Oral History of Harvey Cragon

Interviewed by:
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Harvey Cragon: I'm Harvey Cragon. I'm presently retired. My last employer was the University of Texas at Austin where I taught in the School of Engineering. My wife and I live in a retirement community here in Dallas and I currently write books on World War II computing technology. The first was one on the Colossus computer developed at Bletchley Park to decipher the German fiche [??] ciphers. The second one was on the Torpedo Data Computer used on American fleet submarines to set up the steering equations to the torpedoes prior to launch. I'm currently working on the Norden bombsight. The Colossus computer was an electronic vacuum tube machine. The Torpedo Data Computer was a mechanical analog as is the Norden bombsight.

Rosemary Remacle: Where were you born?

Cragon: I was born in Ruston, Louisiana in 1929. My parents had been married in the early 1920s and they moved to Ruston. He was a manufacturer's representative for a shoe manufacturer in St. Louis, Missouri. Early in my life, when I was about two years old, the family moved to Monroe, Louisiana where I lived until about 1940 when we moved to Alexandria, Louisiana. I graduated from high school in Alexandria, Bolton High School.

Remacle: Did you travel outside of Louisiana when you were growing up?

Cragon: We traveled. I had three brothers and my mother had the task of raising four boys while my father traveled, which was quite a task. We summered sometimes in Little Rock, Arkansas. My parents came from Nashville, Tennessee and I would travel up there from time to time with them. I believe in 1940 we made a trip to Mexico City in an un-air conditioned car with the small cars of that era and four rambunctious boys and two adults. It must've been a harrowing experience for them. I can't imagine doing it today. But other than that, we traveled mostly in Louisiana.

Remacle: Did you figure out early on that you were interested in science---physics, math kinds of things?

Cragon: I guess that I had an interest and some talent in mechanical things, trying to repair the car when it didn't need repairing and the plumbing when it didn't need fixing and that sort of thing and I had been given a kit to build a radio for Christmas at one time. So I guess it was just natural that I would go into an engineering career.

Remacle: Did your parents or teachers guide you in that direction?

Cragon: No, there was no guidance that I can remember other than encouragement. I was interested in model airplanes and that sort of thing. It turns out that I went and got my Bachelor's degree at Louisiana Tech, which is in Ruston, Louisiana, the town I was born in and my parents had familiarity with the school. It was a little backwater engineering school at that time and they knew the faculty. So I don't ever remember any discussion about going anywhere else but Louisiana Tech, and that's where I went.

Remacle: What was your major when you started out and finished?

Cragon: Electrical Engineering.

Remacle: All the way through?

Cragon: All the way through. However, in those days, the curriculum that I had was power plant engineering and electrical distribution. It was classical EE.

Remacle: You entered college when?

Cragon: I graduated from high school in ’46 and graduated from college in ’50. The college environment in 1950 was, as far as employment was concerned, I think there were only 10% of my graduating class had jobs on graduation day. I went to work for the telephone company in New Orleans as an outside plant engineer, staking pole lines and putting poles in people’s driveways and things like that. But the Korean War and the Cold War changed that. So in many respects, I’m a product of the Cold War. After the Cold War started, the demand for engineers escalated substantially. After I worked for the telephone company, I guess it’s five or six months, I was drafted into the Army for two years and spent that time as the communications chief of a heavy tank battalion. There were two things. One, Korea was not tank country so there was not much need for tank battalions in Korea. We were all looking over our shoulders at that time for the Russians to come into Germany and so we were primed to go over there. But the most interesting aspect of being in the Army was that my battalion went to Camp Irwin, California, which is in the Mohave Desert and we were the test battalion for testing infrared night fighting equipment. This was active infrared in those days. We had searchlights mounted on our tank turrets and on our jeeps and the detectors were passive. They were all passive but it detected the reflective infrared from the searchlights. That was an interesting experience and it’s better to be in a tank on the Mohave Desert at night than in the daytime.

Remacle: Tell me why?

Cragon: It’s cold. You can fry eggs on the turret of a tank in the Mohave Desert in the summer.

Remacle: I grew up in Yuma, Arizona so I know [about the Arizona heat]....

Cragon: You know. But anyhow, the thing I learned in California, even though it was in the Mohave [Desert], was that there were other places in this world than Louisiana. I’d also gone to a service school in Ft. Knox, Kentucky during my tenure there. On weekends, I would go up into the mountains outside of Riverside….Lake Arrowhead, what are those mountains called?

Remacle: The Sierra Nevada?

Cragon: It was up 7000 feet, which was cool. So I got sort of a good introduction to California. Soon after, I discharged from the Army and went back with the telephone company. My wife and I decided we wanted to leave New Orleans, so I started searching around and I applied for, and was given, a job with Hughes Aircraft in Culver City. I got introduced to digital computing there in 1953/’54.

Remacle: What was the application at Hughes?

Cragon: In those days, the Soviet threat was the manned bomber and Hughes was building fire control systems to intercept manned bombers. So that was the application. The first ones were analog computers and they were transitioning to digital computers. So they were real-time control systems to steer the aircraft and set up the firing of the weapon. While I was not in the computer itself, I was in a group that made test equipment for it and at that time, I took a couple of course at UCLA in computer design. So that was my introduction to it.

Remacle: When you talked to friends back in Louisiana and told them you were working at Hughes Aircraft, how rare was that to people outside of your own industry?

Cragon: I think it was pretty rare and rather esoteric. They figured “Don’t tell me too much. If it makes you happy, go do it.” When my wife and I left Louisiana, there were tears in our parents’ eyes wondering “Where in the world are those kids going to, this place called California?” It was as if we were getting on a covered wagon to go to the Oregon Trail.

Remacle: When you packed up to go to California, your parents weren’t--

Cragon: My wife had had a cousin who had gone to California in the late ‘30s so they knew you wouldn’t fall off the end of the world, but it was pretty close to that.

Remacle: Were the two of you excited about this opportunity?

Cragon: We were excited about it because we spent time in the mountains where I’d been, Lake Arrowhead. One summer, we drove up the Coast Highway into Victoria, Canada.

Remacle: So you knew what you were getting into?

Cragon: So we enjoyed Southern California. I’d had enough of the desert and we didn’t spend any time out there but we did other things.

Remacle: Was that your first computing-related project?

Cragon: In fact, when I was in college, I had one course on vacuum tubes. I had a 19th century education when you get right down to it.

Remacle: For the 20th century.

Cragon: For the 20th century. Looking back on that, most of the electronics developments during World War II were done by physicists. Physicists were used to making experimental equipment and things like the first radars and first computers and all of that were not much different from the experimental equipment that physicists were used to building. And electrical engineering was a textbook issue. You're going to run a wire from here to here and it's going to carry so much current. You look it up in the book and it says make that a certain size.

Remacle: When you got to Hughes and you had to start thinking about computing, what were some of the new things you had to learn?

Cragon: The whole idea of binary arithmetic and Boolean algebra was totally foreign to me. The idea that there was a machine that somehow you put a set of instructions in and that it would do things was foreign to me. So it was a "start over from scratch" almost, for me. However, I do say that the education I had prepared me for being inquisitive and asking questions and trying to understand. I was totally deficient in higher mathematics. I was out of college probably three years before it suddenly dawned on me what calculus was all about. I was pretty weak.

Remacle: How did you make up for this deficiency?

Cragon: I went into binary arithmetic and didn't have to worry about it. No, that's not true. I just went back and re-did the books. For example, in my work on this submarine computer in the Norden bombsight, my old college algebra and college trigonometry book were right by my side. I'd refer to them frequently because I'd gotten into a mental block.

Remacle: A different period of time, too.

Cragon: Yeah.

Remacle: Did you go back and do any graduate work?

<audio glitch -- long silence>

Remacle: Nobody said "you're going to go do this", whereas kids who graduate from college today know they're going to work in a digitally-based field. They're still going to have surprises but you guys were particularly--

Cragon: Until I got to Hughes, the word "digital" had never come through my ears….until I got to Hughes, the word "digital" didn't mean anything to me.

Remacle: What were the main things you had to learn at Hughes to do what you were doing?

Cragon: The issue in test equipment was how do you verify that things were working right. The computers that were being built had logic cards with diode logic, so we took a rather brute force approach to it, and that is put a counter with patterns into the suspect card and compare it to the output of the good card. Nothing sophisticated, because it really wasn't an issue to know what the output was. It was just to know if it agreed with what you had with a good card. I did work some on the test equipment for the analog computers, too but that was not as much fun as the digital. That time passed rather quickly and there was not a whole lot to be said about it, other than it furthered my interest in digital computing.

Remacle: From Hughes you go directly to TI?

Cragon: No. I think after four years in California, 1957 I guess it was, we decided that Los Angeles was getting too big -- it might've been '56 -- and we wanted to come back east. They were starting to build these freeway things and it just wasn't a place we wanted to live. I applied for and was hired at the Arnold Engineering Development Center, which is outside of Tullahoma, Tennessee. Tullahoma, Tennessee, if you've never heard of it, it's hard to call it a one-horse town; maybe a half-horse town. But that's quite a shock moving from Inglewood, California where we really lived, to Tullahoma. What was there was a wind tunnel facility run by the Air Force. The site was selected because wind tunnels need massive amounts of electricity to run the fans and TVA had lots of electricity in Southern Tennessee along the Tennessee River and so that's why--

Remacle: TVA would be the Tennessee Valley Authority.

Cragon: Tennessee Valley Authority. I don't think they have a surplus [of electricity?] anymore but that's not the purpose of my being here. The instrumentation on these wind tunnels was digital, digital instrumentation -- rather farsighted. The computer -- I was in the service group; we maintained and modified and upgraded these computer systems -- was an 1102, which is one of Seymour Cray's early machines and there were three of them there and I think those were the only three they ever built. That was an interesting experience and finally after about two years, it seemed like a fairly dead-end type place and dead-end deal, whatever you want to call it.

Remacle: Your position there was?

Cragon: I was an engineer or senior engineer or something, just one of the troops. I've been a miserable failure all my life in management.

Remacle: You prefer to be an individual contributor, as they say?

Cragon: Yeah. So we decided that wasn't a place for us and started looking around and after applying for and being offered a position with Texas Instruments, we came to Dallas, a place I'd sworn I would never live. But here we are.

Remacle: Why did you swear you'd never live in Dallas?

Cragon: Louisiana people just don't want to live in Dallas. It's a cultural thing I guess.

Remacle: But yet you and LJ [Sevin] are here…

Cragon: That's right. If we learned, there are better places than Louisiana. Louisiana is a nice place.

Remacle: How did you get to TI?

Cragon: I sent them a resume and I came over for an interview. There was a feeling at TI that digital was the way to go. TI had been in the signal processing business since its formulation in 1929, or processing seismic signals and analog. Somewhere in the '50s, I don't know the date, TI hired a graduate of MIT, Mark Smith who had worked in digital signal processing and got his PhD in that, and had come to TI and started a digital program in the mid '60s. They built a digital computer, first digital computer for processing seismic signals and since digital signal processing is sort of generic, it's sort of the beginning of all the work I did. It's the first computer that I know of that had the multiply and add instruction as part of its instruction set.

Remacle: This was what year?

Cragon: Must've been '65, '67, '68, along that period of time. It was a plug board computer. The program was set up with a plug board.

Remacle: I don't know what a plug board computer is.

Cragon: It is not a stored program computer. You plug a set of jumper cables in and a counter looks at them and says you do this and then you do that and you come back around. Plug board was quite a known technology in the day. This was the way many of the IBM punch card machines were programmed so it was a known technology and adequate for the job at the time.

Remacle: Your first position at TI was?

Cragon: An engineer. I might've even been a junior engineer.

Remacle: And reporting to?

Cragon: I'll tell you the truth. I can't remember who I reported to. In most places I started out as junior engineer. When I went into the Army, drafted into the Army, they had a rank that no longer exists in the

Army. You came in as a private recruit and were promoted to private. I'm probably the only person you'll ever meet who was promoted to private in the Army. Anyhow, I usually started out as the bottom rung of these places in a purely engineering position. Evidently from the work of this digital side of me, somebody at TI had a vision that there was something to this technology and so I was hired.

At some point, I had made a talk to a group of the engineers on electronic miniaturization. There was a lot going on in those days -- the Tinker Toy concept, the cordwood concept, the thin film concept and so on. And after that presentation, someone came up to me and said "Harvey, that's interesting but you need to get out to the expressway and meet this guy, Jack Kilby and see what he's doing." Unfortunately, I know I talked to him because that started the relationship, but I do not remember the instant. Anyhow, I'm sure Charles Phipps has said something about this.

The integrated circuits in '59 and '60 and '61 were handmade laboratory wonders. I helped write a proposal to the Air Force for what was called the Manufacturing Methods contract. This was to sort of transition from the lab bench to a pseudo-production line. So part of this contract was to show you could build enough circuits to make a little computer so the question then was "what kind of computer do we make"? That led to what's been known now as the Air Force computer.

Remacle: Who helped to make the decision about "what kind of a computer we should build"?

Cragon: I've always liked to have smart people around me and I'd hired a young man named Joe Watson who, as part of a project at the University of Oklahoma, had built a transistor desk calculator, a simple four-function calculator, so he was working for me. We made the decision, the two of us, as to what to do. In those days, the architecture in vogue was a serial machine. It was apparent or it appeared apparent, that you could build a computer with fewer circuits with a serial machine than with a parallel machine. I think that has been disproven and unfortunately, we didn't investigate the issue carefully. We just did what we thought we knew how to do. So the challenge was to design an architecture and incidentally, we took the Harvard approach of disjoint program memory and data memory. The challenge was to get a design which would have enough circuits so that we had a reasonable chance of building them and that we could package it in such a way that we could get the heat out.

It's my belief that one of the big challenges of computers since the vacuum tube days has been the thermal design. You either had to air condition the room or you had to get the heat out of the transistors and then air condition the room or somehow. Even today, with the PC, with the heat sinks and the fan, the thermal design is critical. And it was certainly back in 1962 when we were doing this. So we settled on a packaging design that packaged these flat packs about eight or ten on a flat pack that plugged into a copper grid very closely. They were potted and then we would lap them into the grid and get the heat to this copper grid. If you've ever seen a picture of this computer in its demonstration, we programmed it as a full function calculator. I'll come back to that in a minute. But on the back of it, you see a sign, an octagon-shaped sign with statistics and names and what not on it, and that is not a piece of cardboard. That's a 3/8 inch piece of aluminum to provide a heat sink and there's a fan underneath it blowing air up over it. Back to the computer -- How can you convince anybody you've built a computer? It's got to do something. What can it do? We virtualized it as a full function calculator. It had a keyboard, a display and so that's the way we elected to demonstrate it, even though it was not a special function design for the calculator as Joe Watson had built in college. I understand that's the way calculators are built today. They are stored program machines that are virtualized to do what { Harvey, please complete this thought if possible]-- So that's what we did.

Remacle: How many people were involved when you say "we?"

Cragon: Probably four or five of us, a very small group. Jack [Kilby] built the circuits and we put them in the computer.

Remacle: And you were in the research group?

Cragon: No. We were in what was then called the Apparatus Division, which was the government electronics, built radars and sonars and magnetic anomaly detectors and things like this and Jack was out in the semiconductors. So it was sort of a--

Remacle: Symbiotic relationship?

Cragon: No. It's what you can do with digital circuits. It does not have to be that close a relationship between circuit design and computer design. A flip flop is a certain truth table and a gate has a certain Boolean function. And you can specify voltage levels and then something like that, and they go off and build them.

Remacle: What was your next project at TI?

Cragon: We took that computer on a road show and Pat Haggerty had a talk and we went to Wright Field since they paid for it. Incidentally, the person at Wright Field who deserves a lot of credit for this is Dick Albert. I don't know if you've heard his name before but he had the vision -- I hate that word but it was really a vision -- that this is something that the Air Force should be putting money into. That road show brought about some interest in the world.

Remacle: Interest to use ICs as opposed to some other approach?

Cragon: Yes. Interest in people who want to use integrated circuits. Soon after we were back, maybe a month, two months, something like that, we were contacted by Dr. Van Allen at Iowa State University. He had put up a satellite not really knowing what would happen and had a Geiger counter on it and went through what we now know as the Van Allen radiation belt. It saturated. He had no idea of the intensity of this stuff out there. So he contacted us to build a floating point scalar counter to go on his Geiger tube on his next flight. It would be floating points so it wouldn't saturate on him. We did it. It did [what???] and it was a little box about like this, maybe five inches by two inches, two and a half inches, by half inch thick; maybe two cigarette packs type thing.

Remacle: So we aren't talking some big mass?

Cragon: No. We're talking about a little bitty thing. One of the interesting eras that this introduced was that soon after we had sent this to Van Allen, it was stolen. So the integrated circuit has now made equipment so small that it's easily stolen or lost as we know. So we built him a second one happily and it flew on a Redstone rocket sometime in '63 or '64. I have checked with the archivist at NASA and they can't pin it down for me but it's in that period. So we managed to build the thing out of integrated circuits in those days that could stand the environmental shake, rattle and roll of a rocket launch and continue to work. We were quite pleased with that.

Remacle: Did you have some kind of a group celebration?

Cragon: No. You [just] move onto the next job. The next job for us was we were contacted…I can't say too much about this. It was highly classified at the time and I've never been released, so I don't know. But we designed and built some very special purpose computers for a very special application and they were flown in aircraft, no rockets, flown in aircraft probably operationally in '64 or '65. That was an interesting achievement.

Remacle: Was TI making money? Were these commercial successes for TI?

Cragon: I can only speak for what I was doing in the Apparatus Division. Its latest naming was the Government Electronics Division or something like that. I'm sure that that was at least a breakeven proposition because these were cost-plus government contracts. I was still in a junior engineer position and have no idea what was going on in the accounting office, really didn't want to know.

Remacle: How did information about advances in computing technology get communicated throughout TI, across the engineering community in general?

Cragon: Well, the way they got communicated was through IEEE conferences, special interest groups had conferences and I know-- well, there was great skepticism in the early '60s by engineers, equipment designers in general, about the integrated circuit. In fact, in the talk that Pat Haggerty gave on our roadshow, one of the things was that this would save engineers-- the integrated circuit would save engineering costs. Well, that's not exactly what some people want to hear and...

Remacle: Because they were afraid they would lose their jobs?

Cragon: That's right. Now, we can speak to that in a minute but the prowess of a company in electronics was, in many cases, determined by the skill of their circuit designers. Seymour Cray was a prime example of this. He had great architectural ideas but he also was a superb circuit designer and he could squeeze anything out of it that could be squeezed. So the circuit designers in these companies for sure didn't want those guys in Texas designing their circuits for them. That was their job. Now, the problem was that they didn't see that they could do something better than what they were doing. Certainly in the digital world, they could do architecture of general purpose computing and special purpose computing devices. So there was great skepticism. In fact, we were at a conference in Seattle, don't remember the date, must have been '64 or '65, I know the Space Needle was up at that time, and this was on the university campus and I had given a talk to this assembled group about how we could divorce these two things and the equipment designers could specify the circuits in digital terms and those guys could go off and do their thing. I was hooted off the stage. They just would not abide it and I was in tears. I've never been hooted off a stage before, but it happened. Jack was there and I forget how he saved me, but he got up and said soothing words, like, well, no, he really didn't mean that. It's not that bad. So, anyhow, there was great skepticism about the viability of the integrated circuit. As Jack had said, when you applied the yield equations to a chip and the yield on an individual transistor, you could prove that you couldn't build these things. His famous statement is the mathematics was right but the answer was wrong. So great skepticism.

Remacle: How did that skepticism get overcome with time?

Cragon: I really don't know. I really don't know. I think that there were some of these things and others [that you have interviewed], I'm sure, talked about the Minuteman project, which got committed to integrated circuits for one of the versions of the Minuteman and pretty soon the papers at the conferences started saying, well, you know, maybe, maybe, maybe. And so people started doing it. I think it took a long time. Now, one of the things we did, and we must have started this in '63, was another seismic computer called the TI-870. We committed that to this new idea of the TTL logic family, transistor, transistor, logic. And so, after we could show that we had built a substantial computer, this was not a little toy, this was doing real stuff out of TTL, TTL, I think, was the breakthrough that TI had pushed that got people to really thinking seriously about integrated circuits.

Remacle: So you have now been at TI for, what, two years or so?

Cragon: I came in December of '59 and so, by '65, we were building big stuff.

Remacle: When did the advanced scientific computer come?

Cragon: That started in '65. Now, let me hasten to add that, after this vacuum tube machine called the Dark, the seismic...

Cragon: That started in '65. Now, let me hasten to add that, after this vacuum tube machine called the Dark, the seismic equipment group in Houston built a really elegant computer called the TI-AC. These were in the days that computers were named AC, Johnny AC and TI-AC and so on. And so this was the TI-AC, a transistor machine. Very elegant design and they built quite a few of them, I don't remember, dozens, maybe more than 10, less than 20, something like that. So what we started was a replacement for that machine.

Remacle: What generated the need for that?

Cragon: Well, there were two things, I think. One was that that architecture and circuit design was doing about all anybody could see that it was doing in that technical...

Remacle: It was stretched to its limits?

Cragon: It was stretched to its limits. Second was TI needed a demo for TTL. Now, what was the dominant thought? I don't know but I'm sure they were both at play. So we built that and it was sort of a joint effort. The basic CPU was a fairly straightforward 24 bit register file architecture and the group in Houston designed a convolva [ph?] box, an adjunct processor that did vector processing on the arrays of geophysical datum. What we did when we started the ASC, we...

Remacle: Let me ask a question. Did you envision or did somebody envision that the ASC was going to be in the same class as the Cray or was it somewhere down scale from it?

Cragon: We knew about the 7600/7700 of Cray's machines. We knew about the 7600 and knowledge of the-- about the 7600, or was it the 6600? I'm...But the next one, the 7600 was just beginning to be unfolded. What we wanted to do was build the best machine we knew how to do, money no object, at least that's not the way it started but that's the way it ended up. <laughs> So we just did the best we knew how to do. There were a couple of interesting things...

Remacle: But what I'm trying to get a handle on, in my own head, was it in a Cray class...

Cragon: We had told ourselves as being competitors with Cray.

Remacle: Okay. That's what I was wondering. That's my question.

Cragon: Now, whether we were or not is left to others to judge. I thought we were.

Cragon: Okay. We elected to use a meta-coupled logic or sometimes known as current mode logic, which presented another thermal design problem. We had cards with, I think, 17 layers with all sorts of ground planes in them and they were interdigitated between cold plates that carried chilled water, fans blowing up from the bottom and air exiting from the top. Most of the heat was taken out by the water because the temperature of the air going in was approximately equal to the temperature of going out but the air was merely to facilitate the transfer of heat. We integrated the convolvo [ph?] box idea into vector pipelines, which were directly invoked with instructions from the CPU. We put four of those on. You could buy one with one, two or four. No one ever bought it with one so it was always four.

Remacle: Who bought it?

Cragon: Who bought it? The first one went to Asnselvein [ph??] in Holland for Royal Dutch Shell [. My memory is fuzzy on that as to whether TI owned it or Royal Dutch Shell owned it, but we sent a crew over to Holland to run it and maintain it. That was in 1970. One was bought, and I don't remember the exact sequence here, one was bought by the army ballistic missile defense agency in Huntsville, Alabama, to do processing for anti-ballistic missile work. One was bought by the geophysical fluid dynamics laboratory in Princeton, I think, to do weather forecasting. One was bought by the naval research laboratory in Washington to do whatever it was they were doing at the time. Let me back up. This was in the era of what's his name at University of Illinois with the ILIAC-4. I'll think of his name.

Remacle: We'll leave it at the ILIAC-4.

Cragon: Well, a very eloquent man pushing his array processing ideas. I'll think of his name in a minute. The idea of an array processor had great appeal to TI because, by golly, you could build one thing and replicate it. That's what TI knows how to do and you guys want to do something else. We wanted a Von Neuman program machine with vector processors and I don't remember how we finally sold it but it suddenly dawned on us, I think, maybe I can take credit for it, that a vector instruction is a direct invocation of the Fortran do loop. If you've ever done any Fortran programming, which I've done as little as possible, you have a construct called the do loop. It says do this across this array and that's the way you program vector computers. There was no simple transformation of Fortran into array processing. We could take our seismic programs written in Fortran and, with a little tweaking, run them on this machine.

Remacle: So, as time passes, the ICs are becoming more and more critical to computer design, development, performance?

Cragon: Oh, yes. Yes.

Remacle: As you get into the middle of the lifecycle of the advanced scientific computer, was the discussion about integrated circuits pretty much behind you?

Cragon: Absolutely. The issue is what technology to use. The T squared L of the day was not fast enough, ECL was much, much faster, had all sorts of problems with heat dissipation and maintaining the skew or the clock across a 4,000 square foot room and that sort of thing. Well, that problem exists with any circuit, and those all required solutions, which we came up with. By having a vector computer and vector instructions, we could get the Fortran programs over [??]. Let me add that there were papers coming out of the National Security Agency, fellow named Cotton was writing papers on some of their code breaking machines, cipher breaking machines, that we built on. We took ideas from everywhere because he had written one rather insightful paper on managing clock skew and delays across a system and that sort of thing.

Remacle: So how long did the advanced scientific computer or computer family live within TI?

Cragon: Well, it slowly died. Other computers became available and IBM started putting convolvo boxes or vector boxes on their machines. I retired from TI in 1984 and went to UT and I think it was in 1985, I was invited to come out to the TI facility in Austin and turn off the last running ASC.

Remacle: So what did you do between 1978 and '85?

Cragon: Well, I stayed with the project in Austin until '74. I had been fired as program manager. As I mentioned earlier, I have no managerial talents. <laughter>

Remacle: It doesn't sound like you were all that interested in developing it, either.

Cragon: Well, I wasn't too keen on it. Anyhow, I came back to Dallas in '74 because the ASC project was in Austin and was told to be microprocessor strategy manager. Objectives, strategies and tactics were a way of life for TI then. There was a lot of confusion as to what we were doing and what should we do and this sort of thing. I was told to sort it out. There were a number of products. One product I found was called the TMS-1000, which absolutely was a remarkable product as far as I'm concerned for its day. It had some quirks but I think it had those quirks because it-- since the instruction set was borrowed from somewhere else but, nonetheless, a very interesting product.

Went into toys and games and microwave ovens and all sorts of things in those days. Also building a set of what we called bit slicers in those days. These were higher levels of integration of T squared L into functions that you could cut the slice, slice down through a data path of a computer and have the registers and the arithmetic unit and so on in bit slices and hooked these things together and put a control memory on it and you had yourself an instruction memory and you had yourself a computer. I think that technology doesn't exist any more. There was the start of the microprocessor in those days and I don't know the dates and merely can report this as an observer and not as a participant. There was a company in San Antonio called Computer Terminals Incorporated, CTI. This was in the era of the time-shared computer with terminals. They had built a processor out of T squared L to be their terminal. They asked TI and Intel to come look at that architecture and see what could be done to reduce its cost and probably make it out of some MOS technology. Now, that instruction set was implemented identically in the Intel 8008 and also in a product built by TI.

Remacle: What was the TI product?

Cragon: I don't remember its name. I do not remember its name. It was called the TMS something or other, very unimaginative. Actually, TI delivered the first 8008 to CTI before Intel did.

Remacle: Interesting.

Cragon: However, Intel saw something in that that we didn't see and the rest is history. <laughter> There were a number of us, and I was included in this, who felt, at that time, that we were so unsure of that technology and that application of devices like that, that what research money and development we had ought to go into memories.

Remacle: So did that become your next project then, memories?

Cragon: No, no. I believe the TI management was enamored with calculators and that's where the money went and where the effort went, it went into calculators. Well, right or wrong, who knows?

Remacle: Well, Intel certainly has made a lot of money on it.

Cragon: That's right. They saw something and I was amongst the group, you know? Yeah. "But by golly, we ought to do memory, but let's not do that, let's do calculators". "All right". Well, when we decided we really needed to do something, I was a great champion-- the industrial products group in Austin had developed a computer family called the 990, which was in the minicomputer era. They had lots of software, they had operating systems, they had compilers and they had all of that. So I said what we need to do is build a 990 chip, which we did. It became the 9900 and it was a 16-bit machine. It wasn't one of these 8-bit things like the 880, 8008 and the question was, who needed 16 bits? <laughter>

Remacle: People didn't know it yet?

Cragon: There was internal studies produced that showed that 4-bit-- based on the success of the 1000, that 4-bit computers were-- microprocessors were going to dominate the world. Well, in numbers, they probably do still because of the calculators but, anyhow, it was a tough sell of a 16-bit microprocessor.

…There seemed to have been tough sells throughout this whole story.

Remacle: That's the way life is, isn't it? <laughter>

Cragon: And, technically, that was a success. It was used in the TI home computer, which was not a success.

Remacle: Long-term, it wasn't a success?

Cragon: Long-term, it certainly wasn't. Certainly I didn't comprehend the impact that IBM and Microsoft and Intel team made. I was astounded, you know, IBM just didn't work that way. They'd never bring out a product that hadn't gone through the rigors of the organization. Well, that was the conventional wisdom. So, anyhow, I now forget the dates but it must have been in '78, I was in the semiconductor research group as sort of a guru. Not that I knew anything about semiconductors. I still don't know how...

Remacle: So you were the systems guru?

Cragon: Yes. Yes. That's a good way to put it. And I got to thinking, "well, what do we do? " "Well, what have we always done? We've built signal processing". That's what TI's always done and we had enough background in signal processing, digital signal processing architecture and the technology had support. The time had come to put a chip together that would do DSP. Now, Intel, a couple years before, had built an experimental digital signal processor, I can't remember the number of it but 9009 or something like that, that had been in conference papers and they had done nothing with it. You know, if Intel can do it, we can do it, too, by golly. So I put together a small group and I drew the diagram. It was harking back to the old days. It was a parallel machine, obviously, to do signal processing, but it was a Harvard architecture with disjointed memories which you needed as much memory bandwidth as you can get in digital signal processing so separating the memories helped that problem. Then the problem was selling that.

Remacle: How did you bring customers or potential customers into the discussion of what the product ought to be?

Cragon: Didn't.

Remacle: <laughs> “You build it and they will come”?

Cragon: The problem-- everybody says we got to find out what the customer wants. That's what the marketing people say. Got to get-- well, the customer doesn't know that they want what you’ve got in the back of your mind. That's the problem. Now, I'm no great genius at this, but other people have seen the same thing.

Remacle: That is, I think, one of the core differences between technically advanced products and a bottle......of water or something.

Cragon: It becomes a commodity.

Remacle: Okay. So...

Cragon: But talking to-- well, the customers, for this project, and let me back up just a minute. I got together a group of people. There were five or six of us. We had meetings, all of the meeting records are in the TI archives if anybody ever wants to look at them, tweaking the instruction set. In my first pass at it, I did not have a multiplier. I was going to do an iterative multiplication and somebody said, "Gee, you know, we've got enough space on the chip, let's put an honest-to-goodness multiplier on it and speed it up by a factor of six or eight or something." So those were the sort of things this group did to tweak the design, both the data paths and the instruction set. Well, the microprocessor organization was in Houston, so I would go down there and attend their planning meetings and make a nuisance of myself. There was a nice fish restaurant that had wonderful oyster po boys, so along about 9:00 in the morning, I'd say, "I need an oyster po boy" and go get on the airplane to go down and have lunch and then go to their meetings. Finally, a fellow named John Hughes there took up the banner and actually is the guy who sold it.

Remacle: Internally?

Cragon: Internally. That's right. The chore was to, one of “find markets for it” and, two, “do chip design”, which I didn't know anything about chip design and cram all that stuff into a manufacturable chip. That's what those guys in Houston could do so well.

Remacle: So, by now, what year are we?

Cragon: Well, we're in '82/'83.

Remacle: Okay.

Cragon: '84. Well, I retired in '84.

Remacle: So was the DSP your last...

Cragon: The DSP was up and running in Houston as a funded, honest project by '84.

Remacle: Okay. And was that basically your last big...

Cragon: That was my last thing...

Remacle: Your last TI hurrah?

Cragon: Yes. That was my last. So off I go to Austin. They offered me a very nice...

Remacle: What was the biggest difference between being in an academic environment and being in TI, in an industrial environment?

Cragon: Well, in one respect, in industrial environment, projects don't ever really start and they don't really ever end. You get a little money to do this and then it blossoms and then, you know? At the university, the semester ends and it begins and the semester ends. You get the grades in and that's it. Now, that's not true of your graduate students, who are doing research. However, the good ones are self-motivating. They keep their work going and the academic calendar is a marvelous thing after being at TI.

Remacle: Are you referring to chunks of time off or...

Cragon: I'm talking about the beginning and the end and the time to recalibrate, to do your own thoughts and research. I wrote a couple books while I was there that-- two. So...[Harvey, please fill in the answer that I interrupted here]

Remacle: When you stand back and look at your career, both as-- we've covered mostly the industrial piece because that's relevant to the computer history piece, but as you look at the whole of your career, what are the lessons you've learned, business lessons? I don't mean things like “be nice to people” but business, hard-nosed stuff that you think translates.

Cragon: Well, great ideas do not sell themselves. <laughter> No matter how great the idea, it won't sell by itself.

Remacle: Build it and they will come is not...

Cragon: Is not true**…..**I guess the other thing, and I take this from another thing, I take this from a friend of mine at TI, is you've got to be able to tell the difference between a duck and a decoy.

Remacle: Please explain what you mean by that.

Cragon: What I mean by that is, in the late '70s, well, probably in the '80s, I'd have to go back, the great technical idea was RISC, reduced instruction set processors. Now, I could never buy that and certainly the success of Intel and others of taking the most complicated imaginable instruction set and still squeezing more out of it, now, that idea may be resurrecting in some of the simplest things like controllers for iPhones and dishwashers, places like that, but that seemed to me to be a decoy but it had such an appealing...

Cragon: ...argument. Easy to design. Easy to build, you know? That's what I mean by it because you can frequently see ideas that seem so appealing that they're wrong.

Remacle: Looking back on your career, again in totality, when was the most exciting, fun, challenging time?

Cragon: Oh, golly, that's hard to say. I know each time we produced one of these computers, it was always a celebration. I've always had empathy with the pictures we used to see of the control room at NASA in Houston when they had landed or they had rendezvoused or something, everybody breaking out in cheers. I understand that feeling. I don't recall that we ever had such a celebration at TI because you got the next project right behind you and it's in trouble, in crisis and you've got to...

Remacle: But that moment of elation...

Cragon: It's always there. That…

Remacle: So do you consider yourself an entrepreneur?

Cragon: No.

Remacle: Why not?

Cragon: Well, I've never built a business. I guess an entrepreneur is someone who builds a business out of their ideas— the things I did, maybe have led to other people building businesses, but I never did that.

Remacle: If you had one thing that you could do over again your career, what would that be?

Cragon: <laughter> I seemed to have been awful fortunate to be at the right place at the right time.

Remacle: Did you ever regret that you spent so many years at TI?

Cragon: No. No. I think my wife thinks I worked too hard and was gone too much but I was able to do things at TI that most people are not able to do, so I was honored by the professional societies. Based on that work and those honors, I was given a chaired professorship at UT, a very fine institution with only a bachelor's degree so that was a great...

Remacle: That's a very big honor.

Cragon: A very great honor. That's right.

Remacle: Okay. Is there anything I haven't asked you about that you'd like to make sure is part of this history?

Cragon: Well, I really can't think of anything again but to reiterate it turned out I was at the right place at the right time and met the right people to have an extraordinarily interesting technical career.

Remacle: Thank you so much for taking the time to do this. I really appreciate it.

Cragon: Well, I appreciate the offer.

END OF INTERVIEW

