Thelma Estrin and the Origins of Biomedical Computing

By Alexander B. Magoun

IEEE Life Fellow Thelma Estrin recalls a career demonstrating that women and men are equally competent in electrical engineering.

Editor's note: *This month we bring to you an article based on the IEEE Global History Network's Oral Histories series. Since its establishment over 30 years ago, the IEEE History Center has collected the oral histories of prominent engineers. Center staff and volunteers have conducted more than 600 interviews, all of which are available on the Engineering and Technology History Wiki administered by the History Center, www.ethw.org. Scholars in a range of fields have drawn extensively on these interviews as have writers and producers of popular books, articles, exhibits, and documentaries.*

In 1992 Frederik Nebeker of the History Center interviewed Thelma Estrin (1924–2014), first female IEEE vice president and one of the first female Life Fellows. She was noted for her pioneering contributions in the 1960s and 1970s to brain research and biomedical computing. Here Estrin discusses the impact of a strong mother; being one of the first women to pursue an electrical engineering education and profession; her application of computer systems to neuroscientific research; and her efforts to improve society as an administrator. The transcript of this candid interview, in which Estrin recalls many of the people who discriminated against her because of her gender or profession, can be read at http://ethw.org/Oral-History:Thelma_Estrin_(1992). Ten years later Janet Abbate followed up with an oral history located at http://ethw.org/Oral-History:Thelma_Estrin_(2002). In 2006 Deborah Price interviewed Estrin on behalf of the Society of Women Engineers; the transcript is available at http://ethw.org/Oral-History:Thelma_Estrin_(2006). All quotations in this article are from the 2002 interview.

I. NEW YORK BORN AND BRED

Thelma Austern was born in Harlem, Manhattan, in New York City in 1924 to Isidore, a traveling shoe salesman, and Mary, who had owned an automotive parts store before marriage. As the surviving twin of a premature birth and only child, Thelma received especially good care from her mother, a public-spirited and dynamic woman who drove a car and brought her hot lunches in grade school.

> When I went to camp as a young child, I saw her driving a car. I told her, "You were driving a car." She said, "No, I wasn't." It was a different culture, and conventional women didn't drive automobiles. I remember her being different from other women.

With the onset of the Great Depression, the family moved to an apartment in Brighton Beach in Brooklyn, where Thelma attended Abraham Lincoln High School and excelled in her classes, especially mathematics. She was

> always bright in school, but at the same time, I was always very sloppy. I was not neat and careful and would always lose my gloves or sweaters. When we began to write with ink, I always had blotty hands and clothes.

During high school she dated Richard Bellman, captain of the mathematics team at Brooklyn College and future IEEE Medal of Honor winner. He encouraged her to take trigonometry, an elective course. Her future lay in college,

> which was not common in the 30s. When I went to school, probably 80 percent of the girls took a commercial course and studied typing. I still can't touch-type . . .. According to my mother, I was going

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Fig. 1. *Thelma Estrin (Courtesy Engineering and Technology History Wiki).*

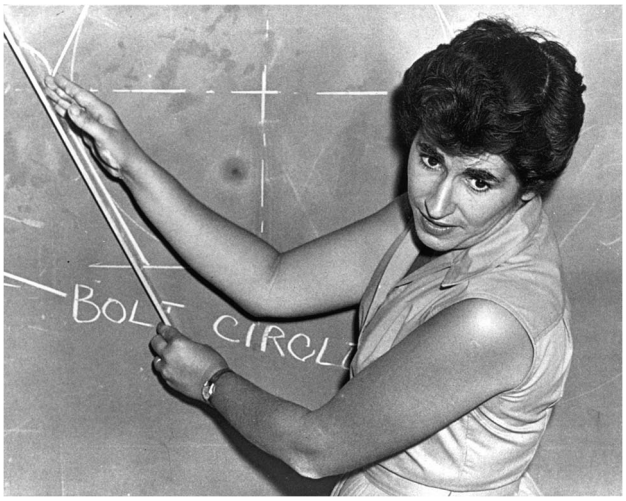

Fig. 2. *Thelma Estrin teaching engineering drawing at Los Angeles Valley College, c. 1958 (Courtesy Engineering and Technology History Wiki).*

> to be a lawyer. . . . I thought so too. I was a judge in our high school court, run by students.

Several factors turned her in another direction. When Austern graduated from high school in 1941, her mother had died of cancer and the best local college was the downtown Manhattan branch of City College School of Business and Management, which "accepted 75 women a semester, and it was difficult to be chosen." She met Gerald "Jerry" Estrin, a senior who had changed his major from history to accounting, and they engaged to marry on 21 December. With the entry of the United States into World War II and the death of her father in January 1942, Thelma enrolled in the Stevens War Industries Training School at the Stevens Institute of Technology across the Hudson River from Manhattan.

> There were three parts to the course. One was basic math and physics taught together . . .. Then there was a drafting course and a foundry course. I did terribly in the drafting course, as I have no natural aptitude for spatial visualization, and had never thought about three dimensional space. As a matter of fact, before I took the Stevens course, I went to a placement center . . .. The person who gave me the results of the test said they had never tested anybody who had done so well in the verbal and done so poorly in the spatial visualization. She didn't think I should go into an engineering assistant course, but I did anyway. The drafting was very difficult for me at Stevens, but I was superior in the two other courses.

While her husband trained in the U.S. Army Signal Corps, Estrin started working as a machinist at the Radio Receptor Company at 251 West 19th Street in Manhattan.

> I would use the lathe, the surface grinder, the milling machine, to cut to rough dimensions the parts that the model makers were then going to use. In the laboratory I was assembling test equipment and helping to repair instruments, under an engineer or technician's supervision. . . . I was soldering and building circuits following a circuit diagram. Or I would test resistors and capacitors to obtain those nearest to their given value. This was a lab, and I began as an electronic technician's helper. I would have become a technician, if I had stayed longer. . . .

She enjoyed the work, notwithstanding the casual revelations by the men around her of their marital infidelities and the patronizing attitude expressed in the company's newsletter: "From a casual survey of her physique, we would venture to guess that she spends more time with a racquet than with Beard and Prescott."[1] Estrin

[1]Quoted in *Radio Receptor News*, in Frederik Nebeker *Sparks of Genius: Portraits of Electrical Engineering Excellence* (New York, NY, USA: IEEE Press, 1994), p. 203. No reference to "Beard and Prescott" or to "Prescott" with an obvious connection to machine tools or shop practice appears in a Google search. Beard may refer to the L. O. Beard Tool Company's combination micrometer and height gage.

decided to become an electrical engineer: "Many of my male friends at Radio Receptor were electrical engineers, and my female friends were draftswomen—which was not a vocation for me." Jerry had also decided to pursue the profession. At the war's end in 1945 the Estrins reunited in New York City, where Thelma had started taking the first engineering courses open to women at City College.

II. EDUCATION ON THE FAST TRACK

The couple wanted to leave New York and through a friend learned about the University of Wisconsin's program. Starting as sophomores and working eighteen hours a day, they graduated with B.S.E.E. degrees in 1948 and completed M.S. and Ph.D. degrees by 1951. Thelma studied under Thomas J. Higgins as she focused on analytical engineering with an eye toward juggling her future family and career. For her master's thesis she applied double Laplace transformations to problems in electrical circuit analysis and electromagnetic theory [1], [14]; for her dissertation she used the method of incremental areas to calculate a two-plate capacitor's charge distribution [2], [15].

Estrin stood out in the department for three reasons. One was her Jewishness: "There were a group of people there who were very pro-German, and pro-Nazi. A couple of their children were in the engineering school, and they blacklisted me. Tau Beta Pi is an honorary fraternity, and if one or two people were against you, that's what could happen."

Others

> commented about my New York accent. . . . "She's a good teacher, but her New York accent . . .." When I think about it today, I realize it was the woman part that they found strange. Actually the students in my class didn't ever believe I was going to do anything with engineering. They either thought that Jerry was keeping me in school to keep me out of trouble or to help him with his homework. The fact is, we rarely work together because we're very different. Jerry frequently worked with two friends of his, and I worked by myself. In my power machinery course, my professor—his name was Watson [may be confused with Kurt F. Wendt], said to me, "It's okay. You can be in my class. I love having you. You're very smart. But you have to promise me when you leave school you must have three children to keep up the birth rate." And I did.

III. BIOMEDICAL ENGINEERING BY CHANCE

Jerry finished a year earlier with the help of a research fellowship that Thelma would not receive as a woman: "I claimed, 'I'm going to continue.' And they'd reply, 'Oh, you think you will, but you won't.' I therefore was given a teaching fellowship." She also won the Ellen C. Sabin Fellowship from the Association of Academic Women, which Estrin used when her husband received an offer to help complete John von Neumann's JOHNNIAC at the Institute for Advanced Study. The couple moved to Princeton, New Jersey, where the pioneering electronic, programmable, general purpose, digital computer had proved more difficult to realize in hardware than von Neumann imagined [3].

The Estrins moved into housing at the Institute for Advanced Study and joined the hard working JOHNNIAC team, which "also partied a lot, too. They would work till eight or nine o'clock. Go out to dinner for two hours and then go back to work again until the middle of the night. Sometimes they would work all night and just get a few hours of sleep."

Thelma verified the mainframe's wiring schematics before resuming her Ph.D. After writing her dissertation and working out multiple linear equations on RCA Laboratories' analog electronic computer, Typhoon, Estrin began commuting two hours each way to Columbia Presbyterian Hospital's Neurological Institute. She had interviewed with Jan Rajchman for a position at RCA, only a couple of miles from the Institute, but the Labs were not prepared to hire the first female member of its technical staff.

> I've since met people who've told me Rajchman gives everybody very rough interviews. But what RCA personnel told me was—and this is funny—"that they didn't have a ladies' room for me at the time." And I said, "Well, what about the ladies room that the secretaries use?" "Well no, that wouldn't be proper."

Instead Estrin began working with physicians and neurologists as a research assistant in the Electroencephalography (EEG) Department at the hospital. Succeeding Robert Schonfeld, she oversaw half a dozen EEG machines and their technicians. Her major task, however, was to redesign a frequency analyzer, "[i]mproving the circuit design of the equipment, and finding what was wrong with it. And also understanding the signals that were coming in and how to analyze them and display the results" [4]. Estrin's ability were worth an author's credit on a research publication [5]. More memorable were the visits to the operating room:

> We were recording the EEG of a person who was having brain surgery. We had electrodes monitored by the EEG recorder, and there was a tremendous amount of noise in the recording, and no EEG was present. . . . I had no idea where the noise was coming from. The EEG technician could not help, and I finally had enough nerve to go closer to the patient

and find out that he was not really grounded. I grounded the patient, and the operation proceeded.

Working on von Neumann's computer and brainwave data led to an insight:

> I began to think at that time whether neuroelectric signals could be digitized for greater accuracy and analyzed by a computer. Because digital techniques are just much simpler and don't vacillate. They either do something for you or they don't do something for you. Whenever you use analog techniques, you have to calibrate them and there are always variations.

IV. BUILDING WEIZAC

The birth of her first daughter in February 1953 removed Estrin from Columbia, and Ephraim Fry offered Jerry an opportunity to help build Israel's first computer, which took the family overseas. Israel had recently marked its fifth anniversary as a nation, and life was

> pretty rough. But I liked it. You had a feeling that every item mattered to the people. If you had a piece of paper, you knew where the paper came from. If a new factory was built, everybody knew about it. Everything had a value at the time and life was very meaningful.

The WEIZAC was modeled on the JOHNNIAC with the intent of using it to answer a variety of scientific and industrial problems requiring complex calculations [6]. The Estrins settled in "a lovely little house near the Weizmann Institute" in Rehovot and hired a nanny, and Thelma improved the reliability of the adder and multiplier with a circuit design that used newer models of vacuum tubes. She worked full time up to the birth of her second daughter in November 1954, and "three quarters time after she was born. It's easy to get help in Israel."

V. BEGINNING BIOMEDICAL COMPUTING AT UCLA'S BRAIN RESEARCH INSTITUTE

With WEIZAC completed the Estrins returned the Institute for Advanced Study, which "didn't want a computer because it made too much noise. Of course it made no noise, and was in a separate building. . . . [w]hen we went to parties, mathematicians were always talking about how great von Neumann was before he got hooked on computers."

After Thelma spent a year teaching mathematics at Rutgers, the State University of New Jersey, she and Jerry moved to Los Angeles. UCLA had offered him a faculty position and they thought von Neumann would also join the faculty. Von Neumann became fatally ill with cancer, however, and UCLA's engineering department would not permit dual family hires to prevent nepotism. Thelma taught at a community college, declining opportunities in the region's thriving aerospace industry because she "was not really interested in traveling a long distance to work in a large aerospace company. . . . [T]hat would have been more difficult for my daughters."

Coincidentally, in UCLA's Medical School, leading neuroscientist Horace W. Magoun (no relation to the author) established the Brain Research Institute (BRI) in 1959 as an interdisciplinary center for understanding brain functions and behavior [7], [16]. A year later Estrin was tapped to organize its first conference, on using computers in EEG analysis, an opportunity she ran with by enlarging the scope of participants beyond those proposed by physiologist Mary A. B. Brazier [8]. "I . . . obtained several Rand [Corporation] mathematicians and some UCLA graduate students. Richard Bellman came to the conference. I really ran the whole thing. Not only the administrative part, but planning and naming the sessions and getting coherence out of the variety of presentations."

The conference was a success and M.D., ham radio operator, and future IEEE Fellow Ross Adey urged the BRI to acquire its own computer as the basis for a data processing laboratory since "[p]erhaps 25 or 30 [BRI researchers] were somewhat interested in the computer." He and Estrin collaborated on a successful application to that end with the National Institute of Neurological Diseases and Blindness, which funded the BRI's DPL for the next twenty years. The grant also enabled Estrin to pursue the development of an analog-to-digital conversion (ADC) system. This was essential for anyone processing EEG data on a computer, and Estrin's device digitized the amplitudes and time intervals between neuronal "spikes" or changes in electric potential [9], [17].[2] "My idea was to ultimately have all people collecting neuroelectric data use a computer system." Because "nobody knew about computer instrumentation and analysis," Estrin "became involved with many problems and instructed BRI investigators on how to use computers for their research."

VI. DIRECTING THE BRI'S DATA PROCESSING LABORATORY

After returning from Israel on a Fulbright Fellowship in 1963, for which the associate dean of UCLA's Medical School forced her to resign, Estrin rejoined the BRI in Mary Brazier's lab. She had improved her ADC system in Israel, which she incorporated in a semi-real time system connecting labs, the converter, and an SDS 930 computer, all on different floors of the institute's building [10], [18].

[2]For earlier ADC devices and systems, see Communications Biophysics Group of Research Laboratory of Electronics and William Siebert, *Processing Neuroelectric Data*, Tech. Rep. 351 (Cambridge, MA, USA: Technology Press of the Massachusetts Institute of Technology, 1959).

Estrin also pursued her own work, "displaying the EEG as a topographical pattern for successive instances of time. . . . The idea of looking at brain waves in space rather than only time is apparent when using an analog to digital converter. Displaying the digits that result in the form of a movie was the idea we achieved by modifying camera equipment" [11].

The problem was the quality of data: "We really needed 32 electrodes, and placement of them took too long. When you finished the experiment, you weren't sure the contacts were as secure as when you started, and if the voltages that were being recorded were really accurate." This led to the "turban. . . . something you could put on your head with all the spacing of electrodes in place." The turban is now a popular device and term, especially among parents whose children are undergoing EEGs.

Because she was the only staff member to understand the components and totality of the Data Processing Laboratory's system, Estrin had been *de facto* director of its $300 000 budget in the late 1960s, when the National Institutes for Health expressed concern.

> For many years the computer committee of the BRI was always looking for somebody to be the director of DPL. We had numerous computer committee meetings and interviewed lots of people. Important scientists would not come because they could not also get a faculty appointment in a department, which is tenured. I finally got the position, because well known outside people would not accept.

Between 1970 and 1980 Estrin introduced minicomputers and microcomputers to improve the real-time processing of EEG data, and recruited and collaborated with researchers. She struggled to convince administrators and sponsors of the value of the increasing value of computing and medical informatics, as EEG studies began to pale in analytic power compared to techniques evolving from the discovery of DNA and Solomon Berson and Rosalyn Yalow's invention of radioimmunoassays. "Today [1992], neuroscience is primarily chemical and biological. . . . [I]t's the molecular techniques . . . and finding out what really is going on at the cellular level that is exciting today."

Estrin closed out the Data Processing Lab from a faculty position she finally gained in 1980 in UCLA's Computer Science Department. There she taught a graduate course on computers in medicine and advised Donna Hudson, who "needed a remote project." Estrin connected her with the School of Public Health, which "had analyzed the effectiveness of chest pain diagnosis in the emergency room. If you came in with chest pain, what are the set of priorities and procedures that you did for triaging?" Hudson wrote a machine-independent expert system, EMERGE, in PASCAL for diagnosis on a personal computer, which she and Estrin generalized for medical audits [12], [19].

VII. LIFE AS A DIRECTOR AT THE NATIONAL SCIENCE FOUNDATION AND UCLA

In 1982, because of her work at UCLA and in IEEE, Estrin was invited to direct the Electrical, Computer and Systems Engineering Division of the National Science Foundation (NSF). During her two-year rotation she oversaw 400 projects funded with $30 million; more significantly she saw the benefits of merging the Bioengineering and Research for the Handicapped programs and persuaded her peers and superiors to do so. Estrin also lobbied for support for funding the National Technological University's (NTU) distance education program via satellite, and pursued the innovation of such programs when she returned to UCLA and was hired to direct the Engineering and Science Division of UCLA Extension.

> Extension should be a very important part of the campus because of the diversity of our population, which needs many types of education in new and interesting ways. I brought the head of NTU to UCLA, and he saw the deans. We discussed the concept of Extension offering NTU courses. Couldn't we get into videotaping? Couldn't we do something to reach more engineers? But UCLA really had no capacity as yet for videotape demonstrations.

Frustrated by administrative inertia and the state's budgetary woes, Estrin accepted a substantial retirement offer and stepped down after five years.

THE MOST IMPORTANT CONTRIBUTION OF A WOMAN IN ENGINEERING

Estrin concluded her career at UCLA teaching courses on women in engineering, and on the engineer or technology and society. The first "was very useful to the women, but the classes were very small. . . . Women who took the course were in [school] for an extra year." The second "was a great course because we could discuss the issues. . . . These were freshmen. . . . Many of them didn't know why they had picked the branch they were in." Teaching was not Estrin's passion although she enjoyed the interaction of classroom discussions. When she looked back at her life in 2006 at the age of 82, even her research accomplishments paled before

> Just saying that women can be as successful as men in the field, and that there really isn't any sex difference between the two, other than the general psychological things that people find. I think it's mostly the environment we live in, and where [the ability] to have a professional life and have a home life just never really existed before. And it, you know, came about, I suppose, in my generation [13]. ■

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