Oral History of Alan and Henrietta Leiner

Interviewed by:
Dag Spicer

Recorded: June 30, 2004
Mountain View, California

CHM Reference number: X2802.2004

ABSTRACT

In this oral history, Alan and Henrietta Leiner tell about the work that they did for the U.S. government in Washington, D.C. at the National Bureau of Standards, where three pioneering computers were designed. In 1950 the first of these computers, the SEAC, was put into operation. It operated successfully for many years, using programs that were stored within the machine. In 1952 the second computer, the DYSEAC, was completed and was installed in a trailer van, thus making it a mobile computer. It was capable of interacting in real time with a variety of external devices, including the SEAC. In 1959 these capabilities were expanded in the PILOT, whose system included a network of three independent computers capable of working together concurrently on a common problem. Alan Leiner and his staff devised the logical design of these pioneering computers. He and Henrietta Leiner subsequently undertook a second career, investigating the computing structures in the human brain, which led to a surprising discovery about the brain structures that contribute to the cognitive capabilities of humans.

ORAL HISTORY

So, it's June 30, 2004 and we're here with Alan and Henrietta Leiner and welcome. We're delighted to have you here. We're at the Computer History Museum in Mountain View, California. We're going to chat a bit about the careers of these two exceptional people and with particular reference to their work in the late 1940s '50s and some of the '60s at the National Bureau of Standards. So, Alan, let me start with you if I may.

Dag Spicer: Could you tell us a bit about just where you grew up, just very briefly where you grew up and what school you went to. Is there anything that shaped your early interest in mathematics or computers?

Alan Leiner: I was born in New York City in 1914 and was brought up in New Rochelle, New York State. I went to prep school in New England, and later to college at Yale, and for some time to graduate school at Harvard. I was interested in astronomy, had majored in mathematics as well as astronomy, but this was in the 1930s during the great depression and the chances of obtaining employment as an astronomer were nil. In the 1940s, however, the U.S. entry into World War II caused the U.S. Naval Observatory to advertise for astronomers in *The New York Times,* and I applied for the job. I was assigned to the naval observatory in Washington, D.C. where I worked for several years, doing a lot of computing.

Then in 1945 I heard about a job with a higher priority in the war effort, a top-secret project at the National Bureau of Standards, and I arranged for a transfer from the naval observatory to the National Bureau of Standards. There I not only met Henrietta but I worked for many years on a series of pioneering projects, initially on the top-secret project to develop a radio proximity fuze for use by the Army on its missiles (i.e. on bombs, rockets, and mortars). Should I go into any more detail about this?

Spicer: Why don't we break there and why don't you tell us, Mrs. Leiner?

Henrietta Leiner: Before I tell about my professional work, let me make a personal comment about Alan's transfer from the naval observatory to the National Bureau of Standards. I was working at the Bureau in a mathematical group that was eager to recruit him, because we needed someone with his computing skills. My supervisor asked me to help with the paperwork and "get Leiner." I did help with the paperwork and Alan joined our group. A year later we married, and after we married I said to my supervisor: "You told me to get Leiner, so I got Leiner." That's my first story for this oral history.

Spicer: Great.

Henrietta Leiner: Now to start at the beginning, I was born in New York City and I went to public school there. To my great good fortune, an excellent education was available for gifted girls. I went to Hunter High School, which was a select high school with an intensive academic program. After taking that program, I went to Hunter College and I found college very easy. I majored in both mathematics and physics, and I became very much interested in the foundations of mathematics, so I wanted to study a subject called symbolic logic. To do this, I went to the University of Pennsylvania in Philadelphia where there was a professor who was a specialist in what was called "modal logic", and I did my graduate work there.

Then came the 1940s, when the U.S. needed more scientists for help in the war effort. In order to recruit them, the U.S. requested the universities to compile lists of those alumni who had majored in mathematics, physics, engineering, etc. As a result, my name landed on somebody's desk in Washington D.C. and I got a letter, asking whether I could come to Washington to do war work for the government. Although I really wanted to continue my graduate work and get a Ph.D. in addition to my Master's degree, I also wanted to do work that could help win the war. To find out about the work that I would be offered in Washington, I went there for an interview. When the interviewer saw a young female, he offered me a job as a secretary in an office! That's how it was then. I said "no" to the secretarial job, stating that I had majored in mathematics and physics and therefore I might qualify for a scientific job. The interviewer then picked up his telephone and said to somebody "I've got a physicist." I said to him "No, no, no, I'm a mathematician. I majored in physics as well, but I'm a mathematician." He replied "From now on you're a mathematical physicist. We need a physicist." So, I was called a mathematical physicist and I was sent to three places to see which job I would like to have. It seems as though I was destined to meet Alan because one of those places was the naval observatory, but I preferred the National Bureau of Standards, so I went to work there.

Spicer: Well, that's a perfect place to ask. In a previous conversation you mentioned that you actually had to leave the computer group once your husband had started working there?

Henrietta Leiner: Yes.

Spicer: Would you explain that?

Henrietta Leiner: During the war, before we were married, we both worked on the radio proximity fuze, and at the end of the war the head of our fuze project was concerned that the talented people on his staff would now want to leave war work for civilian research. To keep this talented staff from getting dispersed, he got the Bureau to start a new research program on electronic computers. I joined the pioneering group doing this work, and later Alan decided that he wanted to join it too. We couldn't both work in this group, however, because by then we were married and there was a nepotism rule that a husband and wife couldn't work together.

Spicer: Was that waived during the war though?

Henrietta Leiner: No. It was not waived and they said it was because they thought he would favor me. He said he certainly would, and that fixed that.

Spicer: Yes.

Henrietta Leiner: After my husband told me that he wanted to join the new computer group, I decided that I would leave the group so that he could join it. I accepted an offer of a job in the Bureau's electron tube laboratory, which enabled me to work closely with the electronic computer group and to avoid the nepotism rule.

Spicer: What I want to ask you actually is how the National Bureau of Standards first got into electronic computers, the movement from punch card to computer record methods, which worked very well during the war (I think on the Manhattan Project). Can you explain how the interest in electronic computers came about at the Bureau?

Henrietta Leiner: Yes. At the Bureau, the head of the project on the radio proximity fuze was a remarkable engineer called Harry Diamond, who had done very fine research work before the war on an electronic harness for aircraft engines.

Alan Leiner: At that time the aircraft engines made so much electronic noise that it wasn't possible to have decent radio communications between them. His invention made that possible.

Henrietta Leiner: And he also had developed a very fine reputation with the Army because of his work on the radio proximity fuze during the war. This made it possible for him to ask the Army, after the war, about the possibility of receiving funds for research work on electronic computers at the Bureau.

Parenthetically I might add that not only the Army appreciated the work that we had done at the Bureau on the radio proximity fuze. After the war our group got a gold medal from King George VI in England because our fuzes had been used successfully to protect lives from the bombs that were projected from Germany. Our fuzes were installed on missiles sent to England, and they were fired at the incoming German bombs, which were destroyed in the air before they could hit people on the ground.

Alan Leiner: The advantage of the radio proximity fuze was that it could be set to activate our missiles in the proximity of a target, which made it unnecessary to achieve a direct hit in order to kill the German bombs. This frustrated the Germans. They didn't understand how our antiaircraft missiles could be so accurate. Our fuze was the reason. Inside the fuze was a mechanism that could be set to activate our missiles at any specific distance from the target (e.g. 15 yards, 100 yards).

Henrietta Leiner: That's the work that we did in our mathematical group. We would compute what were called the arming tables: how to arm the fuze so that it would go off where you wanted it to go off. And during World War II, we often worked through the night until 4 a.m. because the planes were waiting to take those arming tables to England for use against the German bombs, and to Europe for use in the Battle of the Bulge against Germany, and to Iwo Jima for use against Japan. As a result, the Army was very happy with what we had done on the fuze project.

So, Harry Diamond (who had directed our fuze project and who thought that his talented staff could do work on computers as well) was able to persuade the Army to fund our research on electronic digital computers. Our computer work began in 1946, after the pioneering ENIAC was completed, which the Army had funded in Philadelphia. The ENIAC was proof that computations on data could be performed at electronic speeds, but the stored programs could not be modified by the machine at the same speed as the computations on data. So our research was directed at producing a computer in which both the data and the programs of instructions could be processed at electronic speeds. In addition to securing from the Army the funds to start this work, we later obtained substantial funds from the Air Force. Alan, what was it you were supposed to do for the Air Force on the SEAC?

Alan Leiner: In the Air Force, the Office of the Air Controller must plan programs for doing some of the same things that an army does. An army must maintain an enormous inventory of materials, which it must process and update on time, e.g. how many of this or that is needed at what date. Linear programming provides a way of carrying out such calculations efficiently. At Stanford University, Dr. George Dantzig had invented this linear programming method.

Spicer: Simplex.

Alan Leiner: Yes, and he wanted to compute using this method, so he got the Air Force to grant the first large amount of funds to us for developing the SEAC and was the principal donor financially.

Spicer: Oh, okay. And so, SEAC was a way (and just correct me if I'm wrong) to apply computational techniques for George Dantzig. I guess the term "Operations Research" was used? It would put military logistical planning on a rational foundation.

Alan Leiner: Yes. And in addition to this use of the SEAC for military programming, we also wanted to run programs that originated in different scientific departments of the Bureau. The optics department had a program for ray tracing and the first thing we did when the SEAC was put into operation was to run that optics program, and to design lenses with it.

Before that, we had run a far simpler program as a test run, and the success of that simple test led to an unusual celebration. In the test, we programmed the computer to add +1 repeatedly. At first, things didn't go right and we ran the program innumerable times, until the computer printed out the correct results:

one, two, three, four, five, six, and so on. This output emerged on a yellow tape from a modified Teletype machine, which was used as an output device for the SEAC initially. As the yellow tape kept flowing out, we became jubilant because we saw that the SEAC was actually running under its own steam. (The program pulled in from the input tape units on the outside, and loaded a small part of the memory, and then bootstrapped along to fill up the main memory, and then just went through our test, adding +1 repeatedly.) We celebrated this event by decorating the whole laboratory with the yellow tape that kept flowing out of the SEAC.

Henrietta Leiner: As the yellow tape kept flowing out of the SEAC, we became more and more exhilarated because we could see that the SEAC continued to work successfully. When we had started the work, many naysayers had said that it would never succeed but now we realized that we had indeed succeeded. So, we used the tape as a visible decoration, to show what we had accomplished. That evening we wound the tape around all the staircases of the building and, after we had decorated all the staircases, we had still more tape flowing out, so we started hanging the tape out of the windows. The next morning the director of the Bureau arrived and he saw our building with yellow paper hanging all over it. He was outraged and demanded from us "What's going on here?" We told him "It works. It works. Come see that it works!" After he saw that the SEAC was working successfully, guess what he did. He called up members of Congress and he told them that we had this marvelous machine at the Bureau, so they started trooping up to see it. See, he was a politician as well as a scientist and he knew whom to invite.

Spicer: That's right.

Henrietta Leiner: Shortly after that, about a month after that, the SEAC was dedicated formally and *The New York Times* reported that this "giant brain" had been developed at the National Bureau of Standards.

Spicer: One of the questions I have is that one of the impressions we get from people, especially the people in the first generation that I'm thinking of (Cuthbert Hurd at IBM, for example), who told me when they got the 701 running and did some calculation as a test, he said, "Ooh, it just came out. How are we going to keep this thing busy?" Was that a common experience that you would never be able to use all these cycles?

Henrietta Leiner: Let Alan tell you.

Alan Leiner: There was a banker's convention in Washington and some of us explained to the bankers that we had a new machine for them to use, capable of computing 300 multiplications per second, and they said: "Oh, we couldn't use a machine like that. Our girls couldn't put the numbers in that fast."

Henrietta Leiner: You couldn't get people to understand what we had available for them to use. They didn't understand.

Spicer: In these early days was the hardware design fairly straightforward? Did you have any real difficult problems? And then I want to talk about software.

Alan Leiner: For the hardware design, the electronic people devised some unit circuits (a limited number of unit circuits), each of which could perform some logical functions that were needed for the computer to work properly. Also, we invented a notation process in which we could draw some diagrams of the logical functions, and the logic could then be converted into the electronic component form. It worked quite successfully. We did it without any appreciable errors that I ever found out about.

Of course, when there's a pioneering project like this going on, a lot of people are interested and the place is full of people saying, "Can you make something that looks like this?" I had to make decisions about a lot of alternative proposals. A lot of interminable talk was going on, and the boss came to me and said, "For God's sake, can't you do something about this?" Then I went home to my dining room table, where I could spread out papers and work without interruption, and I furiously worked out a logical design that I drew on diagrams, which could then be converted into electronic equipment. And, all I can say is it worked to everybody's surprise.

Spicer: Your function was what we would call today an architect, is that right?

Alan Leiner: Yes, that's right, I was called a system architect. The system architect has to decide what operations the computer shall perform and how the computer shall perform them. Our designers recorded the specifications for these operations on our diagrams of logical functions (so-called block diagrams), which took the form of boxes. Each box described the logical functions that had to be performed by a part of the machine. Each box was connected to other boxes by lines that specified the flow of information between the boxes. Details then had to be worked out and specified for each small piece of the logic (called a 'stage'). Wiring connections between thousands of stages had to be specified accurately. Then the stages were implemented by packages of hardware that could carry out the logical functions.

Spicer: And so can you tell me who your influences were, I guess the IAS machine obviously or did you just come up with this?

Alan Leiner: Well, we had people from the IAS [Institute for Advanced Study], one person in particular who was a graduate student. I don't think he had much experience on computer design then, but he had some good ideas.

Spicer: Do you remember his name?

Alan Leiner: Yes, Ralph Slutz.

Alan Leiner: But he was a physicist and he didn't want anything to do with computers after the SEAC was finished. He then left our computer group to do work on the radiation belts in the upper atmosphere, the Van Allen belts.

Henrietta Leiner: He still worked at the National Bureau of Standards but in Boulder, Colorado, not in Washington, D.C.

Alan Leiner: I'd say the most significant influence on the SEAC was Samuel Lubkin. He was a very brilliant man and he had a lot of ideas, some of which I decided to use in the SEAC's logical design.

Spicer: So, let's talk about SEAC and the software. Do you have any interesting software stories?

Alan Leiner: I didn't have too much to do with software at that time because there really wasn't any. Everything was programmed in machine language and it was well along before anybody implemented what was called "automatic programming." I remember that one person was talking about how to get people to use the machine and he said, "Well, since everything is in binary numbers, we'll have to get a lot of clerks on hand to convert decimal numbers into binary numbers" and of course the answer was "What do you think the machine is here for?"

Henrietta Leiner: There was a programmer at the National Bureau of Standards by the name of Ida Rhodes.

Spicer: I saw her name, yes.

Henrietta Leiner: She was really more prescient than any of the rest of us because she foresaw what could be done with computers in a way that none of the rest of us did. She stood up one day at one of the Bureau of Standards lectures and she was always very dramatic. She said the time is coming when we will have all the libraries of the world at our fingertips to consult. The rest of us thought, "Well, there goes Ida again." She was closer to right than any of us.

Spicer: One thing that I noticed was that a deficiency of SEAC was the very slow I/O, is that right?

Alan Leiner: That's right. When the SEAC was first put into operation, all of the I/O [input/output] devices were modified Teletype devices. Input was either from a tape reader or keyboard; output was to either a printer or a punched paper tape.

Spicer: Can you tell us about that or any other strengths or weaknesses of the system, lessons that you learned?

Alan Leiner: One of the strengths of the SEAC was that we made it easy to expand the system and thereby the use of the machine. Of course this machine was supposed to be produced quickly with a minimum of money spent on it, so we decided not to build a lot of facilities into it initially but to design the computer well enough so that eventually some new facilities could be connected to the machine. We put in extra connections, which didn't go anywhere initially, but they were there when we needed them later to expand what the SEAC could do.

A lesson about a weakness of computers, which we learned from previous computers that were developed elsewhere, was that their design had made no provision whatever for facilitating how people would use the machine. There were machines where they loaded the memory by giving the mathematician a screwdriver--an insulated screwdriver—and the mathematician ran around touching places inside the machine to put in zeroes or ones. So, I devoted considerable thought to overcoming this weakness by designing what I called the "manual monitor system" in the SEAC.

The "manual" in this "manual monitor system" referred to the things that the operator could do by merely punching the input keyboard. By doing this, he or she could monitor the program being performed and could read out the individual instructions. The machine had a one-instruction-at-a-time mode, which did one instruction and then waited and printed out the contents of various registers and instructions. It could be left running by itself that way and it provided a simple way of online debugging of the SEAC programs. Of course, the programs needed a lot of debugging. Programs always do. So, I think we were ahead of most people in figuring out what the user had to put up with when he or she sat down at the machine. In short order our programmers had written a program for decimal-to-binary conversions (and vice versa, of course), and it wasn't nearly as bad getting started as it was in some places I've heard. Do you want to know more about the SEAC?

Spicer: Absolutely, yes.

Alan Leiner: Initially, one of the things that we were limited by was memory. Memory was expensive and we initially used only 512 words of memory.

Spicer: Were these liquid filled [mercury] or solid?

Alan Leiner: Initially we used mercury acoustic delay lines.

(The main memory consisted of 64 glass tubes, each about a yard long filled with mercury. A quartz transmitter entered an acoustic pulse into one end of a tube and a quartz receiver detected the arrival of the pulse at the other end. It took the acoustic pulse 384 microseconds to travel from one end of the tube to the other, making it possible in this delay line to store eight words of 48-bits each. With eight words held in each glass tube, 64 tubes could hold 512 words, which was all that we had in the beginning. Later we expanded the memory by adding an experimental Williams-tube type of storage, which stored 512 words in 45 cathode ray tubes, with 45 bits available in parallel. Therefore, after this upgrade, SEAC employed both acoustic and electrostatic memories, consisting of 512 words in the acoustic delay line storage and 512 words in the Williams-tube storage, or a total of 1,024 words.)

Spicer: Was this initial memory (the delay line) a reason why the system architecture of SEAC was serial?

Alan Leiner: Yes. The serial idea was built into SEAC because initially the only fast way that we had to store pulses was in a delay line of some sort.

Spicer: So, you upgraded the memory to Williams's tubes.

Alan Leiner: Yes. The Williams tube (a cathode ray tube) was used not only as a storage device but also as a display tube. You could look at the face of a Williams tube and see what was stored there because the ones were illuminated and the zeros were blank. We used it because it was a parallel device, which supposedly is much faster than a serial device. So, initially we started with a serial device, with 45 words going through, one microsecond after each.

Spicer: 45 bits.

Alan Leiner: Yes, 45 bits (I should have said), not words. For the next machine that we designed, the men in my group came up with an idea for making an adder that would add 45 bits in one microsecond.

Spicer: This is a serial parallel conversion?

Alan Leiner: It's a serial parallel speed but it was serial basically, made out of serial components, and it was 100 or 50 times faster. I forget exactly what speed it was.

Henrietta Leiner: I think we gave the museum some of the published papers about this work. Was this Arnold Weinberger's work?

Alan Leiner: Yes, Lynn Smith and Arnold Weinberger.

Spicer: Okay. I wanted to ask you about the problems that SEAC was designed to address. What kind of problems were people solving on it then?

Alan Leiner: We solved the general-purpose problems that the scientists at the National Bureau of Standards put on the machine.

Spicer: These would be scientific problems?

Alan Leiner: Yes. Some of these problems are listed in the pamphlet written by Henrietta for the dedication of SEAC.

Spicer: The lens maker's formula was one of those?

Alan Leiner: Yes. I suppose I can tell you that the AEC [Atomic Energy Commission] gave us problems and the National Security Agency gave us problems.

Henrietta Leiner: There was some classified work that I wasn't allowed to mention, when I wrote. The classified stuff we never wrote about. We knew about it and we did the work but we never wrote about it.

Alan Leiner: About other problems that SEAC tackled, I remember that there was a man who came up with something called the DYRO (Dynamic Representations of Operations). We got a telephone line from the Washington airport to SEAC, and on a scope we put in a radar picture of the flights then going on around the airport. At the same time, we fed information into SEAC. So, the radar information from the airport was available to SEAC, which could compute various simple things at the time.

I remember an amusing story about our equipment at the time. The SEAC was in a building that got kind of dilapidated. In the room that SEAC was in, space started appearing between the walls and the floor. We closed the room off so that people couldn't see it, but we put the scope and the keyboard outside in a little compartment, and we put a black cloth over where the wires went. A general came in to see us, and he was astonished that we had compressed the equipment so much.

<laughter>

Spicer: Into your little typewriter, yeah, right. Well, what was it like when you walked into the machine room? Was it noisy? Did it have a smell to it?

Alan Leiner: Nearly everything smelled of ammonia from the copying machines. It was the atmosphere we were brought up in. And the Teletype was noisy and greasy, and it was a pain in the neck, so we replaced it with something better called the Flexowriter, which is more like a typewriter with paper tape readers. The paper tape readers drove the Flexowriter, and the SEAC produced the paper tapes that went into the Flexowriter. Essentially we were using the Flexowriter as an output device for the SEAC.

In addition to these paper tapes, we also used magnetic tapes that went into an output device devised in our lab to solve a difficult problem. The problem was how to get a big reel of tape rolling in milliseconds without flying apart to pieces, and to record at those speeds on the tape. So, a fellow by the name of Jim Pike produced an output device which he called "Pike's Peak," in which the tape was spewed out of the machine but in between two vertical pieces of glass. The separation between the two plates of glass was equal to the width of the tape, so the tape couldn't get twisted or distorted in any way. And so these big glass plates, which were a yard across and a yard down, contained this unrolled tape and it worked very well.

Henrietta Leiner: I want to add something. Everything that Alan said is true but I want to add that the computer was in an air-conditioned room. The rest of the place was not air-conditioned in those days, and Washington in the summer when you're not air- conditioned is really something. So, although the computer room was dilapidated, we couldn't wait to get into it because outside it was so muggy and so unpleasant that we had to put jars of salt tablets in the hall. We did this so that the scientists could go out of their labs to take a salt tablet because we would perspire so much in the summer doing the work that we'd need the salt.

Spicer: Wow! How big was the machine I mean when you looked at it?

Henrietta Leiner: It was the length of the room.

Spicer: Maybe 30 feet long?

Alan Leiner: I think you can answer that question by looking at the photographs that we gave you of the machine.

Spicer: Did it have special power, like a motor generator in the basement or anything, anything special?

Alan Leiner: I don't know. I don't remember.

Spicer: The thing that amazes me is how fast you put this together.

Henrietta Leiner: In two years we went from Alan's design to a dedication day when the computer really worked well.

Spicer: And it went until 1964?

Henrietta Leiner: Yes. It was decommissioned in 1964, so its active life was quite long, almost 15 years. When it was decommissioned, the Bureau donated a piece of the equipment to the Smithsonian Institution, which wanted a memento.

Spicer: Good. So, did the style of problems change as it went through its life? What made it last is what I'm asking. How did it last so long?

Alan Leiner: The scientists at the Bureau had increased their use of the machine. At first, it was very hard to get the other scientists to use it in their work. It really was revolutionary, the idea of sitting down and typing instead of reading instruments with microscopes and so on. And so its use proceeded rather slowly. I remember going around trying to persuade scientists to use it and it was a difficult job. I can tell you one story though. A young fellow that worked for me had a job previously in the optical section, spectroscopy section, and he observed an elderly woman who had spent her life doing an interminable series of calculations. He thought he could help her and so he said, "Give me some of your work and I'll put it on the computer and see how it works, and you won't have to do it this way". She gave him the stuff--six months' worth of work-- and he took it away and he brought it back in a day or two all done and printed out, and she burst into tears.

Spicer: Ah, just frustrated, all that time wasted.

Alan Leiner: About the drudgery of doing mathematical computations, I experienced this at the U.S. Naval Observatory, where we used the punch card machines that were available at that time. With those computers you could die carrying the trays of cards around and putting them in place. I kept thinking: "There must be a better way of doing this". And it remained kind of an abstract idea until the notion of better computers was inspired by---

Spicer: ENIAC?

Alan Leiner: Yes. ENIAC was a programmed computer in the sense that the later computers were.

Spicer: It didn't store its programs.

Alan Leiner: At least it stored programs in plugboards and things of that sort. This really was a culmination of something that I wanted for a long time before, but I had no notion that it was a possibility. So there was a lot of satisfaction for me in using the SEAC.

Spicer: I wanted to ask a question. I wanted to ask you about a quote by, I forget who it was, a famous computer designer who said, "Don't worry about having original ideas. If they're truly original you'll have to ram it down people's throats. Don't worry about people stealing your ideas because if they're original they won't believe you anyway."

Alan Leiner: Yes. That's true.

Spicer: And then the other thing I want to ask you about is the term "Giant Brain". I think you may be uniquely qualified to answer how it came up.

Henrietta Leiner: The reason that the journalists called the SEAC a "Giant Brain" was because it was so big, so fast, and so different from the mechanical computers that we used to use on our desks. But we disliked the term "giant brain" because we thought it was a misnomer. We regarded our computer as a giant tool for the human brain.

Spicer: So, what came after SEAC?

Alan Leiner: The DYSEAC came after the SEAC. It was developed for the Signal Corps, which wanted a machine to operate out of its proving grounds and to do various kinds of computation that it needed to do in the field. So, for this Signal Corps machine, our engineering group took the original components of the SEAC and designed a new hardware package, which my staff and I utilized in our logical design of DYSEAC. This new hardware package sufficed for implementing virtually 100% of the internal logic of DYSEAC. Each small piece of the logic was called a "stage", and the logical structure of the entire computer was completely described by specifying the one-to-one wiring connections between the stages. It required extremely close control of the identity of each one of thousands of stages, as well as each pair of connections.

What bothered me about these wiring connections was the question of how this avalanche of data could be recorded correctly. So, what I did was work out a simple method whereby we could use paper cards to do it accurately. Each small stage of the logic was represented by a little paper card, and on that card would be written the name of the other stages to which this stage was connected. Further, each card had a tiny magnet embedded in it, as did the tray in which the cards were loaded. When the tray was loaded up with cards, the magnets kept the cards in a stable location, so that they were very easy to work with. The work involved taking the logical diagrams, which contained all the necessary connections of the stages, and transferring to each little card the connection indicated on the diagram. It was very easy to check and you could have one person check another person's work.

Spicer: This was a design methodology.

Alan Leiner: Yes. I improved this design methodology by considering how the designers could talk to each other about connecting a place in the machine to another place in the machine. You give each place a name and what kind of a name can you give it, numerals? That really isn't the right way to do it. So I got an idea from someone about generating pronounceable names, and we worked out a scheme for generating four-letter words on a computer. Then I devised a scheme for making them pronounceable. As a result, our computer could generate alphabetical lists of four-letter words that were pronounceable.

These lists, however, posed a problem because we could not use some of the words; they were considered indecent and unacceptable socially. The designers had to be able to discuss the words among themselves in talking about their design, so they had to have names that not only were pronounceable but also were acceptable socially. The only thing to do, therefore, was to run off the whole list of names and delete from that list any words that were socially unacceptable. But to do this was difficult because the place was always full of visitors and we didn't want them to see us compiling indecent words for deletion from the list of names. So, one of the fellows came in at night, when no one could see what he was doing, and he deleted the indecent words from the list of pronounceable names.

I wrote a paper for the ACM [Association of Computing Machinery], giving the algorithm for generating pronounceable names, and it's really very good because it's an error catching thing. If you made an error, you came up with an illegitimate name and, of course, the computer could always check legitimacy. So, all of the data on our logical design was put through this screen and the odds of an illegitimate name getting through were very small, negligible. I don't know whether anyone else used it but I always thought that it was a good idea.

Spicer: And you ran that program on SEAC or DYSEAC?

Alan Leiner: We ran it for designing the logic of DYSEAC, which was basically very similar to SEAC but it had improvements in many ways and extra operations.

An important property of DYSEAC was the ability of the computer to interact in real time with a variety of external devices, including another computer such as the SEAC. Also, in each of our computers, we provided for extra arithmetic operations whenever possible.

(For example, I remember when designing the SEAC that some people would say "The machine has got to add, subtract, multiply…but divide is out of the question. It is much too complicated for the machine to do." So I initially designed the SEAC arithmetic unit to add, subtract, and multiply. Having done that, it became apparent to me that with a serial computer able to multiply, it can be made to divide as well by providing a trivial amount of extra equipment. I then put the divide operation into the SEAC. Similar situations presented themselves with the DYSEAC and the PILOT also, where we included square root, binary-to-decimal conversion, floating-point arithmetic, etc. Things like that happen as you go along.)

In designing the PILOT, we found it feasible to extend the utility of the system by organizing within it a network of three independent computers which intercommunicated in a way that enabled them to work together concurrently on a common problem. The system could be used not only for processing business and scientific data but also for automatic communication in real time with other computers, which could be located at a remote distance from the PILOT if necessary. Our design made the PILOT fast enough and flexible enough to accept, with little or no advance notice, a random stream of information about events occurring at a remote distance and to respond appropriately. This design was completed in 1959, and that year I reported on our work at the first international conference on information processing, which was sponsored by the United Nations (UNESCO) and was held in Paris, France.

POSTSCRIPT

Henrietta Leiner: In 1960 Alan decided to leave the National Bureau of Standards and work instead at IBM’s main research center in Yorktown Heights, New York. As a result of our move to New York, I was able to make a change in my career too, which I wanted to do for the following reason. I knew that computers could do some of their cognitive work much faster than could the human brain, but I also knew that computers were less versatile than the human brain in processing information. For this reason I was intrigued by the question of how the human brain achieved its versatility, and I wanted to investigate this question professionally. I went back to graduate school to learn about the brain’s anatomy at Columbia University in New York, where I received excellent mentoring from an anatomy professor (Dr. Charles R. Noback). His guidance enabled me to do research on the brain subsequently, in collaboration with an eminent neurologist (Dr. Robert S. Dow).

Fortunately, this work on the brain turned out to provide both Alan and me with rewarding intellectual activities because after Alan retired from IBM he joined me in my research. We then published (as co-authors with Dr. Dow) a paper containing our theoretical prediction about a brain structure called the cerebellum, which is located at the bottom of the human brain. This low-level structure is known to contribute to motor skills. We predicted that it also could contribute to mental skills. At first our prediction was met with incredulity that a low-level structure could contribute to some high-level capabilities. But subsequently this prediction was confirmed experimentally in several research laboratories, both in the U.S. and abroad. We therefore continued our work on the cerebellum for many years and published a series of additional papers on its cognitive capabilities in the human brain.

The response to our published papers surprised us. We were deluged with requests for reprints from all over the world, even including Siberia! In fact, our work attracted the attention not only of other scientists but also of the press. *The New York Times* in 1994 devoted several pages of its science section to an article about our work.

To summarize the work that we did from the 1940s through the 1990s: we embarked on an intellectual journey of discovery through the burgeoning field of computer research and the burgeoning field of brain research. The knowledge that we acquired in research on powerful computers helped us in our research on the human brain; we found that some fundamental principles underlying the processing of information could be applied equally well to understanding both computer systems and the nervous system. In applying such principles to the human cerebellum, we concluded that the processing capabilities of this structure had been underestimated in the past. Rather than regarding it solely as a motor structure, we identified it as a treasure at the bottom of the brain, a powerful treasure that can contribute not only to motor dexterity but also to the mental dexterity that is characteristic of humans.

