town for the last year of high school, took some physics. And finally went to a junior college to get some more. But I was really either going to go into music or engineering. I didn't know which. And after Pasadena Junior College, where I got another year after high school to get more chemistry, I took the Cal Tech entrance exam, which was a very tough one. It took a day and a half. So I took that, and found I had passed. And I was so excited by that at that time, I said, "The heck with music." I went to Cal Tech.

House: What year was that?

Bagley: That was in '42 maybe. I don't know.

House: So the war had just started.

Bagley: Yeah, it was just starting. The war had started two-thirds of the way through the freshman year.[1] I applied for the-- what do they call it?-- Enlisted Reserve Corps. Some recruiters for the Navy and Army came down to the Cal Tech campus and made speeches about how "We got a war going on; you guys need to keep your education moving though, and so if you join the Navy thing or the Army, the Enlisted Reserve Corps will make sure you get your education." And it was a way of signing people up, and I shortly found I was drafted anyway. But I had already applied to be an air cadet, because my brother had gone into that. He advised it. He said, "This is a good thing." And we both liked it because my dad had been a pilot in World War I, <inaudible>. So we went into that, and two-thirds of the freshman year was done. When I came back, I wanted to join Cal Tech as a sophomore, but they said, "No, you only had two-thirds of the freshman year, and you don't even have calculus yet." So I said, "Okay, I'll take exams." So I went home and studied from the library, got books on calculus and stuff, and studied enough over a couple of months that I went in and took their entrance exam as a sophomore and passed it. So I went back to school at Cal Tech. As you remember, they had, in your first year, everybody took the same courses-- engineering and science. In the second year, you got to say whether you wanted to be a scientist or an engineer. And what I wanted to do was be a geologist. And so I said engineer, and I had chemistry courses. I had physics from a guy named Robert Millikan, a Nobel Prize winner, and chemistry from a guy named Linus Pauling-- Nobel Prize winner. And seeing that these were just plain old human beings was really kind of a good thing to see. Really was. And--

House: Small classes?

Bagley: Small classes, yeah. Very, frankly. But it was tough courses. Boy, you know, if you got a C, you were pretty damn good. So I found out my chemistry was a little bit tough. I thought it was a memory program; I didn't like it. But physics was getting exciting, so I went on that direction to engineering, and then finally in the last year only at Cal Tech you were able to decide which kind of engineering, so I went electrical. They had the electrical engineering department. Mr. Royal Sorensen [ph?] was dedicated to electrical engineering of a massive scale. If you didn't go into power, you were a sissy if you started fiddling with electronics. And so I think only three or four of us out of the whole class of EE went into

[1] [Interviewee's note] This would indicate that he entered probably in the spring 1941

electronics, and the rest were trained to go in making generators and things like that for dams. And I was graduating, or I was about to graduate as a senior from Cal Tech in electrical engineering, when my wife and I took a trip up to San Carlos in the Bay Area here to see her sister and her sister's husband. <inaudible>

House: This was 1948 roughly?

Bagley: What?

House: 1948?

Bagley: Yeah, about then. His name was Nicholas Borotynski, a Russian fellow. His dad had been executed in Russia. He was a White Russian. But Nicholas as a kid had escaped and he had come to America, and had gone to Cal, and he was working as an engineer. And he said, "Well, what are you going to do when you graduate? Where are you going to go? Big company or a little company?" I said, "Well, I think it'll be a little company." I've been interviewed once or twice by some of these big guys and one company told me I would probably spend the first year or two designing pulley brackets if I went with them. Another company had an ad for engineers that they thought was intriguing. The company had their ad showing a whole bunch of desks and guys sitting at them, and said: "Join us. Acres of engineers." Well, that was not appealing. It was the dumbest ad. So I wanted to go with a small outfit, and Nicholas said, "I've met a couple of guys in the San Francisco Engineers Society Club that I think are pretty good. If you want to go with a small company, you ought to look at them." And I said, "What do they do?" He said, "Well, they make measuring gear-- electronic measuring gear." That didn't sound very exciting. And I said, "Will they try anything new?" And he said, "Yeah, will they ever. Right now they're working on a lettuce picker." I said, "What's that?" "Well, it's a machine..." They make an apparatus that goes on a crossbar that fits on a tractor and is wide enough to cover four rows or six rows sometimes with an electric eye over each row. And you down a field of a farm where seeds have been planted to germinate into lettuce or something, and as the leaves come up, you want to keep the big leaves and wipe away the little leaves on each side so the biggest leaf has room to grow. It's called crop thinning. And it has to happen at a certain season every year when the leaves are just right. And a man had come to the Hewlett-Packard company and asked that they help him with this electronic problem he's got."

He says, "I have to get 90 people from Mexico every year to come up for one week," and he said, "It's not a way to run a business. Somebody's got to learn how to do this automatically." His name was Marihart-- very fine fellow. It's interesting, one of the things he had done-- he knew he wanted to get some electronic guys to work on his problem trying to make this an automatic system to thin the lettuce, and he had looked, and there was more than one in the area. But he was a good guy. He looked at the Dun & Bradstreet on each one of them, and he found out these two guys named Hewlett and Packard had a little company that had the best D&B rate-- Dun & Bradstreet for financial integrity. And so he went to Hewlett and Packard and asked if they would help him on that, and they said, "We're not in that business." He said, "But I need your help, and I'll pay for it." So they started work on his lettuce picker for him, under the name of MPH-- Marihart, Packard and Hewlett. It was a tiny little company. But when I was there-- well, anyway, that excited me, so I said, "I want to work there." He said, "You should apply." I said, "How do I do that?" He said, "Well, you look in the back the Radio Amateur's Handbook, and I think they've got an ad in there for an oscillator or something with an address, and you write to them, and I'll tell them I know you." And so I did. I wrote a letter, applying for a job, and got a very nice polite refusal from Mr. Hewlett: "We're not hiring this year. But come around some time. We'll talk to you."

Anyway, I had read that by that time the IEEE proceedings had an article with Hewlett *et al* in it about something called the distributed amplifier, and it was a breakthrough in gain bandwidth for an electronic tube amplifier. I had learned at Cal Tech that there were very serious limitations on making an amplifier that had a certain bandwidth and gain, because every tube-- that was the only thing that amplified in those days-- had a capacitor accidentally built into it. And so there was a certain curve you could not pass on gain bandwidth. But this article showed how if you sacrificed for delay, you could trade off delay and still get the gain. So you made the vacuum tube capacitor that you had to have just an element of a delay line. It was the capacitor that went down the coil. So you had to have the right kind of a coil between tubes lined up, and you made a unit that had a certain amount of gain, but it had a delay too. And whoa, was that exciting to me. The thing that really got me was that optimum gain for each of these segments of an amplifier was E: 2.716.

House: Is that right? That appealed to you.

Bagley: Yeah. I thought, "Those guys, they're not just fooling around. They know what they're doing."

House: Did Schrock co-author that with Hewlett?

Bagley: No, it was before Schrock was given the assignment. Norm Schrock, when I got to see HP, was working on that.

House: I knew he worked on a distributed amplifier.

Bagley: But he had to drop the other work he was doing, which looked pedestrian I guess. He was discussing an oscilloscope. So they put that thing away up in the attic so he could work on this grand new breakthrough distributed amplifier. So they were 10 years later getting into that business.

House: So that appealed-- the lettuce picker is why you picked HP.

Bagley: The ability to try something new, yeah. Yeah.

House: So he turned you down at that point. And then what did you do? Did you go back to school?

Bagley: I applied to Stanford. Well, I wanted to get a master's degree. It seemed like a good idea at that time. I applied at Cal Tech and they said, "Okay." So I applied to Stanford too, because I had, on a visit, seen that they had a hell of a lot fancier-looking equipment for their labs and stuff. And Cal Tech was a very frugal outfit. They had some oscillators that were pretty good, but most of them we got to use in their so-called lab had paper dials with pencil-marked frequencies on them and stuff. It was very homemade stuff. Very frugal outfit. So when looking at Stanford to apply for a master's there, I saw on the wall a little piece of paper on the bulletin board about the Hewlett-Packard friendship. And I said, "Hey, what is that?" And I met Joe Pettit, the engineering recruiting guy for Standard, and he said, "Oh, that's a friendship where you get some money for doing some stuff for a company, working with them.

We have a number of those." And I said, "I'd like to apply for that." And he said, "Well, your grades at Cal Tech are good enough that I think we can get you some sort of a friendship. You don't need that one." I said, "No, I want that one."

House: "He turned me down. I want to go there."

Bagley: Yeah. I had been turned down for a job there, so I thought, "I'll worm my way in." And I was lucky. I got half of that friendship, and another fellow, Quentin McKenna, got the other half. And we found what we were supposed to do-- this was just before we entered Stanford for master's degrees. We were to meet Dave and Bill and see what the fellowship was all about. Well, we had lunch with them, and Dave and Bill asked us, "Do you have any inventions in your head? Anything you'd like to work on yourselves?"

House: They asked you that? You just graduated from college. They wanted to know if you've got any inventions on your mind.

Bagley: Yeah. "Do you guys have anything you'd like to work on?"

House: Isn't that quite a question.

Bagley: And we both said, "No." I had, but I didn't want to say it. It was a dumb idea of static-less radio. And so they said, "Well, if you don't have any ideas of your own..." They chatted with us at lunch and then said, "Come back in a couple of weeks and we'll see if we have some ideas for you to work on on the fellowship." And so we met them again two weeks later, lunch with them again. Very nice fellows. And they said, "We make measuring equipment for electronics, but electronic measuring equipment can be used in many fields, and right now we're interested in the very fast growth of nuclear physics as a field in science, and we'd like you to spend the first quarter in the library at Stanford to just look at what they're doing in nuclear physics and see if there's something that they would like to measure that they can't measure as well as they would like to. And in the second quarter, you can propose how you would make such a device to answer that problem for them, if you were going to make a measuring instrument. And if you think it's a good enough idea, in the third quarter, before you come out (graduate), you can go to spend a little time in our lab and we'll find a place you can work and see if you can make the thing that you designed in the second quarter." So we did. And I found out that the nuclear physics guys had gone from the Geiger tube where milliseconds between pulses was fine, to the scintillation counter, where a photo-multiplier tube looked at a crystal and you could get very fast radioactive counts. And the sources they were working with were getting hotter and hotter, and they wanted a tenth of a microsecond resolution time between two pulses. And at that time, they could only do it to about 5 microseconds, and they wanted to go much faster. So I had looked at that in the first quarter as a need. In the second quarter, I said, "Well, now I got to study electronics." I looked at what counting methods there were already in electronics, and I found out a bunch of flip-flops were used and cascaded normally to divide by two with each flip-flop, and then scale down a high frequency to a lower one, which would feed to a commercial device. Well, I managed to see how they done that, and then I saw that they had capacitors-- again, limiting the speed of these flip-flops, just like it did the gain of an amplifier. But they were using-- in a particular circuit it was fairly fast. They had not only the vacuum tube itself with its capacitance, but a couple of limiting diode capacitors. Each diode was a tube, and it had more capacity. Well, the germanium diode had just come out. And so I said, "Hey, that won't have the capacity the tube has for a rectifier diode." So I said, "I'll try that high-speed counting circuit, the flip-flop circuit, using germanium diodes instead of vacuum tubes for the diodes that clamped the signal."

House: This was 1949.

Bagley: Yeah. Yeah.

House: So Shockley invents the transistor in '46.

Bagley: Transistor wasn't there yet. The diode was.

House: So you had access to germanium diodes in '49.

Bagley: Yeah.

House: Who made those? Bell Labs?

Bagley: I don't know. I forget who made them. But they were coming in at that time, and yeah, the IC-- I mean, the transistor-- was not there yet. That came much later.

House: But the diodes were.

Bagley: But the diodes were. And it was a very interesting breakthrough in science, and so I became interested in that in the second quarter and said, "Hey, that's what I'll do. I designed a flip-flop circuit that clamps the voltage swing so it's fast, between two germanium diodes instead of two vacuum tube diodes, and that way I can make it much faster." And I proposed that, and-- it's interesting-- when I proposed that, with a little meeting with Bill Hewlett, who liked to see what you were doing, he said, "If you want to take that design and try to make it work in the third quarter, come on out to the lab. I'll give you some test equipment. You can see if you can make it work." But he said, "I have an idea. I'd like for the scaler that you're making for nuclear folks-- they don't care if it's strictly binary all the way." Divide by two, four, six, eight." He said, "I think it ought to be something that divides by ten, because then it would be useful for more than just nuclear scaling. So when you get up and start fiddling in our lab, try to make it divide by ten instead of two to the n^{th}." And so looked at that and found there were ways to do that where you had a cascade of four flip-flops. But when the last one got to eight, when it flipped, it meant you had got to eight, and you fed back, and it cancelled a couple of things, so it only had two more counts to completely do the cycle-- therefore dividing by ten. But in feeding back from the last flip-flop to the second or so, there was a time delay in there. And so I decided, "Okay, we can beat that too. We'll anticipate when that one is going to get to eight by knowing what the other flip-flops are doing, and we'll send a signal ahead to get ready, and instead of feeding back, we'll kind of feed ahead and say, 'It's about time. Bang. Make it ten.'" And that worked. And it made it pretty fast as a decade machine. So I went to the lab at Hewlett-Packard in my last quarter at Stanford and they sat me down in a Quonset hut they had out in back with Quentin McKenna, my buddy on the fellowship. And his idea had been not only do you need something to measure the high-speed pulses coming in, but you need a pulse generator that can generate such pulses and bring them to within a tenth of a microsecond to test what you were doing. So that was the idea. And he was working on that. I was going to make the high-speed counter; he would make the thing that measured it. And while at HP, I had to have test equipment, and they said, "Well, we have an oscilloscope, but most of the good ones are in use in the lab. But we have an old one up in the attic that you can use." So they went up in the attic and they got this old oscilloscope that Norm Schrock had worked on, and they brought it down. It was two boxes. A box under the bunch had the power supply that generated five different voltages, and on top was the display unit with its controls, and it was the Hewlett-Packard Oscillosynchroscope.

House: Oscillo-what?

Bagley: Oscillosynchroscope.

House: So what is a synchroscope?

Bagley: They had heard about the synchroscope. They had met--

House: The DuMont guys <inaudible>?

Bagley: <inaudible> guy.

House: Oh, they had met Vollum already.

Bagley: Vollum, yeah. And he had called his ___________. He says, "I'm going to make it synchronizable-- synchroscope." And they thought, "That's a good idea." Packard had tried to hire Howard Vollum. He said, "No, I don't-- I'll start me own thing." But they had heard about his idea of synchronizing on very fast events, and so they were going to do the same. And it was called the Hewlett-Packard Oscillosynchroscope. And it was hard to keep it working. It had been a prototype. There were two of them in the attic.

House: So let me stop you there and just ask, because the story I heard-- and this may not be quite right-- was that Norm did that work in '42-'43 for somebody here in the Valley, for some early work.

Bagley: For HP?

House: Well, no, he did it for HP, but they did it under contract for somebody. I think Jack Petrak told me that story. And Vollum actually didn't start his company till like '47.

Bagley: Yeah. I think that's right. But his idea was--

House: And Hewlett met him during the war and said, "You ought to go talk to Dave for a job."

Bagley: Okay. Probably right.

House: And that was like '44 or '45. So I'm wondering-- that led me to believe that HP actually invented the thing before Vollum did. But I never thought it was triggered. I thought it was just a synchroscope like the old Dumont ….

Bagley: They saw-- what they had in the so-called oscilloscope, as made by DuMont and even RCA, was something that had had a ______________ sweep circuit-- bang, bang, bang-- and so you had a sweep.

House: And you were lucky if it ever worked.

Bagley: Yeah. But that-- you could get a rep rate that was pretty consistent with that, but you couldn't synchronize against an external event and see it.

House: But this one actually had a way of triggering, or synchronizing it.

Bagley: Yeah. That was the idea. That was a breakthrough.

House: So Norm <inaudible>.

Bagley: So they had called that the oscillosynchroscope, but when the distributed amplifier breakthrough in gain bandwidth came around, Dave and Bill decided, "Hey, that's interesting," and they put Norm Schrock off of his oscilloscope and put it on a distributed amplifier.

House: I don't think that's in the literature anywhere. Do you? Have you ever seen it?

Bagley: I don't think it is that I know of. But as you know, Jack Petrak was working for another company at that time, around there. Norm was still working on the oscilloscope development, and this other company needed-- for some vacuum tube work they were doing-- they needed a very fast scope. And they had called HP, the measuring company in Palo Alto, and said, "Do you have a scope." I think somebody talked to Packard and said, "We'll send a couple of guys up with something we've got." So Norm and another guy went up and visited the company where Petrak worked, and helped them turn on this prototype oscilloscope. And it worked.

House: So that's the genesis of Jack's story.

Bagley: Yeah. Yeah. That's right.

House: So there's something going on here. I mean, just listening to each piece you've described, whether it's the lettuce picker, or a synchroscope, or, "Gee, why not a decade counter instead of a count by binary," or "Hey, you're a couple of kids sitting around. We were thinking about nuclear physics." I mean, this is a remarkable creative sense that you're describing.

Bagley: Yeah, they're not a very big company there, and they're already trying to find guys, by having this fellowship as one recruiting tool bit, that have ideas. And I was, I think-- I think I was the third guy to get it. Two guys before me had had the fellowship, and they didn't get hired. But I had used that gimmick to try to get into the company, and it worked. They said, "Okay, you seem to have this prototype in the third quarter at Stanford. You seem to have something working pretty good." And I said, "Well, I'd like to continue working on it." And they said, "Okay, continue working on it, and you can work for the Hewlett-Packard Company." So that was the way I got in.

House: That's how you got in. Did that became a product?

Bagley: It became a product called the 520A nuclear scaler. And I learned a hell of a lot--

House: How fast, 10 megahertz?

Bagley: Huh?

House: How fast a machine?

Bagley: It would resolve two pulses with a tenth of a microsecond.

House: So that's 10 megahertz.

Bagley: Yeah, 10 megahertz. And we called it 10 mega-cycles per second, of course. In those days. Ten megacycles. But the scaler people wanted something that would divide down and actually run a mechanical Veeder-Root counter. So we divided by 100. They would have been very happy if it divided by 64 or 128, but Hewlett had still said, "Let's try to make it go decimal," and that's what we had done. And had a very good patent issue on the way we did it, as a matter of fact. But after--

House: So you got a patent on the feed forward piece of the _________ counter. Is that what--?

Bagley: That's right, yeah.

House: Did you get one on the germanium diode __________?

Bagley: I don't know that we included that. That was kind of state of the art to use a diode, and we had only made a transistor <inaudible>. I don't think our patent said anything about the kind of diode. I don't think--

House: Then HP had a competitor show up called Berkeley Labs.

Bagley: Oh yeah, later.

House: Oh, that was later. Okay.

Bagley: But first of all, I want to talk about what I learned trying to make from my prototype an instrument that was salable.

House: Oh, I bet that was an learning experience.

Bagley: It was <inaudible> because-- yeah, Hewlett said, "Okay, continue to work on it, and it looks like you're right. They do need something that's that fast. But let's see if we can make an instrument out of it." So I was given an "L" number. That means you finally had a lab project.

I was now working for HP. And I had some L number which was the-- Noel Eldred, the sales manager of Hewlett-Packard-- they didn't have a marketing guy then; they called him sales manager-- he was put in charge of saying which products, which ideas that the engineers had were worth making a product out of. And so my product idea apparently was good enough that they gave it an L number. It was a legal lab job that I was working on. And Brunton Bauer at that time was the chief engineer of the Hewlett-Packard Company, and he had worked-- his company was an audio company. Audio oscillators, audio voltmeters, wave meters-- except for one device, which was a 700 megacycle voltmeter. I found out when I got there that that was pretty good. It excited me. And that was Jack Petrak's project. And it was just so far ahead of the competition. It would measure voltage of an AC signal as high as 700 megahertz. And one of the things I found out they had done in order to do that was it needed a very high impedance probe. You couldn't use clip leads to get reasonable accuracy on a measurement of that frequency. Had a very high frequency probe. You'd go out and touch the thing you wanted to measure. And in that probe, it had to have this very fancy rectifier diode. To get to 700 megahertz, there were no diodes good enough for that. So the Hewlett-Packard Company, then a very small outfit, had gone to a tube manufacturer and described the kind of tube they wanted, and this special tube was made just to run the probe of the 410B 700 megahertz oscillator.

House: A vacuum tube.

Bagley: Huh?

House: A vacuum tube.

Bagley: Vacuum tube, yeah. It was in the probe-- a tiny diode probe to be the rectifier to turn the AC into DC so that the regular DC dial would show it. So that was not only interesting that the company would go that far to have somebody make a special tube for them-- this was not any pedestrian outfit. The other thing that was impressive about that was that with their other voltmeters, the one Packard had designed for audio frequencies, to certify that it was accurate, they had a way of getting a Bureau Standards check on it-- yeah, it was accurate-- but you couldn't do that at 700 megahertz. There was no way that the Bureau Standards could measure that. So that's when Dave and Bill an Petrak took an experiment back-- showed the Bureau Standards how it could be done, with a certain length of ___________ delay line-- you calculated from science what that loss would be. You put a bolometer out the end of it. It was resistance measured with changes with temperature in a calibrated way, because you could try DC to see what temperature changes and resistance change was. Or its heat-- its resistance was responsive to a certain level of power. So they showed the Bureau Standards how you could measure a high frequency, or justify it, by getting that frequency after a certain delay line length, to heat that bolometer in the same way that a milliwatt of DC made that change in the resistor or bolometer. And so they said, "Okay, that's good. That's science. That'll work." And so they said, "Okay, you're accurate to 3 percent." So that was impressive to me to find out how far they went. When they said they wanted go ahead of the state of the art, they meant it.

House: So when you joined, that was work that had already been done.

Bagley: Yeah. Petrak was still working on it at that time, and I got to see that, and I got to find out how they had finally made the Bureau Standards certify it by showing them how they could measure it.

House: So it's not just that they were curious, and it's not just that they were stimulating these ideas. They had a tremendous perspective on what to do and the science that drove it.

Bagley: And a hell of a background. Packard had been a radio amateur and--

House: Where did that come from?

Bagley: And Fred Terman at Stanford, who had been the boss of Hewlett and Packard-- I mean, the instructor for them-- head of the EE department-- was a hell of a sharp radio amateur, and he had also made sure that whatever he did was scientifically sound. And so they learned an attitude I think from Fred Terman about being just as scientifically sound as you good. A good educator should teach you that.

House: Sidebar on that: You know the story about-- you mentioned Cal Tech was emphasizing power, and you were a sissy to go into electronics.

Bagley: Yep.

House: In 1935, what's now the Accreditation Society for Engineering came to Stanford and they voted not to accredit them because they were doing too much of the sissy stuff, and they weren't doing enough power engineering.

Bagley: That's right. That's funny.

House: When Terman was running it.

Bagley: That's really funny. Yeah. And it was funny, it those days, McGraw-Hill published two books I was interested in when I was at Cal Tech. One was an electrical engineering book. The other was electronics. McGraw-Hill would allow a junior or senior student to get a free subscription to the electrical engineering magazine, but not electronics. They said, "We don't think that's..."

House: "...going to work," huh?

Bagley: No. But we could, of course, join the IEEE and get the IEEE proceedings. So that's how we got to see what was going on. But it's very interesting. Our prof at Cal Tech said, "No, you're not going to do any sissy stuff." But we did anyway.

House: I think that was (a view) commonly held around the country.

Bagley: But the grounding you had in physics and the fundamentals at Cal Tech was very good, very strong-- gave you great confidence, no matter where you're going to go.

House: So bring it forward now a little bit. So you've built the nuclear scaler.

Bagley: Yep. And now we're trying to make a product out of it. So I demonstrate it, and I'm up to a megahertz already. I'm trying to get it to 10, but I'm up to a megahertz. I went to the chief engineer, Brunton Bauer-- bragged about it. He said, "Well, I made a decade divider a year ago. I made it take a quartz crystal oscillator and divide it by 10, 100, 1000, so we got a tick out every second. So I made decade counters." "Oh, show me," I said. And he showed me his 100-kilohertz divider, where it had flip-flops arranged to divide by 10, but he wasn't quite sure it was going to be 10. So after he divided by 10 with this so-called digital method, he had a tuned circuit at 10 kilohertz before the signal was then fed to the next decade, and then a giant tuned circuit at 1 kilohertz to make sure-- between decades it went into a sine wave they were sure of.

House: Kind of an error checker.

Bagley: And so I said, "Well, mine goes clear to a megahertz. Yours only went to 100 kilohertz." At which point Brunton said, "Yeah, but you had an oscilloscope to work with. I designed this with a voltmeter and an oscillator." He made a counter, in other words, without ever seeing the wave _________.

House: But it sounds like he did use a quartz crystal as the initial part.

Bagley: Well, that was the oscillator, yeah. Any frequency standard in those days was quartz crystal.

House: What had you used?

Bagley: The same thing-- quartz crystal-- to make a <inaudible>.

House: Or were you doing time interval? You were just doing nuclear counting.

Bagley: Well, yeah. Let's go to nuclear counting. Back then-- because I had to learn how to make a product for HP. So I was by myself making a nuclear scaler. Nobody else helping me. I had a technician who'd come in once in a while, but I was the guy, and I was supposed to know what the product was supposed to meet, what customers would want, and so forth. And at one point, as I was getting on with it, I said, "Hey, RCA has a scaler, and it goes to 1 megahertz, but they have a couple of features we're not putting in this." And I said, "Maybe they know what they're doing. Maybe I ought to add those features." And Hewlett said, "Do you really think those features are necessary to what you're doing?" I said I didn't think so, "but RCA-- that's what they think is a good idea." And he said, "So you think you want to copy RCA?" And I said, "Well, we probably should." He said, "Any time we start copying somebody, we can fold up our little tent and walk away." He said, "You do what you think is right."

House: Great story. I love it.

Bagley: Isn't that great? Boy, what inspiration.

House: That's insight of a high order.

Bagley: Then I had it working finally up at 10 megahertz. "By golly, I've got it." And I showed it to Hewlett, and he said, "Hey, that's pretty good. It works up to 10." And we used one of ____________ oscillators, <inaudible>. "By god, it does go to 10." And I said, "Yeah. So I guess we ought to make a product like it is." He said, "Well, wait. How far does it really go?" I said, "It actually goes up to damn near 11 megahertz." He said, "Oh, that's not enough. If we're going to make something that says 10 megahertz, it better go to 13." He said, "I want a margin of what we tell people they're going to get." So I learned I had to go back to the drafting board, get the damn thing to go to 13 megahertz. And then a little later, I got that going, and I had used the RAD Lab instrumentation book that showed how you make electronic instruments, and it showed if you were going to go up to 30 megahertz with a receiver or something, you had to have this point-to-point wiring from tube to tube, very nice and close stuff. And I had done that the way I designed this counter, and Hewlett said, "Hey, that's not going to be easy to produce." He said, "People are going to have to very carefully put things on here. We don't want it that way. You use our method of a Kingman card, where we have these two big cards on each side of the row of tubes, and you put the resistors and diodes up in those cards with wires long enough to get down and reach the socket." I said, "That'll slow it down." He says, "Well, you'll have to speed it up again by something, but that's the way we want to produce things. We want to make it produce-able. Manufacturing cost is going to be key to something like this." So I had to make this damn thing in the old-- the method they had used for audio equipment almost, and I had to make it with these Kingman cards, because it would be manufacturable that way-- much cheaper.

House: So there's a plus and a minus there that I'm hearing. One is "We want to make it manufacturable, cost-effective and all that, and we've got a standard method of doing that, thanks." And the other is, is that it's curious to me that he would sort of ignore, it sounds like, the physics of longer wires and stuff like that.

Bagley: Oh, he knew you had to try harder. That's all. Everybody tries harder.

House: And if it wasn't able to be done, did you ever have a sense that he would have allowed the geometry to change?

Bagley: I thought it would be awful tough as hell, but I studied that, and I knew that if there were certain ways the wires could be fed down that did not make loops-- a couple of right wires going down from the card-- didn't have a great <inaudible>.

House: So the basic premise just challenged you to be more creative.

Bagley: So number one, I had to get up to 13 megahertz if we were going to sell it for 10. Number two, it had to be something you could manufacture. The company's catalog had a slogan on the front of it-- "Inexpensive Quality"-- at that time. And they meant it. And so I had to get the cost down. And I said, "Okay. I got her on the Kingman cards, and it still goes to 13." He said, "Well, how does it go temperature?" I said, "Oh, it's pretty good I think." He said, "Well, we have to know better than that." He said, "You go out-- we have a temperature chamber out in the Quonset hut. You go out and you make damn sure it goes over a very wide range of temperature and a wide range of humidity before we can say it's good." And so I went out and I started to connect it, work in that temperature chamber-- which was an old meat locker. They had taken an old meat locker because it had insulated sides and made a temperature chamber out of it and the humidity, they had a way of changing the humidity.

House: Oh, for crying out loud.

Bagley: So what I did was take two prototypes inside the heat box and one on the outside and I got the one on the outside synchronized to a scope. Every time the tick came out of my divide by 100 and the scope looked at the two pulses coming from the internal ones. So I had to make sure that, as the temperature changed, that there was no missing pulses, that the delay from the outside divider was exactly the same as it was on the inside and there was no movement. Well, that took about another month and a half or so to make sure and I found germanium diodes had a hell of a problem with temperature. We had to be very selective. We had to make sure of their back resistance. By that time, we found only one company who could consistently make germanium diodes that worked and it was very interesting.

House: Who was that?

Bagley: Oh, god, I can't remember the name of the company.

House: Wasn't ________________?

Bagley: No, it wasn't, it was somebody else but it was very interesting because, later, I got this thing, the scaler working, okay? Now you got a product that goes into the catalogue and the sales team for the Hewlett-Packard company was supposed to sell this thing. Well, we had every sales engineer that they had managed to get selling their stuff by going go to the right kind of sales representatives was a degreed engineer in electrical engineering. They were measurement consultants in electrical engineering. They were damn sharp guys. They were not nuclear physicists, though.

House: Yeah.

Bagley: And they didn't- what's a gamma ray, you know? <laughs> They did not know how to sell to nuclear. But, anyway, we did sell enough. It was a breakthrough at the time and, as a result, I got to go visit CERN in Geneva and see all the stuff they were doing because they installed...

House: You were 24 years old?

Bagley: ...a number of them. Huh?

House: You were, like, 24 years old?

Bagley: Yeah.

House: So they just put you on a plane and said, "Go figure it out."

Bagley: Yeah. Well, yeah. And so I had-- it worked. They wanted a lot of them but it was not a hell of a big market compared to what was booming on the outside in aerospace with the defense industry.

So Hewlett- he said, "That thing's awfully hard to trigger. You might get something a little better, easier triggering. You need a lightning bolt to make it go," he said. "Put some good high speed amplifier in front of it and fix it up." And I was working on that at the lab when I got a letter from him. He was back east visiting his old friends in the Signa Corps and they were about to put out an R&D contract for a five megahertz frequency counter. He said, "I have told them we can already go to ten." And he said, "I think what we ought to do is just start making it." He said, "Stop with that nuclear scaler amplifier you're making," in his little letter, he said, "Just drop that, turn it into a frequency counter. Put your counting device together with the frequency standard," which we call a 100D, "to time an open gate to measure the number of counts that happen in one exact second" was controlled by the crystal oscillator. So I did it. I dropped the amplifier that I was working on and started to make a frequency counter. I was told, you know, "Your box will sit next to that frequency standard." And I thought, “hell, this is going to be kind of clumsy, to have a two-box system.”

So I continued to work on this frequency counter but I took the oscillator system out of the 100D frequency standard and built it into my instrument, making it a fairly big instrument. It's interesting, we had to have a name for it. We finally called it a frequency counter, the first time that had been used. I found out later, I was so proud of this thing, it was the first digital instrument, my scaler was the first digital instrument HP had ever made and probably the first one in the Valley but, when I made the frequency counter, I said, "Boy, this is pretty good." Something very new. Then I found out that, two years before, H&P had sat down, even before I came to HP, and said, "Some day we’ve got to make a frequency counter." They had a meeting every year, Dave and Bill together, just the two of them, to decide what products might be worth looking at in the measuring field. So they had been thinking about frequency measurement all the time I was working on this nuclear scaler. So finally, when Hewlett wrote me that letter, said, "Drop the nuclear thing, we're going to make a frequency counter," and he told me how to make it with two boxes and I decided,” oh, hell, I got going.”" I made it with one, which, as you remember, mister innovator, Chuck House, that that's the way they allowed you to do, you didn't quite do what they wanted you to do. <laughter>

House: Well, but they let you.

Bagley: But that was very important. That was their delegation...

House: But they let you.

Bagley: ...decisions made at the lowest possible level.

House: So, again, you touched on another thing that I think was characteristic of Bill. He sent you the letter. He didn't say, "Do it" necessarily. It was a suggestion more than a command, probably.

Bagley: Pretty strong suggestion, yes.

House: Strong suggestion. But it was based on, it sounds like, from what you say, that, for he'd, for two or three years, been noodling about this and then he meets some guys that have the need...

Bagley: A real need, correct. Yes.

House: ...outside and that triggers the letter.

Bagley: Yeah.

House: Right?

Bagley: Yeah.

House: Along with the fact that you had something close.

Bagley: Yeah.

House: And so he kind of put all that together and said, "Hey, how about this?"

Bagley: Yeah.

House: He went to Geneva to-- I mean, he took the company international before anybody went international.

Bagley: That's right. He sure did.

House: Almost on the same kind of whim, if you will.

Bagley: Yeah.

House: I mean, he'd pieced together three or four things out of his own history and then the Treaty of Rome and then he says, not Packard, but Hewlett, says, "Hey, we ought to be there."

Bagley: Yeah, he was very much living in the national...

House: And then sends kids over to figure it out, right?

Bagley: That's right, yeah.

House: There's something really magic here.

Bagley: Yeah.

House: Don't you think?

Bagley: Oh, I think so, yeah. They, as you may remember, had a sort of corporate executives and it didn't say internationally but it said you will make instruments that advance the state of the art and the science of electronic measurement. Hewlett said, "Hey, you know, that's happening all over the world, we don't just confine it to our local neighborhood at all." So he was very strong in getting this overseas, yeah, very strong.

House: Tell me the Berkeley Lab story.

Bagley: Oh, yeah. We came out at ten megahertz. They had done a frequency measuring device but they called it EPUT machine, Events Per Unit Time. They were able to go as high as 200 kilohertz. They got up to 200 kilohertz with their so we were 50 times faster. Yeah, 50 times faster. So we came out with ours but I had the very high speed the first two decades were of my own design. I divided by 100 from ten megahertz down to 100 kilohertz and, at that point, we needed more decades to go clear down so we could count ten to the eighth pulses. So I needed six more decades. Rather than design the low frequencies decades ourselves, we decided, "Hey, we'll buy these things from Berkeley Scientific." Yeah, it was called Berkeley Scientific at that time. So we started taking their low frequency dividers and putting them into this big box called a frequency counter so that you saw their readouts, columns of neon bulbs zero to nine in each case, and that was another thing. It showed that you could make a device with little units, sub-units that actually had part of the display for the whole instrument in it, mount them right behind the panel. So we ordered quite a few of their decade counters and our machines started to take off, we ordered more and more of them. About that time, Arnold Beckman was looking to expand his chemical measurement business, another good Caltech fellow. He had bought Berkeley Scientific from a man who was a great guy, who ran Berkeley Scientific. He was from the Plymouth Religion, which had a tithing requirement for that religion, meaning that, every year, you gave not 10% but 20% of what you own. It had limited his growth of his company a little bit but he had been very successful in making these EPUT meters. We beat him and we used their own equipment for a lot-- that's how they knew we were going pretty gang busters with our machine, was a number of things we bought from them. We later decided to expand that plug-in concept where you could see, from a unit. It was a concept where you can make a box that has plug-ins in it that are part of the display. Well, we said, there's another thing. Besides this measuring frequency, we could measure time interval with this machine and “why don't you make one of those, Al,” says Hewlett. So we started working on that to measure time interval by letting two pulses open and close the gate while we're counting ten megahertz between the two pulses and it's a very accurate way of measuring time interval. So we built that into a new box and this front panel design starts to get looking pretty funny because it measured frequency, various range switches on that, time, various range switches, and the box is getting bigger. Then we accidentally discover that, when we're trying to measure a frequency that has a beat with our internal 10 megahertz oscillator or got in there, that somehow that low frequency of the beat between these two things, coming from the inside internal standard, we started measuring that damn beat frequency. We said, "Hey, wait, let's take it higher with that technique." So we started to make plug-in boxes. We built into the main box the heterodyne oscillators that would beat against something at 30 megahertz by having an oscillator at 20 beating against it and we started counting the difference frequency and, after awhile, the box was getting a front panel you could not understand at all.

House: Well, the thing was huge.

Bagley: It was huge. It really was.

House: Then you had that plug-in thing, right?

Bagley: Packard had said, "You going to have a catwalk to service that thing?" <laughter> But the heterodyne converter idea looked like a hell of a way to make or the ability to precisely measure frequency to go much higher. So we were working on that. Actually, at one of the sales-- every year, we had all salesmen come out and get a sales seminar from HP, "This is what's coming out." By god, every year, we had to have a whole new set of products. That was part of the company culture. Get ready for the next New York show in March. Got to be ready. So every year they would come out and learn what we're doing but what I showed them was a giant box that was almost hard to decipher. I could see that so I had the idea, if we could make a plug-in display unit, like, from the Berkeley Scientific decades, why not make one of these converter boxes also a plug-in and another book for time interval? So we designed a box with a big hole in it where we plugged in the final function and then another thing happened at that point. Until that point, I was a typical Hewlett Packard engineer, was in charge of a whole product all by myself. Nobody helping. Every engineer in HP had his product area. That was delegating to the lowest possible level. You could get a technician to help you sometimes and I had the best guy in the world who didn't have a degree, Ed Hilton, was a technician...

House: Ed Hilton didn't have a degree?

Bagley: No. Oh, no.

House: Is that right?

Bagley: Oh, no.

House: But what a talented man.

Bagley: Oh, boy, what a doer. He was a source of inspiration to me. In fact, one of the first times I saw that was when I was making the mechanical box to hold all this stuff for the frequency counter, I had a very funny thing. It was about 10 slabs of aluminum on the sides to cover the thing in such a way it could still be air conditioned, more or less, by the thermal flow of the heat. He said, "That's clumsy as hell." I said, "Yeah, but I know the guys can manufacture it that way." He says, "Give them a challenge, too." He said, "Take one hunk of sheet metal, cut the design you want that hole to be in and let them try to make it." I said, "That's going to get some guff from them about all this fancy sheet metal." He said, "No, you just tell them that's what you want." <laughs> And that was his can-do attitude. They can do anything you ask them to do out there and they liked the challenge. So I did. I found out how important it was later, that can-do attitude. He could do anything, that guy, no degree. What came out a little bit later, but-- anyway, now I was making plug-ins that would either convert this fundamental building block of a high speed counter into either a frequency measuring or a time measuring unit and expand its frequency range up to many- up more than 100 megahertz with plug-in heterodyne converters. There was a saying with Hewlett-Packard at the time that was poorly worded, I think. We called it the next bench syndrome, meaning what the other engineers next to you want is what you ought to design for every engineer. If they have a need, and you're in a certain area, listen to them, find out what they would do if they were designing the instrument. Make it so that the guy on the next bench to you wants whatever you're designing. We found out, after our frequency counter was used to calibrate some of the oscillators and signal generators and frequency, and to monitor the drift and other parts of it, that they didn't like to have this eight digit number, digital number flashing at you every second and try to write it down. So we made a printer. We decided, "Hey, that's the way they've got to do this" and so we made a high speed printer and I had this very fine technician, Ed Hilton, who had already showed me he had the ability to do things mechanically as well as electrically, and I had already had him make a low frequency counter where HP never tried to just be a “me, too”, I'll guarantee that. But if you had the best high frequency counter, people came and wanted something cheaper for their lower frequencies so we filled in the line and Ed Hilton said, "I can make a lower frequency. Give me a job." I made him the project head for a 100 kilohertz counter, I think it was. He did a fine job, showing me he, even though no degree, he could do fine work. So we saw the need for a printer so that you could keep track of all these fine numbers that would come flashing at you, without trying to write them down every time a second came by. I asked him, he had shown mechanical expertise, too, so I said, "Can you make a printer for that?" and he said, "Sure." He started working on it. It got into being a little bit of a kluge mechanically and so we got some advice that we probably ought to get a consultant in mechanical stuff. So Ed knew of this other guy on the outside who came in. We hired him as a consultant. He had done some work in that field. He helped us make the printer wheels that we needed to print on a piece of paper. Every time our counter had a particular reading eight digits wide, we had to get that information over to this mechanical device, which would set its wheels for that number, eight wheels, and print it. Well, if we had been smart, we would have used a binary cable for those eight digits but that's 32 wires. That seemed dumb. We have eight digits, we took eight wires so we developed a staircase analogue representation of the counts on each of eight wires and sent that to the printer. So it decoded that thing and set each wheel according to it and, bang, printed it. But we made a printer that worked pretty good. It would print out, it would go ten prints a second, actually, with Ed's-- Ed was in charge of that and he did a hell of a fine job. It was a new thing mechanically for our production department, too. It had pieces in it that were made, you know, tiny little print wheels, and they had made things like that. They made electronic instruments. Well, Hilton found that the quality of what they were doing to make this high speed machine work without skipping a beat or anything was a little tough for them. He decided what they need to know is why we're making those requirements, why this has to be a tenth of a mil accurate for this piece and not for that one. So he made a giant replica of the print mechanism on a four by eight board and took it up to the manufacturing department. Big print wheels and latches and things on it. He showed them exactly how it worked, "So this is why it has to be a tenth of a mil accurate here and not here" and so forth, educating a production department. All of a sudden, the bugs cleared up. We had a real working printer.

House: You've seen our big computer downstairs in the Computer History Museum?

Bagley: Yeah.

House: Great mechanical kluge.

Bagley: That's right.

House: It reminds me of that.

Bagley: This was a pretty good kluge, though.

House: Did you sell it?

Bagley: We started making a printer and it sold just to run our, you know, for our frequency measurement. Out in Colorado, there was a fellow trying to measure voltage digitally at that time and they wanted a printer, too, so that opened up another thing. Who gets the credit for this combination of a volt meter out of Loveland, Colorado, and a printer out of Palo Alto? Who gets the credit for having done that? The company finally came up with a system for giving credit to people-- a system for more than one division of HP, a value-added system credit so each outfit got credit for what the customer finally bought.

House: So we're about at the end of our time here on this tape but I want to ask one question around that. Was that HP's first printer, do you think?

Bagley: Yeah.

House: So did that predate the Moseley acquisition?

Bagley: Yeah, it did, yeah. Moseley was an XY analogue computer printer. This was the first one.

House: We had analogue on a chart...

Bagley: Charlie Fitterer, I want to say, did a scope plug-in printer.

House: Who?

Bagley: Charlie Fitterer, I think was his name, did a scope plug-in about '61 or so but this was earlier than that. Okay.

House: So, Al, you've given a great description of how you got to the company, kind of what your early background was, some of the first projects you worked on and all. I'd like to concentrate for a little while on Dave and Bill. You've done a lot of that just by the stories you've been telling. They come across incredibly dedicated on the one hand but creative but the thing I think that sounded most impressive from the last discussions we've had is this willingness to give responsibility very low in the company. I mean, they delegated, from the beginning, apparently.

Bagley: Oh, very...

House: I mean, that's so incredible, for people with the reputations they have and the way the CEOs operate today.

Bagley: Oh, it's so different, yeah. We learned a lot about that. Getting decisions made at the lowest possible level was very important to them. They thought this was where the best decisions are made. If possible, get it down there. So they delegated. As a young engineer, here, I'm still in college, I get hired and I'm immediately put in charge of a product line to make nuclear instruments, you know? I found that every other lab engineer, that every product that was being developed was a one-man show. The guy was, to some extent, the business manager for his product area. If you were making signal generators like Art Fong might be, you better know what the customers want and what the competitors are doing that's falling short of what they want. You're in charge, buddy, and you better make something that is easy for them to understand and operate. You don't want a complicated front panel that-- you're in charge of almost every aspect, the engineering design, the human design of it, the reliability. With my counter, it was a new thing, more complex than they had done before. It was the only digital thing in there. Another guy, who was out in service, which was the service department was the outfit that would test our things before it was shipped, and if there was something wrong, he would fix it before it was shipped. One guy, Marvin Willrodt, was out there and he came up with a brand new idea, having worked in test for awhile. He said, "Let's do something new here. We don't need just an instruction manual for our instrument, we need a service manual for something as complicated as this counter." So he wrote a service manual and it was the first service manual HP ever had to go out to people who might service this. If you bought one of the machines, you could get the operating manual and, if you wanted, you also got the service manual to keep it going. That machine was very interesting. It had 88 tubes and something like 88 germanium diodes also. That was a hell of a reliability problem.

House: You're talking about the...

Bagley: The counter.

House: The 524 counter.

Bagley: Yeah. 524, ten megahertz counter. So it became very interesting for us to study the probability theory of when is the thing going to fail? Every tube was supposed to be good for 50,000 hours but, if you had 1,000 of them, you get a failure every 50 hours. So we had quite a study on that. The company that made our germanium diodes, finally we were making so many counters that we had to-- they expanded their company and moved to a different place. Their new diodes did not work like the ones in their old factory.

House: Oh, really?

Bagley: They didn't know why. They moved back to the old one and continued. <laughter>

House: Is that right?

Bagley: The mysterious state of the art in semiconductors.

House: So HP didn't build its own diodes at that point?

Bagley: Not at that point, no. Because we could buy them. But, as you know, we did later.

House: So there were a lot of things that went on a little bit later around this counter. You licensed LED technology so that you could change the readouts.

Bagley: Yes.

House: This probe that you mentioned that had the tube in the tip, it seemed to me we went into semiconductor technology pretty early.

Bagley: Oh, we did.

House: Frank Boff and some of those people, Horace (Overacker)...

Bagley: Yeah. Oh, yeah.

House: Help me understand some of that because those were sort of before the Valley knew about things like that, I think.

Bagley: That's right, yeah.

House: Again, it's that leadership that these guys were showing. It sounds like it was a quiet leadership. It was a kind of that's how they operated.

Bagley: Let me go back and relate it to the counter again because that's the only digital instrument we made and the ________________ came afterward. Later on, we made transistorized decades. When the transistor first came out, we thought, boy, we need to do something with the transistor. So I bought what transistors were first available and they happened to be from a fraudulent French outfit. By mail order, we ordered some transistors from them. They were little globs of mud with three wires coming out of them. They were nothing.

House: There wasn't anything inside?

Bagley: <laughter> Later on, we got some real transistors and we got a R&D contract to make a transistorized decade, divide by 10 and indicate the remainder with transistors. We tried and that tried that. We could not really make it reliable so, after eight months of the one-year R&D contract, we cancelled out. We said, "This is not reliable enough at all. Let's quit." Later on, transistors had to come in and so we had now the ability to make really good transistorized decade counters. That was quite something because we had-- the transistor was just coming out. One of the conferences I went to was a navy conference in Bozeman, Montana, where the navy would go around to get colleges interested in being in the navy as a technician. ________________ Sanchez, they had one more than that. At Bozeman, they had both a classified section and an unclassified section in their technical talks. In the classified section is where I learned about the transistor. I had already heard about it because it was a local development from Fairchild here but they pointed out it was growing, the fact that the complexity was growing. That got me very excited so I decided, hey, we better learn how to make our transistors, too. That's where electronics is going. So the biggest volume HP had of any single device was the decade counter that we had finally made for ourselves outside of going to Beckman for them. So we had about 100,000 of those things we made every year. I thought, hey, that's a volume that is big enough to justify learning how to make ICs. I went to the Fairchild guys and said, "Hey, we can buy your flip flops," they gave me the complete price setup, but I said, "What if we wanted to go farther and have you make us a decade?" "Oh, we could do that." I said, "Yeah, but that gets you into making our designs. We don't get to design it any more." And I said, "That's okay. Your proprietary design. If you want something with four binaries in a row, we'll make it." I said, "Are you sure?" "Yeah, we got a contract with Beckman already." <laughter> Our competitor.

House: Really?

Bagley: Yes. So we decided none of that. That was when we decided we ought to make our own ICs. There was a company-- well, first of all, Motorola, I believe it was, had started to make transistors and you could go down on the-- I mean, integrated circuits. They had a course. You could send some guys down there. They were selling their integrated circuits by educating you on what was in them. We sent three guys down there. One was a development engineer, Merrill Brooksby, another was my can-do anything, Ed Hilton, and another one, the manufacturing fellow, John Morton. They went down and took this course and they came back and said, after five days of a course, they said, "There is nothing black magic there at all. We could do it if you want to make our own ICs." So at that time, another guy named Glen Madland[2] in Phoenix had started a company called ICE, Integrated Circuit Engineering. He said, "I will teach you how to make your own ICs." So we talked to them about what kind of a course you give and he explained the course and so we had about ten of our engineers take ICE's course. They expanded it a little bit, said, "You know, you're going a little faster than we want to go and there's a guy at Stanford who teaches some additional stuff, name is Jim Angell. Go to him and he'll teach you more about it." So we started getting some extra lectures from Jim Angell but our guys were so active in, you know, pursuing this, they found that Jim Angell was six months out of date. Things were moving pretty fast. He could educate you on what happened six months ago. So we decided we just got to go ahead and do it ourselves. So we got permission from Packard to go into making our own integrated circuits. He asked a lot of questions and I said, "Well, there's 100,000 of these damn things we make every year. If they could be on one chip instead of on four vacuum tubes, it'd be a hell of a breakthrough." He said, "Well, okay, try it." So we started with Ed Hilton in charge of the department. We decided we might be able to get somebody with some experience already in that field and we got a guy whose name I cannot remember right now, very nice guy, who had gone with a company that they thought they were going to go into the integrated circuit business and started and then cancelled. He was available. We got him. He reported to Ed and we started making our own integrated circuits. We had to learn how to make the mask first so we had this-- we learned how you do that. You take a picture of a big thing that is four feet square and make it so it is four millimeters square. You reduce it so you can make lots of chips on a single wafer. The wafers were, at that time, about three-quarters of an inch in diameter. That was a typical wafer. So we had this big-- Packard came down to see how we were doing once and we showed him our integrated circuit laboratory and we took him into this room which was the camera. It was a room, the camera, on which you put this four-foot square rubylith mask, took pictures of it, and he said, "What the hell? Why are you guys- what are you trying to make things tiny for?" We said, "That's the way you make them cheap." "Well, damn it," he says, "you go ahead. Do what you're doing but, after you get one of these tiny things to work, make one full size, the size of the wafer, and show me that it's not cheaper." Well, <laughs> he didn't understand ________________.

House: There's what he missed.

Bagley: Yes. One thing he missed. But he said, "Go ahead." So we went ahead. Ed Hilton running the shop and, later on, after we had many chips on the wafer and we were doing okay, for a gag, Ed made the same circuit blown up to what was all one chip on the one wafer full of one circuit.

House: He gave it to David?

Bagley: Ed ran that shop and he found out that it was the step and repeat requirement was pretty tough to position the camera movements. He was the guy who said, "Hey, we got to do that by counting wavelengths of light" so he made a camera that would step and repeat by counting wavelengths of light to

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[2] http://www.gbv.de/dms/ilmenau/toc/019943083.PDF

be precise in his movement. Then I thought, that's great. There's a guy with no degree but he is a can-do man. He and an engineering helping him made this step and repeat camera. Who was it? The guy from Motorola had come up, Les Hogan, was visiting one day, he talked to Hewlett. And Hewlett said, "Oh, yeah, we're trying to make transistors, too, and integrated circuits ourselves." "Could I see it?" So Hewlett sent Les Hogan down to see what we were doing. When he saw our step and repeat camera counting light waves, he said, "My god, that's ahead of the state of the art." But Ed was doing it the tough way. You had to convert the wave lengths of light and count each cycle as you moved from DC. Well, that was very tough to convert measurement gimmicks from light wave frequencies down to DC and calibrate because the machine would stop. Now you have DC. You move a little bit, you got a new wave, you got to count it. I recall, at that time, that that was a problem that early radio had converting radio frequencies to audio and that they'd gone to the heterodyne system. So I said, "Why not two frequencies?" I designed, on paper, a thing that showed two lasers, each of a different frequency, set to be, by beating them against each other, they were set to be one megahertz apart and it went out into light waves and it was such that it converted your frequency you worked with for counting cycles down to one megahertz, a heterodyne system. I showed that to my very good friend, Len Cutler, and he said, "You know, I think it can do that but it's going to be hard to keep the two lasers aligned. Let's do it with one laser. What you do is you make a laser that has two frequencies coming out of it."

House: So you can split it...

Bagley: Then you're sure it's collinear and your beam will go down to the mirrors and everything.

House: Like a Zeman splitter?

Bagley: Yeah.

House: Is that what that is?

Bagley: And so he said, "We can do that." He was a hell of a scientist as well as a hell of an engineer. He had been the guy who had made our cesium clock for us. Anyway, he said, "Do that with one laser and two frequencies." So we decided to do that and he showed us how to make the laser. He made it. The first were kind of a problem with drift over time. We finally learned to make them with no glue but only compactly held together by pressure so there was no gasses inside to slowly deteriorate the laser. We got a couple of guys named John Dukes and Gary Gordon to go ahead who had shown great ability to do electronic things and make the instrument to go with the laser that would translate that into a number, a digital number, so we could measure distance by counting the two frequency laser. It became a product. The company decided that that was okay for awhile and other divisions looked at the Santa Clara division doing crazy things like making lasers, distance measuring to microns, and they started calling us the science fair. They had seen us using science before and they liked to joke about it. We had used it before when we could not get enough voltage to run a nixie on the counter, it needed a 300 volt swing or so. You don't get that out of a transistor. We had transistors that could run a neon bulb and that would-- we made our own photoconductor to read the neon bulb. That had a voltage swing. You could make it just to change the variable resistor. You could get your 100 volt swings out of that. So we had made our own photoconductors to run our nixie tubes. Another thing we were called the science fair. But it worked and worked damn well. But we did that, making our own laser and making this interferometer, and we were now in a market that was slightly different than electronics. We were measuring mechanical distance, you might say. One of the outfits that wanted that was the people who made the very fine machine tool called the Milwaukee-Matic, automatic machine tool called the Milwaukee -Matic. That guy, the head of that company, said, "Hey, I like what you guys are doing. I want to get two or three of those." I said, "Okay, we'll make them." But then, about a week later, I heard that the company thought, "Oh, this is a goofy business, let's not go into laser measurement. That's for mechanical stuff." They were about to cancel my project after we had spent just about a million bucks to make the thing work. I was disturbed by that. I went and I told Dukes and Gordon, the engineers on it, "You got to get off this project. I'm afraid it's not going to be something the corporation wants to be in that area." They were very disturbed and acted like they were doing something else but continued working on the instrument because they were good guys. <laughs> They head of the Milwaukee-Matic company[3] heard I was about to cancel it and he says, "Hey, that's too bad." I said, "You can keep it alive." I said, "I'll give you a hell of a good penalty clause for a minimal charge for canceling 18 units if you order 20 and only want two." I said, "I'll bet, if you can give me an order for 20, I'll bet we can stay in business with you." So he said, "I'll do it. I know what you mean." He ordered 20 laser interferometers. I showed that order to corporate and they said, "Okay, we're in business." So we got to stay alive and we shipped him his two and gave him a very low penalty for canceling out 18. <laughter> He kept us alive on that.

House: Let's go back on that. Who asked you to cancel it? You said corporate?

Bagley: Yeah. Corporate. They didn't...

House: Was that Bill and Dave or was that...

Bagley: Well, no...

House: ...some planning group?

Bagley: ...that was John Young area by then. Al Oliveria was kind of sales marketing head and...

House: So it didn't bump to Bill and Dave?

Bagley: ...he was not sure. What?

House: You don't think Bill and Dave were involved in that?

Bagley: I don't think they were. I think Hewlett might have been. Hewlett might have been. Because I remember once, at the annual division review where, every year, Dave and Bill or whoever was in top management asked you to put on a review of what you were doing in your division, show your new products and where you think you're going, are you making any money or not? At one division review, Packard had seen the laser interferometer demonstration. He had, at the end of the review, said, "Hey, that's the kind of thing we ought to do. We ought to innovate and that's a hell of a good example of what we can do if we try." So I remember him being favorably impressed by it.

House: Okay.

[3] http://pipesfamily.com/KT%20INFO/The%20First%2010%20Milwaukee-Matics.pdf

Bagley: I'm not sure if he was running the company as a CEO at that time. He might have been.

House: So this is what time period?

Bagley: But they decided this is a crazy thing, you're getting your science ahead of your engineering and you're making things we don't know how to sell, just like you did with nuclear, you know? We found out we couldn't sell without having nuclear physicists as sales people.

House: So let's tease that apart a little bit because there's a lot in what you just said, I think, that would be germane. First of all, to do this first step and repeat was something nobody was yet doing in the Valley.

Bagley: Nope. They had thought about it...

House: The Valley is just about to begin to go big time into semiconductors.

Bagley: Oh, yeah.

House: Did you sell any for that purpose?

Bagley: Laser interferometer, yeah. We thought we were going to measuring machine tools with it. That's what we made it for.

House: Right.

Bagley: We did remember what Ed Hilton had already showed us, to measure wavelengths alike, you can make a step and repeat accurate.

House: So that'd be...

Bagley: And so that...

House: That became a big business?

Bagley: That became the main market for our laser interferometer ________________. It still is today.

House: Still is today?

Bagley: Yeah. When we came out with that laser interferometer, we had six competitors. In one year, there was only us. That's how much advanced we were with our state of the art machine.

House: Well, were the others being aimed at this IC market, do you think?

Bagley: I think they were, yeah. But all of a sudden, ours worked. In fact, IBM was buying chips from various people and they made a funny requirement that you will make step and repeat using the Hewlett-Packard interferometer.

House: Okay.

Bagley: It became that well known and they wanted to make damn sure it was accurate.

House: So that's the next bench thing. You got in the business to build them because who was the company that was doing the decade counters?

Bagley: Oh...

House: Building them for Beckman.

Bagley: Beckman, yeah. Berkeley Scientific.

House: But you went to an IC company?

Bagley: Yes.

House: Fairchild.

Bagley: Yeah, Fairchild.

House: So you go to Fairchild and they don't have a step and repeat.

Bagley: Well, no, they don't.

House: And they'll build you the stuff, but you lose control of your process. You say, well, hell, let's build our own ICs.

Bagley: Yeah.

House: Oh, gee, if you're going to do that, you need to move this thing reliably. Nobody does that. Let's build a kluge that does it.

Bagley: They had other ways of doing it and there may have been some of them thinking about laser stuff and the repeat gimmick but, you know, we had kind of a feeling <laughs> that let's try the most precise thing we can do and that's why Ed Hilton, on his own, said, gee, no degree, this guy, but "Let's count wave lengths of light and then we can position these things."

House: But it's this next bench syndrome is what each piece of that illustrates.

Bagley: Yeah, it is. Right.

House: Hey, we can do that.

Bagley: Yeah.

House: We've got a need here. How about if. And then you remember radio used a heterodyne and, I mean, it's a giant symbiotic relationship that goes on here.

Bagley: It is and it has included in there, of course, that we can try anything, we can do anything. Yeah.

House: And the company...

Bagley: Take big steps, big steps.

House: And the company let you. Bill and Dave encouraged that.

Bagley: Well, we, at that time, had become a bit conservative, I think, at the top layers of the company and they were starting to wonder a little bit.

House: Okay. So that brings me to a question. So this HP way you're describing as sort of, at one level, indescribable. I mean, it's just a mood and a feeling. But it must have evolved. So you're now hitting a point that, what, this is the early '60s?

Bagley: Yeah.

House: Mid-'60s?

Bagley: Yeah.

House: They got more conservative.

Bagley: Yes.

House: Describe that.

Bagley: Well...

House: What did the old timers of the time think? Like, what the hell's going on here?

Bagley: Yeah. There was some- a funny thing happened on the way to... <laughter> the market. We had- Packard with his sense of you owe your community something, going to the defense department to be deputy director of defense. Something he didn't want to do but he felt, god, all my employees even were in the war. I got to do my part. So he accepted that job. He had been chairman of the board and CEO both. He left and he let Hewlett run the company. Hewlett said, at his introductory thing about him running the company, "We're going to be more professional now. We've got to get rid of our seat of the pants way of doing things. We're going to be more professional." And we had had an example of a hell of a sharp professional, an MBA student recommended by Stanford Business School called John Young. He came in and he started working in finance, then marketing, and showed that he was just a hell of a sharp guy, was a graduate MBA, Master of Business something. He was very impressive. He really was and Hewlett said, "We need more of that. We need more professional management, less seat of the pants." And we started hiring more and more MBAs. Now these are guys that are just extremely sharp in finance and in marketing but they're not necessarily guys who have grown up with technology inside them, like radio amateur kids have and they were a bit conservative about going too far out in science and stuff. And so it was a little bit of a tougher sell now when these MBAs started to be the guys who made decisions for the company. It became a little harder to sell advanced science stuff to them and that was when they were going to shut off the laser interferometer but they knew that, I mean here's this big company we liked Milwaukee-Matic and they ordered 20 of them but that kept us alive in that. But there was a conservative thing that came in with the business management professionals. There really was.

House: So let me come back on that because to me, and I came much later than you, there were two things that from my perspective looked like they really changed or had impact on the management thinking. One was the 150 oscilloscope. We're going to go up against Tektronix and we've gone up against Berkeley Labs and we've gone up against GR and Dumont and we whipped them all. We go up against Tektroinix and we got our head handed to us.

Bagley: You're damn right.

House: Okay so that's one failure.

Bagley: Yep.

House: But you can kind of excuse it. On the other hand, the scope turned out to be the biggest selling instrument of all time so it was huge you know.

Bagley: Oh, yeah fundamental.

House: So to flunk out against— for the world's biggest instrument company to flunk out against one company on one product which happens to be big that's a black mark and I was in the scope division and that was painful.

Bagley: Oh yeah that was.

House: So you talk about being in the science division. We were the dog meat division. But then the second one was we did the 2116 computer which was a very bold step and then we couldn't sell any of these things and so I'm just wondering if maybe they're looking at both of these things that were new flyers, off in new space that didn't work particularly well or weren't being seen as having worked very well; perspective on that?

Bagley: Well, yeah. It's interesting.

House: Would those have been important in their thinking or not?

Bagley: Let's go back to the 2116 just beginning when a very sharp engineer named Kay Magleby who had done very sharp product development for us and he wanted to take an advanced degree at Stanford. We had a program, HP did, for its engineers. They could go back and take another at Stanford. He went there and he was gone for a year and then he came back. And Packard went over to HP Labs where he heard this fellow had come back to work in HP Laboratories under Barry Oliver and Paul Stoft and he asked Paul Stoft, "What do you got this guy doing now?" "He's making a computer." "He's doing what?" "He's developing a computer." "Well what did he do? I thought he went to Stanford." "Yeah. He took computer science while he was there." Packard said, "Oh my God, we're not a computer company. How often do I have to tell you. We're a measuring company." And so Packard storms out. Stoft yells after him, he says, "Let us show you in a couple of weeks what we're trying to do." And so Packard yells, "Okay" and leaves. Two weeks later they put together a show that showed how a computer could put together a number of instruments and make measurements that were totally impossible otherwise, by using computer controlled instruments. And Packard … so finally he grudgingly admits, "Yeah we can make one of those I guess." But what does he do? He tries to buy DEC. He goes to DEC and they say, "We're not selling." So then he says, "Well I guess we'll have to try it ourselves." And he found another little company that had some guys with digital experience, Union Carbide. I forget who it was decided they weren't going to go in it. And so the project was continued under Paul Stoft to make this computer design to eventually go down to our system house which was Dymec, making systems using instruments and there we would not buy DEC computers anymore. We could make our own computer work with these instruments. The design went there and so Bob Grimm was the head of Dymec at that time and he had a heck of a time. The company didn't know anything about computers. There's a very great picture in one of the annual meeting photographs of Noel Eldred, head of marketing and Carl Cottrell looking into this box and said, "Where are the COBOLs?" That's how much we knew about computing. Grimm was running it and he had his hands full but they finally got to make a computer that worked. Well Packard had been very cautious about our getting too crazy about stuff and he did not want us to go against IBM. That was a dumb thing to do. So the corporate objectives which defined the company's field of interest were changed slightly. They would not just be electronic measurements. Computers were allowed if they aided electronic measurement. We will make computers that aid electronic measurement. That was put formally into the corporate objectives.

House: It was, okay.

Bagley: It changed, the first real change in our field of interest ever. And then grudgingly they were allowed to make this thing that was an instrument controller and along with that was a very bright engineer called Dave Ricci who developed with some help from a Loveland engineer a way of interconnecting many instruments and computers in a system that was unlimited by how many instruments you could have on it. It was called the Hewlett Packard Interface Bus (HP-IB) and that became a very important thing for systems using many instruments. So you could take on giant measurements where you had many sensors on an airplane wing and you were trying to see how it behaved in a wind tunnel and things were measuring temperature, pressure, and everything but you come up with one computer display that tells you how efficient this wing is. So we found a new measurement area with those computers. The computers were pretty damn good. In fact, one IBM guy said, "Hey that does some things we can't do. That's pretty good." It had been designed to be multiple input. It had some very good ideas in it and that got more guys interested in just measurement computers to making more computers and that's how we got into that business. But it took Packard a long time to really say, "Hey, okay that's a good business to be in." But he was a delegator as you know, Chuck. He would say, "I'm not sure we ought to do that." That was always the challenge. That's where he started every time. That was an inspiring challenge. "I'm not sure we know how to do that." "Oh yeah, I'll show you we do." And so we had guys at the lower level you might say making computers anyway.

House: That's a piece of the HP way that I don't think is captured very well in most of the written histories that he would kind of start from a skeptic standpoint but he would allow you to prove it.

Bagley: Yeah that's right. That's right.

House: And it almost stimulated you to want to prove it to the old man, right?

Bagley: Yeah, oh yes.

House: So it was at one level a real motivator.

Bagley: But he delegated. "By God if you really think you can do it show me."

House: But it was a curious motivational technique almost.

Bagley: It was. It was yeah.

House: And very different than most CEOs.

Bagley: It happened in more than one way. Yeah, I remember Bruce Wholey was running a manufacturing division as well as his own division and he wanted all these automated machine tools and God they were expensive compared to your standard lathes or milling machine. They were terribly expensive automated machine tools and Packard said, "Oh, God, I don't think we need to do that." And so what Wholey did was put together about a quarter inch report full of paper, a quarter inch of paper report and he brought it to a management meeting that showed that we could make a return on investment with the most precise calculation of return on money you could make if we had these damn machine tools and he said, "This will prove it to Packard." He went into the management meeting and there's Packard and it was time for Wholey to come onto the meeting agenda and he hands out this quarter inch thing to the people at the meeting, executive council guys, and says, "I'm going to show you that we can make a very good ROI by adding these automated machine tools to our machine shop." Packard looks at it and it's a quarter inch thick and he said, "You really believe this don't you?" Wholey said, "Yeah." He said, "Okay, go buy them."

House: Didn't read the report?

Bagley: No, no. He put the challenge forth "Prove it to me" but he knew. He did that so often by saying, "Hey, I'm not sure we ought to be" but that was his way of inspiring you to do it right anyway kind of.

House: So Hewlett wasn't so much a skeptic in that way?

Bagley: In that way, no, no.

House: How was interfacing with him?

Bagley: That was interesting because Hewlett was always trying to look way out. In fact, one thing he surprised us about one day we had a weekly Friday morning talk in our lab when there was only a few engineers. Each Friday a different engineer would get up and talk about his project. One of the ideas was to learn how to give a talk but also to share your ideas with the other engineers in HP and see if they had any comments on the way you were approaching your project but we had them regularly. Then one meeting Hewlett came in and said, "Hey, I have a new idea I want to try out on you guys. You got your noses to the grindstone and here we are trying to advance the state of the art in measurement technique and you guys all just got your nose to the grindstone. I am suggesting that we need to think more out in the wild blue yonder and I think how would you like it if every Friday you were told to get off your assigned project and think of blue sky things we could do?" My God, we said, "Hey, we are under this great pressure to keep the instruments moving. We're a profit making company. We got to get something to the New York show every year on time. And we had all experienced the pressure of that and we don't see any way that we can do that. We're all working 80 hours a week." But we thought, "Hey, boy, that sounds exciting." And then I think the Packard influence came in. We were told, "No, you keep your nose to the grindstone on that project."

House: Thanks anyway.

Bagley: What happened … their old colleague from Stanford, Barney Oliver, was at Bell Labs, a hell of a great scientist at Bell Lab working on trying to get television to run down a telephone line and they had tried to hire him before but they finally did with Hewlett's idea that we need to be looking farther out into science in engineering. And so he put together Hewlett Packard Laboratories taking R&D that had been given to divisions before would not be set aside for corporate and instead of every Friday us working on blue sky ideas a different bunch of guys would be far out. It would be run by Barney Oliver as the chief of HP Labs. And I think that was probably between Packard and Hewlett a little bit of an argument where Hewlett's idea, "Hey every one of you engineers, take your nose off the grindstone to think blue sky every Friday." That probably got toned down a bit by Packard's business sense that, "No, we got to keep hustling. If you want to do far out stuff let's say we get a far out group."

House: So that's even a debate today. You know Google has this take every Friday off and people from the outside go in and say, "Well how's it work? How busy are you over here?" And they all say, "We're working 80 hour weeks."

Bagley: Yeah.

House: "Well then how can you take Friday off?" And it's got the same conundrum built in. But when I joined HP I was told every Friday afternoon you can do what you want to do.

Bagley: Uh huh, uh huh.

House: And I did pretty much.

Bagley: Where did you join HP?

House: I started in the scope division in ’62 in Palo Alto and we kept that going for quite a while. I don’t remember how formal it really was but you knew that you were invited to think bigger always.

Bagley: Yeah, okay, yeah, yeah.

House: So that’s an interesting dichotomy you point out between Bill and Dave. They did division reviews and you’ve mentioned that a couple ways. Was that a mechanism they could coach the engineering teams? I mean it got away from them somewhere it seems to me by the early ‘60s. It’s a bigger company and they can’t be very involved directly.

Bagley: Yeah, they believed in delegation so much that they turned over, as I said earlier, a product line with one engineer and he delegated. Let him decide what’s next. That happened to me when my frequency counter thing was so good that we had to make more than one of them and then later the printer and later oscillator and by that group of things that were associated with each other, technology for example, digital, only one in HP. We had a group that was dedicated to measuring frequency and time and we were delegated and this later became not just an engineering group but a division. You will manufacture it. You’ll market it, everything. But we’re now delegating major pieces of HP to divisions and they know supposedly how to market their stuff, but we have one sales force. You got to work with that. But otherwise you have your own finance department, your own personnel department and manufacturing and you got to learn how to do that. Well they delegated so much that I think it left them feeling they were almost out of the business and I think that helped stimulate the acquisitions that happened later.

House: Okay.

Bagley: I really think it helped them because they were now running a big company with many divisions where they had said, “You guys do what you think is right. Do it.” But they would see every year a formal review of each division, what it thought it was going to do this year, what it had ready for the show, what it was going to do next year, not a formal five year plan but pretty damn near formal. But you almost wonder if they didn’t think of acquisitions because they didn’t have much else to do and we did. We hired a damn good one. We bought Moseley, a very creative inventor of the XY recorder. We bought his company. That was a good addition. We were still in the same business. Hewlett’s background, his dad had been a doctor, and he had a Stanford project to make a medical instrument once and he always wanted to get back into that somehow so that’s when we acquired Sanborn. We got them right after the Harvard Business School had put a case study together on Sanbom showing that they were over the hill technically but we bought them. We were in the medical business. And a bunch of acquisitions that were made, some of are now forgotten that we were really damn near whims and did not turn out to be very successful things.

House: One doesn’t get a lot of discussion but I think you were involved with was the LED business.

Bagley: LED business.

House: Yeah, the light-emitting diode business.

Bagley: Oh, yeah.

House: Describe how you got in that and where you think it went.

Bagley: Okay. First of all our counters had to have a digital readout. It used a Nixie tube which would glow with a different number, a pack of two. H&P had been so interested in what was happening in semiconductor business that besides us fooling around with it in divisions they hired some guys from various places, Bell Labs, RCA included that had semiconductor experience, IBM too. Anyway, they brought a bunch of guys out and started another little company just to look at advanced semiconductor stuff. If we were doing something very advanced we wanted that little company, HP wanted that little company to work on it and the semiconductors that we

—**House:** It was HP associates?

Bagley: Huh?

House: Was this HP associates?

Bagley: Yes, yes, that's what it was called run by Jack Melchor, I believe, when it started.

House: Yeah I think that's right.

Bagley: And they had guys that had been in the forefront of semiconductor science in there. They were going to get us into that so anything that us divisions had fiddled around with was supposed to go there eventually if it was semiconductor related. Some of it did. Some of it didn't. We had already had Horace Overacker, one of the first engineers in HP, growing silicon crystals in ingots so we could slice them and make things. We made our own. But when we hired these guys why he was told to go down and report to them.

House: So he was doing that in the late '50s I think for silicon diodes for voltmeters.

Bagley: That's right, yes.

House: And I think he built the diodes for the probe head on the sampling scope.

Bagley: I think you're correct.

House: Fifty-seven, '58, '59. I think HP built the first silicon in the valley.

Bagley: Yes, he did.

House: I could be wrong.

Bagley: Well not maybe the first in the valley but it was typical of how far we would go, like I told you that vacuum tube that Petrak had put in his instrument was made strictly for his instrument. We'd go as far out as we could go. If you're in the measurement business you have to have a technology better than the thing you're measuring.

House: And Frank Boff?

Bagley: Huh?

House: Boff and the diode.

Bagley: Oh, Frank Boff. That was a discovery that he made. He was trying to make a frequency converter box to go ahead of the counter to go up to many gigahertz by having a harmonic that was rich enough we could beat it down from ten gigahertz down to 100 megahertz and measure it with a counter. He came to me one day and he said, "I'm getting something very unusual here. Come and look at it." And I said, "That's just pretty good. This is a damn sharp harmonic." He says "It's not just damn sharp that's better than theoretically possible with a non-linear resistor. Something's going on." And I was impressed. This guy was an engineer but he knew what was theoretically possible to harmonically get out of a non-linear resistor. He said, "No, something is going on here." I said, "Okay let's take a look at it. Let's see when the waveform generates that harmonic let's look at how you clip it to make a sharp edge on it and see what happens." So we put it on one of the first sampling scopes that came out of Colorado Springs, a nice high frequency thing, just barely working prototype and we saw that the sign we've got up there and it was just chopped at the top which would make harmonics but it also was chopped and it started ringing like mad right after the chop. He said, "That's not _____." It was just a blurry picture. We saw the wave come up and blur widely and disappear and go down. Finally the sampling scope sharpened it enough we could see that something was ringing at a very high frequency right at the top of the waveform when we clipped it with this we thought non-linear diode. Frank had studied that phenomenon enough that he had found an article about what could theoretically happen if there was a non-linear capacitor and he said, "I'll bet that's what it is." And sure enough it was a non-linear capacitor that was causing not just an IR resistance versus current curve but a capacitor for the current curve and when it snapped it really snapped and rang. So we decided we had really found something new and we called it the Boff Diode. People recognized it. In fact, there were many articles written at that time that referred to what's now the step recovery diode. It's a Boff diode, a very sharp engineer.

House: That's what it is the step recovery diode it's called today.

Bagley: Yeah it's a step recovery diode. But he had discovered it and taught us how to make more of them. Well we found out what kind of a semiconductor Horace had made that made this damn thing do that and we started finding out how to exercise and make it more so and so we made our own step recovery diodes for a frequency converter from frequency measurement. That technology we had had to be put back into Hewlett Packard Associates, the gang we had hired later so that they would know what to do with it really.

House: Didn't you also license an LED capability from Siemens in that mid-'60s timeframe?

Bagley: We had LEDs to run out displays at one time. I don't know.

House: Maybe Fred Schroder did that or somebody did that.

Bagley: I don't know.

House: It might have been Atalla and that group. I don't know.

Bagley: Well John Atalla was HP Associates and I was going back to visit the Burroughs Company division that made nixie tubes, that made our digital displays, and he said, "I want to go with you." So he did and we heard, we talked to the nixie people and what we wanted was their nixie seemed to be a one-inch round. We wanted to make it only three-quarters of an inch wide if we could make a new glass tube that we could put eight digits on a single instrument so I'd have room for a plug-in. And Saul Kuchinsky[4] the head of that division at Burroughs said, "Sure we can do that." But then at lunch, John Atalla said, "You guys are going out of business. Did you know that?" And the Burroughs guy, Saul said, "No, what do you mean?" He said, "There's going to be light emitting diodes semiconductors that could just kill the nixie that's all. You ought to be aware of that. They'll make an eight segment display." And he was really— he started arguing somewhat intentionally and I had to apologize for him to this guy who was doing us this great favor and I said, "John just stopped smoking and it bugs him" I said. That's why he's so intent about LEDs. But Atalla was right and we started making LEDs ourselves.

House: We used to explain Barney's behavior by saying, "Well he's on a diet so that's why."

Bagley: Yeah that's right. That's right.

House: Were we a big user from a Burroughs standpoint of the nixie tubes?

Bagley: Oh, God, we were it oh yes, oh yeah. Yeah. Burroughs was a funny company. They had divisions and the New Jersey division made nixie tubes at Burroughs Company that was another company. I used to commiserate with Saul Kuchinsky, the head of that division, because he was another division manager that didn't particularly think corporate knew what the hell they were doing. He talked about how the way they ran divisions they had to make sure they were on good legal grounds in so doing and the legal department had finally overtaken the top corporation at Burroughs. And he said, "I have to issue a report monthly now. You have an annual review. I have a monthly review where I take the three people from corporate headquarters who represent my division, tell them what we're doing this month, send them back so that they're in the corporation and they talk to the president directly about what this division is doing." And he said, "It is the most bureaucratic impediment to progress to have those guys come out and say, "I don't think you ought to be doing that." In other words, Burroughs was not really willing to delegate at all. They were scared to death of having remote divisions.

House: It sounds like you were a big customer for him.

Bagley: Oh, very, oh we were it.

[4] https://spectrum.ieee.org/tech-history/dawn-of-electronics/the-nixie-tube-story-the-neon-display-tech-that-engineers-cant-quit

House: HP being a big customer.

Bagley: Yeah.

House: Voltmeters and counters were probably two of the biggest uses of nixie tubes around.

Bagley: They were, no doubt about it, yeah. We had quite a few of them.

House: We never thought about going into that business ourselves.

Bagley: Making the tubes, no we did not. We had a friendly enough relationship with Saul Kuchinsky and his division at Burroughs that we were very happy with what they were doing for us. They were very eager what we were doing. They saw the digital thing coming fast and they said, "We got to make more of these." For a long time they were the only digital indicator you could get.

House: Coming out of that meeting did Atalla then say, "Well hell I'll build you the replacement?"

Bagley: I thought Atalla was exaggerating at that time. I didn't think that he was right. I loved the nixie tube so much. I didn't think that he— I thought he was overshooting. He followed up on it later and especially when the Model 35 (the handheld scientific calculator) came out. We had that with an LED display.

House: Oh that's when it clicked but that was a long time later.

Bagley: It was quite a while later but that's when we started making them for sure and that's when another funny thing happened. We did not have transistors that would drive the LED. You couldn't buy them or integrated circuits and my division's integrated circuit department was asked, "Could you make an IC that will run LEDs?" "Yeah we can." So our part of the HP calculator was to make the chips that ran the LEDs. We were another job shop you might say. If you need something special in your integrated circuit or your transistor you can't get on the market we'll make it for you so we made all kinds of goofy things in our transistors. We were told that's the way you got to do it.

House: So there are some other phrases used about HP, MBWA, Management by Wandering Around?

Bagley: Yes, very important.

House: Yeah help me appreciate it. Sometimes Doyle gets credited with that but that made it much later.

Bagley: He made up the saying MBWA I think.

House: Okay so he made up the saying but it was a style that they had.

Bagley: Oh, yeah, yeah. Yeah, Packard was very good at that. He wanted to know what was going on in the company and he always was around. He had delegated to a large extent the technical end of it to Hewlett, but Packard was the business manager but just as sharp technically as Hewlett. In fact, at Stanford he had better grades. He really was really able to understand technically what you were doing but he thought it better be part of a business and he would run that. So he let Hewlett be technically the guy in charge of technology and R&D but Packard was around all the time. He would come and look at your project and see you were taking notes about what happened as you were doing it. He said, "Let me take those notes. You just go ahead with what you're doing." He'd write down and he would make very good technical comments on what you were doing. When we sent instruments to the New York show every year he wanted to know what we had sent there and he wanted to understand how they worked. I remember at one New York show he said on the airline back there, "I read your manual on that counter and that was damn tricky what you did in there to put a delay line in at this particular point." He knew technically what the hell you were doing. I'm reminded of when later we made the wave machine. He developed the wave machine for the aquarium at Monterey. It was a quarter horsepower motor than ran that whole wave machine. I said, "Hey that thing … that was amazing. You only used a quarter horse little motor to make all those waves." He said, "You don't think I don't know how to design a resonant tank circuit do you?" That was a radio amateur term.

House: I love it.

Bagley: He was a hell of a good engineer and so he knew what was going on there. He shared that with Hewlett. Hewlett he was an inspirational guy, Hewlett, in saying, "Hey let's look ahead. We're not going to let anybody beat us. Let's keep going ahead." Packard was a bit more conservative. He had that "prove it to me" kind of aspect. He would say, "Well I'm not sure you ought to be doing that."

House: What built the loyalty?

Bagley: God they loved each other really. It was very interesting. When Packard went to the Defense Department and we had a meeting. We had just acquired the Varian Building I guess it was the Varian spare building in Cupertino. There was a big open house for that. We were going to have a dinner party and everything down there and so every employee was asked. "We're going to have a nice party. We've got a new building in Cupertino." Hewlett gave the keynote talk up at the rostrum and he said, "We're going to miss Dave. I worked with him for so many years but we're going to take the company a little bit different way. Dave and I actually had the same objectives for this company forever but we had little different ideas about how to get there." And he said, "It's my turn. We're going to try something a little bit more professional management." And that was partly because he had been inspired by John Young, the business school graduate, who was a hell of a sharp business guy. And so he said that … he said "But I want you to understand that Dave and I worked together for so long that" and then he broke up. He couldn't talk.

House: Really?

Bagley: We could see that he was emotionally trying to explain his relationship with his buddy Dave and he was quiet for damn near two minutes before he could get back in control of himself and say, "But we still had the same objective."

House: I love it.

Bagley: Yeah it really was a hell of a partnership. They used to do everything together. They'd go hiking together. They bought the San Felipe horse ranch, no cattle ranch together, all kinds of stuff.

House: So there were a few people during those early years who left and you hear some of the names, Duane Dunwoodie, some of the characters if you will, the guy that went over to the Ukraine with the mag tape stuff over at SRI.

Bagley: Yes, yeah, yeah.

House: Why did they leave? I mean almost everybody stayed for a very long time.

Bagley: That's true, a lot of them. Boy I'll tell you I was not the only engineer who had offers from other companies. We were so damn happy at HP a lot of them stayed. Some guys didn't, Duane Dunwoodie and Bill Jarvis. Bill Jarvis had been a marketing guy at HP but at one point HP didn't make a camera to look at the oscilloscope screen and take pictures so Jarvis knew from his marketing experience it sure would be nice to have it. And so he and Cort Van Rensselaer designed such a camera and tried to sell it to HP and they didn't want it. "We don't need that." So they started the company called Jarvan and they started selling cameras that would work with HP scopes. The company said, "Okay, we need it. We'll buy it." But that got Bill Jarvis excited so he started his own company (this became Wiltron, sold in 1990 to Anritsu). He saw that you could make a company and it could work. He hired people like Pete Lacy and Duane Dunwoodie away from HP and went into a competitive business with us.

House: So they were spinouts essentially?

Bagley: They were spinouts, yeah they were. The company, as you probably remember, actually encouraged that. They had that funny ad that I'm sure you remember where it said, "Want to start your own company? Learn how by working for us for awhile." That was a recruiting ad for engineers. They meant it.

House: I saw that like the year I came to the company and I was just amazed that they would run an ad like that.

Bagley: Yeah, yeah.

House: And they did. They took pride in people who went out and did their own thing it seemed like for a long time.

Bagley: They did. People talk about this attitude of respect for your fellow man and respect for your employees. It was respect for not only our employee and your fellow man. It was respect for other companies. That's why if you ever in your division ran a negative ad that implied some other company wasn't as good as you, boy you really got taken to the woodshop on that. You do not ever talk down about any other company. We don't do that. We are a company that on its own is going to grow. Talk about integrity, even financially you're not going to borrow money. We'll earn it. Then we'll spend it.

<overlapping conversation>

House: You never mentioned that before. Say a little more about that.

Bagley: The integrity part of what?

House: No, no the no borrowing money.

Bagley: Oh, yeah. Yeah that was something both Bill and Dave came from the depression era and they had seen some pretty damn sad things happening and they decided if they're going to have a company of their own they will not ever go into debt. They'll never borrow money. They saw too many crashes with people jumping off of buildings and everything. And so they decided they would never borrow money and they started a company with $500 or so down in their little garage next to the house. But they also did get some encouragement from their parents. There was some start-up money, $500 donations once in awhile came in. But as soon as an oscillator caught on and it started a product line that started growing they said, "Okay that's it. We will never borrow money. We've had a couple investors." And they never even got any outside investors until many years later in '58 when they went public, whenever that was. But the idea was if you can't make products that are a big enough contribution that you can make enough profit to keep your own company going you don't deserve to have a company. You got to earn it first and then you spend it. And they had people in HP, business people who said, "Hey this is no way to run a company. For God's sake, if you want to go out in the computer business against IBM you go into massive debt." Packard said, "Goodbye, find a good job elsewhere." While Packard was gone a little of that conversation with other people who said, "Hey we're doing great technically but we're not playing business like we have to play business. If we go into a little better long-term debt we could do some great things." Hewlett was getting convinced. And when Packard came back from the Defense Department he raised hell with that and said, "We will not do it." They were a big company by that time. He said, "We do not do that. This company earns it. Then it spends it." So the idea of a particular financing situation was just stopped right there. We'll continue to do it ourselves.

House: So that and the ethics piece are pretty good evidence they had some very strong guidance, ideas about how to run a company.

Bagley: Yes.

House: It wasn't just the delegation. It was "We're going to run it our way."

Bagley: Oh, yeah fundamentals, yeah, yeah. Yeah integrity means that the specs that you put on your instrument are something that you beat. The customer is going to get something a hell of a lot better when he opens the box than you told him it was. That is your main piece of ad. Your own instrument is what's going to sell more HP instruments and so we had to make sure we were that way. There was no shortcut, no kidding. Boy, if you ain't really better than what you said you don't come to the catalog.

House: So I was assigned a 20 megahertz plug-in when I came and Tech had a 15 megahertz plug-in.

Bagley: Yeah, yeah.

House: And I was told the 30 percent number, right? Pretty soon I'm doing 26 megahertz right? There was a lot of excitement and I supported it. "Well we could advertise 25." That's another big integer right? And 25 versus 15 sounds a whole lot better and boy did I get shut down I mean like, "Oh no, no, no."

Bagley: Oh, yeah, yeah.

House: Because what if it leaked up to 24.8 so 20, we'll call it 20. You do 26 just fine, very educational.

Bagley: You know that was also inspiring to a bunch of guys who were already working 60 hours a week to go to 80. We were so proud of what we were doing and the company even in the corporate objectives say the sense of satisfaction that our people will have for doing a good job will be one of our driving instincts. It said something like that in the corporate objectives. Boy did we have a sense of satisfaction, the corporate objective of contribution said "You will advance the state of the art in this science" and hell yes we were very proud of that because if you did that you could make enough profit that you didn't have to borrow money.

House: Another place that shows is in the community role they took.

Bagley: Yes.

House: They had an objective on citizenship. Say a little about that because I think, again, talk about instilling pride in employees to talk to your neighbors and friends and the community.

Bagley: Yeah, oh boy I'll say, very strong. Yeah I had a personal experience there where in the printer business we were going to have a printer to go to the New York show and I had two versions of the printer being life tested and I needed another couple of weeks to decide which one we would go with. Packard said, "Do you want a couple weeks more?" I said, "Yeah we do. We want to continue the life test." He says, "You will decide tomorrow which one of those two things it will be and you'll go." That upset me. Ed Hilton was in charge of those things and it upset me that Packard would be that urgent about it. So I called his secretary and said, "I want to talk to Dave." And I was told, "Okay, come in at ten o'clock." I went in there and Packard was on the phone and I was going to complain bitterly about how he had just jumped on our project and didn't let us do what we wanted. I heard him talking. He was talking to another trustee on the school board. If these kids, if we don't build another building for a couple of schools right now these kids are going to be in double shift and we have a baby boom and we cannot force these kids to have to have two shifts of school. He said, "Damn it, we need more buildings so we've got to get more buildings going." And he was talking to the other guy on the school board where Packard had the foresight to see with the baby boom that we did not have enough school buildings to handle the population growth that would come from that. He was forcing the trustees to go his way and the school board because of that, it was very known later, but it shamed me so much that I was sitting there complaining about this minor thing about a printer that he wanted done tomorrow. When I saw the degree to which he worked for the community it was really something. I think the industrial park at Stanford benefitted from Packard helping say "This is what you ought to do in the industrial park." Our relationships with our competitors were always very gentlemanly, very, very good. I think the ultimate of his saying "You owe your community quite a bit and you ought to repay it" is when he went to the Defense Department. I really think it was the same thing. We had people like Noel Porter who became the mayor of Palo Alto. We had people like Don Hammond beside us become head of the school board. Barney Oliver being a great advocate of education, had been head of the school board, and that was his service to the community. And so when his term expired, Don Hammond went into it. He became head of the school board and he found he had to do all kinds of things to make good education but that was contributing to the computer. Everyone was supposed to do something like that to pay back the community we lived in. He felt so strongly about that that when he was the head of the Defense Department, a major speech he came out to San Francisco to make was to chew out other management companies for overpricing the stuff that they sold to the Defense Department. He said, “You owe it to your country to do that on a more reasonable basis. The country needs you and you got to quit this stuff with the $600 toilet.” He didn’t use those words. But he saw the way contracts were coming in that they were really overpricing stuff to the Defense Department. I met a guy who came from New England out here. He had a company called Transitron making digital displays and I met him for lunch one day and he said, “Hey, I just bought a whole bunch of HP stock, a whole bunch.” I said, “Why?” He said, “Your boss, Dave Packard, just joined the Defense Department and you guys are going to find business like mad.” I said, “You do not know Dave Packard.” That poor guy lost his shirt.

House: The stock never went anywhere.

Bagley: Hell no. The stock declined.

House: I love it. I love it. Well you’ve given a wonderful set of perspectives here, Al. Is there anything that I haven’t hit that you think is important to say?

Bagley: Hell, yes, you know that.

House: We could go on for hours and hours.

Bagley: We would, yeah. I am just like many people so proud of the association I had with two very great people and the company that they made, yeah. I could talk forever on it Chuck. You know that.

House: Well thank you very much for the interviews today.

Bagley: Thank you.

END OF THE INTERVIEW

