General Electric Enters the Computer Business—Revisited[1]

H.R. (BARNEY) OLDFIELD

Perhaps General Electric got into the "Computer Business" without tremendous foresight, but the first steps in that direction were immensely successful. Starting with the Bank of America's Electronic Recording Method of Accounting (ERMA) system, and combined with the development of Magnetic Ink Character Recognition (MICR) for the rapid processing of bank checks, and backed by one of the largest corporations in the world, GE had the opportunity to effectively chase and catch IBM in the field of data processing. Succeeding developments also portended well for the future but the continuing reluctance of the GE headquarters to support the Computer Department competitively with other companies whose one and only product was a computer eventually led to the sale of the operation to Honeywell Corporation. This is the story of those beginnings as seen and remembered by the first general manager of the Computer Department, H.R. (Barney) Oldfield.

MIT and World War II

My first contact with a calculator came in the autumn of 1934 when I purchased a technological marvel—a ten inch slide rule—from the MIT Coop. Having mastered that device by my senior year, I was introduced to the beautiful and delicate Coradi waveform analyzer. I was never sure why it worked, but it had a polished glass ball—a low tech mouse if you will—gimbaled in two dimensions such that it could be guided over a tracing of a complex waveform and, after a number of passes, produce a frequency spectrum. We used it to analyze propeller vibrations as picked up by an accelerometer and reproduced on film by a recording oscilloscope. Later, as a research associate in Stark Draper's Instrumentation Laboratory, I was permitted to manipulate the Vannevar Bush differential analyzer which we used to solve non-linear differential equations associated with wing flutter. I always stood in awe of these computing machines, never completely understood their inner workings, but became a reasonably skilled user.

Being a so-called Army Brat, I had enlisted in the Reserve Officers' Training Corps (ROTC) during my freshman year in college. In mid-1941 I was called to active duty and assigned to the Army's Antiaircraft Artillery Board in Fort Monroe, Virginia, to act as a Test Officer. Each branch of the Army had a board responsible for establishing the detailed requirements for new types of armament and associated materiel needed to accomplish that branch's mission, and then testing the prototypes and production equipment to make sure that they were capable of doing the job. The mission of the Antiaircraft Artillery, a split-off from the venerable Coast Artillery Corps, was to provide defense against air attack from enemy aircraft. This mission carried a great urgency because of the beating the British were taking during the blitzes—to be reinforced by the beating the United States would take a few months later at Pearl Harbor.

Microwave devices were beginning to emerge from the MIT Radiation Laboratory in 1941, though the program was so secret that I had not been aware of the activity while there. One of the top priority projects was the XT-1 target acquisition and gun laying radar. I was assigned as test officer, and was to be closely associated with the project for the next three years.

The XT-1 was a miraculous device, capable of locating and tracking a high speed aircraft with an accuracy of far less than a degree in azimuth and elevation and plus or minus five yards in range. Its mission was to furnish continuous data to a computer (called a "director" in those days) which would make predictions of future target position for aiming the antiaircraft guns and setting the fuse. The existing M-7 electromechanical director, a thing of cogs, wheels, ball and disk integrators, and small motors, was unable to make use of the accuracy of the XT-1. It would take a much improved director to do the job.

One day in early 1942, on the test range of Fort Monroe (where the antiaircraft board was initially located), a small trailer appeared, shepherded by a gentleman named George Stibitz. It turned out to be the T-10 electrical director, developed by the Bell Telephone Laboratories. It consisted of a spe-

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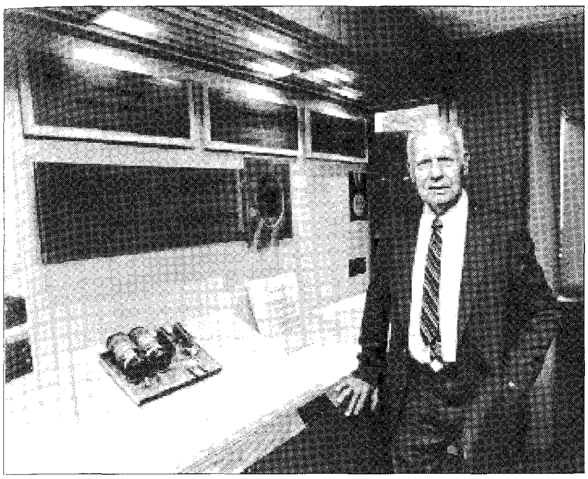
cial purpose analog computer with rack upon rack of DC amplifiers and potentiometers, and it solved the ballistic equations using target position and velocity information furnished by the XT-1, and in turn fed firing data to the remote controlled 90 millimeter guns and their automated fuse setter. The total system worked so well we were sure we had a winner on our hands.



Early computer pioneer George Stibitz. **© CBI**

By April 1942, the Antiaircraft Board was relocated from the comfortable surroundings of Fort Monroe to the mosquito infested beaches of Camp Davis, 40 miles north of Wilmington, North Carolina. The XT-1 had been given the military nomenclature of SCR-584 (the SCR standing for Signal Corps Radio) and the T-10 had become the M-9 director. Camp Davis was an ideal site from the standpoint of testing, because we were free to fire-at-will over the water without the distraction of Chesapeake fishing boats.

I vividly recall the day Secretary of War Henry Stimson, his staff, a contingent from England, a group of VIPs from General Electric, AT&T, Westinghouse, MIT, and Bell Laboratories—the developers and manufacturers of the equipment arrived on site. The SCR-584, M-10, and a four gun 90-millimeter battery were dug into defensive positions along the beach to simulate combat conditions, with the audience on a slope behind the beach.

The demonstration began with a B-25 aircraft towing a copper-mesh flag target, crossing in front of us at about 15,000 feet. The audience oohd and aahd as the lacy parabolic antenna of the SCR-584 swung around, settled on the flag target, and continued to move as the target flew along. I was up on top of the trailer, eye glued to a bore sighting telescope mounted on the antenna axis, ensuring that the radar beam was pointed at the flag target instead of the aircraft—one of my more dangerous assignments of World War II, considering the parabola was equipped with powerful servo motors which would whip the heavy pedestal around at lightning speed if the XT-1 should lose the undulating flag target.

The "commence firing!" command rang out, and there was a thunderous roar as the guns fired in unison. Seconds later, four puffs of smoke and a short flash of fire blossomed at the forward position of the flag target as the shells exploded. The target itself, torn to pieces, slowly fluttered to the earth as the spectators cheered. It was antiaircraft history in the making!

The climax of the demonstration occurred when a Northrop drone aircraft dove out of the sun directly at the beach area. There was an uneasy stirring in the audience but the SCR-584 antenna whipped around to capture the high speed target, and again the guns thundered, and the aircraft disintegrated, pieces drifting into the ocean. Secretary Stimson was impressed.

In 1943 my responsibilities had increased to encompass the entire radar-director-gun system which made up the new-age antiaircraft weapon. I recall some of our problems when I accompanied the first of these systems to be deployed in the Mediterranean theater. It was a humid mid-summer in 1943, but with the temperature plunging at night, the M-9 was subject to constant environmental fluctuations which unbalanced the temperamental OC amplifiers. We had to maintain a man at the console continuously to read each amplifier's null meter and adjust a potentiometer as each one drifted off.

Despite the crude nature of the director/computer as measured by today's standards, the M-9 gave a spectacular account of itself at the Anzio beachhead in early 1944 where continuous attacks by the Luftwaffe and the German panzer tank divisions attempted to drive the Allies from Italy. The system worked.

Returning from the Mediterranean theater in 1944, I was assigned to the Army Air Corp's Air Communications Office. There I was assigned to the airborne fire control program. One of the highest priority projects was the computerized fire control system for protection of the B-29 Superfortress, then readying itself for the invasion of Japan. Another was the PG-13 radar designed to provide firing data for B-25 aircraft designed especially to attack the Japanese cave redoubts which caused havoc with the Marines in the Pacific.

I recall my disgust at a politically powerful group calling themselves the "Manhattan Project." They preempted the entire inventory of AN/APG-13 light radars originally allocated to our project. Accusations of bureaucratic autocracy flew thick and fast throughout the Pentagon. It was much later when we discovered our miniaturized radars had found a home as a part of the arming device for the atomic bomb.

When the war ended I was considered to be an expert in the application of analog techniques to real-time system problems. Unfortunately, analog techniques were already on the road to obsolescence, so most of my hard won expertise was of little value in the market place. However, the experience of working with creative physicists on the one hand and largely non-technical Army officers and enlisted men on the other, and to some extent acting as a translator between the two, turned out to be of some practical value.

Early days at General Electric

When I was relieved from active duty in October, 1945, I returned to MIT and the Instrumentation Laboratory, only to find that my previous position as a research associate had been filled. With a wife and two young children to support, I left the academic womb and sought a job with industry, ending up in the Government Division of the General Electric Company at Electronics Park, Syracuse, New York. My title was Manager of Air Force Sales: Me a salesman?? I was, and still am, the type who becomes invisible when trying to order a hot dog during football game intermission or competing with the flock of shoppers at a delicatessen counter. Surprisingly, I found myself enjoying the competition for government contracts at a time when most of the economy was shifting from wartime pursuits to a civilian economy, and I did rather well at the job. In 1947 I was promoted to manager of sales.

During my five year stint as a marketing man I was involved both with R&D contracts and production contracts, mostly having to do with radar and communications systems. My first contact with digital computers came in 1948 when the Air Materiel Command at Wright Field, Dayton, Ohio put out a request for bid for a digital computer to be used for their Aerodynamics Laboratory.

Our own Electronics Laboratory in Syracuse had been itching for a chance to design and build a computer, It was labeled OARAC, Office of Air Research Analytical Computer, and according to Herb Grosch, was based on Aiken's Mark III computer[2]. We were able to put together the winning proposal, and I believe OARAC was accepted and shipped to Wright Field in mid-1954, constituting GE's modest entry into the digital computer field. I never knew what use was made of OARAC, because by then I was off on another venture.

During the Korean War the military expanded its appetite for new and more sophisticated weaponry, both offensive and defensive. The defense industry, including GE, was suddenly faced with a heavy load of R&D projects but with not enough electronic engineers to handle the load. In the case of General Electric's Electronics Division, many of the best engineers had been absorbed elsewhere by the lure of commercial television, FM radio, tape recorders, and the like.

It happened at that time that General Tom C. Rives, from the Army Air Corps Air Communications Office, was a consultant to Walter R. "Doc" Baker, GE vice president and general manager of the Electronics Division.

Rives and I had worked together in late 1944 when I was assigned to the Air Communications Office, and we had developed a good rapport. At Doc Baker's suggestion, we undertook the task of studying the shortage of engineers and proposing a solution. Rives was a good friend of Charles Burroughs, head of Cornell University's Electrical Engineering Department, and the three of us met several times to explore the possibility of developing an industry/university relationship.

The resulting proposal was to establish the "GE Advanced Electronics Center at Cornell," to be located at the Ithaca, NY airport in a building owned by Cornell University, sufficiently removed from the campus to prevent contamination to the academic purists in Cornell's Arts Department but close enough for GE engineers to establish residence and work for advanced degrees. It was also convenient for Cornell graduate students and faculty members in the Engineering and Physics Departments to act as consultants—an important income supplement, considering Cornell was remote from a source of consulting.

The project was approved by Solomon Hollister, Cornell's Dean of Engineering and by Doc Baker. There was grumbling on the part of the Cornell academic elite and by GE's own Electronics Laboratory director, Lloyd DeVore, who sensed competition for corporate funding, but the opposition was quickly snuffed out by the urgency of the situation. I was given the title operations manager and sent to Ithaca to organize the laboratory, recruit staff, oversee building modifications, and deal with faculty. It was understood at the time (1951) that an eminent scientist would be appointed to act as director of the laboratory, but one look at the wooden laboratory building at the airport cooled even the most ardent candidates. The most impressive of these was William Edson, head of the Georgia Tech Engineering Department. Bill wisely opted out and went to Stanford to work for Ted Terman. By default, I became director.

It was rough going for the first two years, but the basic concept turned out to be sound. We added a few good people from General Electric to act as project engineers for the programs we inherited from the backlog of unfinished engineering projects at Electronics Park. One was the development of a lightweight search radar system to be installed in a blimp for detection of low flying aircraft and torpedo boats. The project engineer was Walker Dix, who was to emerge several years later as the program manager of the GE 625 computer several years after I had left General Electric.

One member of his team was Karsten Solheim, who designed the antenna for the airborne radar. Later, Karsten would join the mechanical design group of the ERMA project in Menlo Park, and, still later, he would invent the PING line of golf clubs and become a millionaire.

Perhaps the most important project of the laboratory was the development of an X-band radar system using a klystron and traveling wave tube instead of the conventional magnetron, and so organized that the frequency could be varied pulse-to-pulse in a random manner. The project engineer for this project was Sid Kaplan of the General Engineering Laboratory in Schenectady; one of the team members was Jay Levinthal who would later join the ERMA engineering team.

We recruited an interesting mix of part-time faculty members the from Cornell, junior faculty members from less prestigious universities hopeful of pursuing doctoral programs at Cornell, and young engineers from other companies excited by the opportunity to work for GE while attending Cornell part time.

Initially, we had a problem because most of our projects were classified, but eventually we obtained non-classified projects from the Signal Corps and the Office of Naval Research. One of these, headed up by Bob Wooley, involved the development of high-density packaging of semiconductor circuits, later to find an application in the GE Computer Department when Bob became the project engineer of the NCR 304. Bob and I were given visiting faculty appointments at Cornell, and together we developed Cornell's first course in digital computers.

I was pretty pleased with life in a university environment. The visiting professor appointment carried a number of privileges with it, including the possibility of completing my own doctoral program, and I even considered returning to university life on a permanent basis. Fate intervened.

2. The Mark III computer was the first of the Harvard machines to incorporate magnetic drum memories, individual drums being designated for instructions and data.

A Bank of America advertisement touts its new computerized check reader, 'ERMA.' It couldn't read handwriting, and never made a mistake. Then ERMA gave us the fastest check handling in service in banking. And personalized checks!

The scene shifts to Palo Alto

It was 1953 and the engineer shortage had abated. The GE Advanced Electronics Center at Cornell was going well. Based on government contracts for the most part, the operation generated a modest profit and furnished ongoing product opportunities for Doc Baker's military departments. At the same time, microwave communications, microwave radars, and microwave ovens were emerging as important commercial product areas. GE's Tube Division had lagged behind in terms of developing new types of microwave tubes, and was fast being eclipsed by Raytheon, AT&T, and Litton.

It happened that Stanford University, financed primarily by their huge linear accelerator program, had become the country's major center in terms of high power klystrons and traveling wave tubes. Fred Terman, then Dean of Engineering, had, in parallel, catapulted Stanford University into a series of ambitious university-industry ventures, beginning with Hewlett-Packard and Varian Associates, and destined to expand year-by-year to create what was to be known as Silicon Valley. He was another wartime buddy of General Tom Rives, and he made it clear GE would be welcome to replicate the Cornell program at Stanford.

I was on Baker's "short list" as a specialist in setting up new ventures in conjunction with universities, and I was sent out to Palo Alto with Rives to explore the possibilities. It was a bitter cold day in November when we left the Syracuse airport, and I still recall the thrill of basking in the warm sunshine when we reached the Stanford campus. I was not a native Californian, but my career Army Officer father had been stationed at both Fort McArthur in the Los Angeles area in the early 1930s and at the Presidio of San Francisco just before World War II, and I had often missed the climate and the way of life in California.

It took little persuasion to convince me to turn over the management of the Cornell Laboratory to Walt Hausz, a fine engineer from GE in Syracuse, and to undertake a start-up operation devoted to microwave tube and microwave system R&D, to be located at Stanford Industrial Park. So was born the "GE Microwave Laboratory at Stanford" in late 1953.

As had been the case at Cornell, we had an interesting board of scientific advisors. There was Tom Rives, representing the military thinking, counter-balanced by Athalstan Spilhaus, Dean of Engineering at the University of Minnesota, a recognized expert in oceanography and a rigorous mathematician. Another, my boss, was George Haller, recently Dean of Engineering of Pennsylvania State College (now University) and newly appointed Director of Laboratories of GE's Electronics Division. Finally there has Fred Terman, distinguished electronic researcher and teacher turned academic entrepreneur, representing Stanford University. I enjoyed the opportunities to interact with these giants of World War II scientific breakthroughs. They don't make 'em like that no more!

My only contact with computers, other than with Stanford Research Institute's carefully guarded program, during the years I was with the GE Microwave Laboratory at Stanford had to do with a research contract we had obtained from the National Science Foundation to study and, if feasible, implement an idea we had for a microwave computer. This was the brain child of Bill Edson, who had passed up the GE Advanced Electronics Center at Cornell but later became a consultant of the Microwave Laboratory and acted as our director of Microwave Systems Research.

The basic idea was to make use of the incredibly wide bandwidth of circuits operating in the 30,000 megacycle range to mimic digital computer functions but at much higher speeds. I don't know how the study turned out, because I left the

Microwave Laboratory early in 1956. This time I was especially reluctant to depart the area.

The ERMA competition

In 1950 the Bank of America had contracted with Stanford Research Institute (SRI) to develop a prototype computer-based system to automate, to the extent possible, the slow and labor intensive checking account bookkeeping system of the bank. It was an especially important problem for the then world's largest commercial bank, whose hundreds of branches throughout the State of California were awash in paperwork and were on the verge of cutting the quality and type of banking services they could offer the residents of California.

SRI undertook a five-year study and system development program which resulted in a massive hard-wired computer, a high speed check sorter, and a developmental model automated character reader to read numbers imprinted on the checks in magnetic ink. The project was super-secret, but Fred Terman arranged for me to tour the system in 1955. I was suitably awestruck by the thousands of vacuum tubes and diodes which made up the computer, but I gave no thought to any possible GE involvement in SRI's ERMA program.

It was mid-December, 1955, when I received a visit from my boss, George Haller. To my surprise, he was not inquiring about progress at the Microwave Laboratory but was on a mission for Doc Baker. Some months before, the Bank of America had invited proposals from the industry to complete the development of ERMA and manufacture a quantity sufficient to automate all the branches of the Bank of America. All of the business machine companies and several electronics companies were expected to bid, and several proposals had already been received by the Bank.

General Electric had been included out of recognition of its size, but was not expected to bid. Doc Baker, anxious to get the company in the commercial computer business had, according to Haller, elicited from President Ralph Cordiner, an agreement that if the Electronics Division should be the successful bidder for the ERMA contract, Baker would be permitted to form a Computer Department to implement the program.

Cordiner had been adamantly opposed to an entry into the computer business, but his staff informed him it was a safe bet, because the order would obviously go to IBM or UNIVAC, or to one of the business machine companies. Baker had selected me to make the proposal, in part because I was on the spot and in part because I had been successful in starting new ventures. The carrot at the end of the stick was that of becoming General Manager of a new Department. I was thrilled at the opportunity and immediately went to work.

The administrative manager at the Microwave Laboratory was George Trotter, who had also worked for me when I was manager of sales of the Government Division in Syracuse. A superb salesman of highly technical systems, George was an ideal partner in our quest for the ERMA contract. We immediately formed the Industrial Computer Section, becoming its first two employees and swinging into action. We were supremely confident of our ability in the systems marketplace, and it mattered little that a digital computer was a part of the package. We had gone after and landed bigger fish in the past.

We found the responsible party at the Bank of America to be Howard Lief, vice president and controller. He welcomed the presence of General Electric as a contender, though he was surprised at our late entry in the race and did not hold out much hope.

Lief was quite open about the nature of the competition, noting that there were 29 bidders to that point, not the least of whom was IBM. It seemed IBM had offered a cool $10 million to buy the rights to ERMA, but without any commitment to produce the system. This would have given the bank a substantial profit on their investment, but Lief was seeking long term operating savings rather than a quick profit. He felt IBM might simply shelve the project to eliminate competition to their own product line, leaving the bank without its needed automation equipment.

There were three major technical risks involved with the ERMA project:

1. The vacuum tube computer designed by SRI would have to be converted to transistors to fit into projected Bank of America facilities. In 1956 the only transistorized computers were either one-of-a-kind laboratory models or special purpose military machines. In addition, there were no quantity suppliers of computer-grade transistors at that time.
2. The automated character reading device which would act as input to the computer and the check sorter was still in the developmental stage and would require substantial improvement and refinement before it would be suitable for use in banks. Indeed, IBM and Burroughs were vigorously promoting competitive techniques and the American Bankers Association had not made a decision as to a "common language" for check processing.
3. The high speed check sorter was an electro-mechanical marvel, but its adjustments were so critical that it would spray checks around the room on occasion. Like the character reader, it was a laboratory model requiring an unknown amount of refinement.

Fortunately, we had a great deal of technical competence within the Electronics Division of GE and the company's General Engineering Laboratory in Schenectady (GEL). George Jacobi of the General Engineering Laboratory in Schenectady and Bob Johnson of the Electronics Laboratory in Syracuse were made available part time to Trotter and me, and they did a superb job of answering questions and coming up with proposed solutions to systems problems.

The verdict, after consultation with SRI, was that the perceived technical problems were solvable, but it would take at least two years to complete the first ERMA capable of being installed and operating in the banks. The cost to complete the development and produce the 32 ERMA systems was estimated at $30 million, using costing techniques we had developed in the military business.

Because we were entering the bidding late in the game, we decided it would not be possible to develop and test circuit details before bidding. Our marketing strategy was, first, to emphasize GE's competence in the electronics field along with the company's financial strength and ability to stay the course.

Second, and here we took a cue from Howard Lief, we concentrated on meeting operating cost savings rather than meeting technical specifications. Our objectives were related to such things as number of operators required, system up-time, and throughput of checks and information. This was a risky strategy because we here essentially agreeing to solve the bank's problem rather than delivering an assembly of equipment to specifications which might or might not do the total checking account bookkeeping job. However, the risk was balanced by the fact that the bank, in turn, would have to be flexible if we should have to vary our approach in midstream, so long as such was necessary to make the total system work. We believed Howard Lief also favored a "performance" contract rather than a conventional "production" contract.

On February 3, 1956, we submitted our first proposal to the Bank of America. It has been accused of being highly fictional [McKenney and Fisher, 1993] but, in fact, it embodied the philosophy outlined above. It served mainly to provide an official commitment to the program. Most of the proposing and negotiation from that point on took the form of meetings we held with both Howard Lief and SRI, with memorandums of understanding taking the place of published documents.

We submitted a revised proposal on March 5, 1956, covering some desired performance options, and that was the last of our written proposals. Meanwhile, engineers from Texas Instruments were swarming over SRI, confident the contract was theirs based on SRI's recommendation to the bank. They were perhaps overconfident and neglected the principles of effective marketing.

In early April 1956, we were called to Howard Lief's office. There, atop a filing cabinet, sat a beautifully crafted scale model of the future ERMA. A brass tablet on the mahogany base was inscribed, "To the Bank of America from Texas Instruments, March, 1956." Lief's glum expression mirrored our disappointment, but he suddenly broke into a smile and handed me a sheaf of papers. It was a Letter of Intent to the GE Company announcing award of the ERMA contract to the Industrial Computer Section which at that time consisted of two people. "Take this to your boss and have him sign it or a reasonable facsimile, and we'll call it a deal."

With the ERMA Letter of Intent in hand, I ascended to Cloud Nine and made my way to Syracuse. I recall the meeting in Doc Baker's office, attended by Ike Kaar, Baker's division director of engineering, and George Haller. Baker, after having the contract vetted by Bob Estes, division council, had signed the document and dictated a reply pledging his support and that of the GE Company as a whole to the commitments made by, "Mr. Oldfield." This made me feel pretty good because others not close to the program had viewed our proposal activities with skepticism and even some alarm.

Baker, at that time, also issued an organization announcement assigning the Industrial Computer Section to Bill Morlock's Technical Products Department in Electronic Park. "That will give you a temporary home until you build up your own staff and determine where the Computer Department will be located."

I was not too happy about the delay, being anxious to get back to Palo Alto to start implementing the program as it had been proposed. However, I recognized that a temporary base with existing administrative facilities would probably be necessary for several months. I found a small office in the so-called Transmitter Building, got on the telephone for a few hours, and dispatched Bob Johnson, George Jacobi, Jay Levinthal, and Dave Zaheb to Menlo Park to start working with the SRI ERMA group.

the Computer Department could not be located in Palo Alto, or anywhere else in California for that matter, because of the unfavorable business climate of the state.

Our proposal has been based on initially leasing space at the SRI complex (which we did) pending construction of a addition to the Microwave Laboratory building on the Stanford Industrial Park to act as the headquarters of the Computer Department. The addition was to include offices, engineering laboratories, and space for assembly and test of ERMA systems.

Production circuit modules, designed in Menlo Park/Palo Alto, were to be subcontracted, by previous agreement, to the Technical Products Department in Syracuse. We had an informal option from Fred Terman for land for future expansion at Stanford Industrial Park. This plan, approved by Baker, was considered by far the least expensive way of doing the job, and was guaranteed to have Fred Terman's support in building up a first-class technical staff.

My first serious setback was the decision made at 570 Lexington Avenue by President Cordiner's staff—usually referred to simply as "570"—that the headquarters and manufacturing facility of the Computer Department could not be located in Palo Alto, or anywhere else in California for that matter, because of the unfavorable business climate of the state.

It is true that California had, and still has, legislation favorable to labor unions, and even lacks a right-to-work law, but companies such as Hewlett-Packard, Hughes Electronics, Varian Associates, and AMPEX thrived in the environment because their products had a high technical content and a relatively modest factory labor cost. I argued with anyone who would listen that computers represented the ultimate in technological content, and should not be held to the same site selection rules as appliances and steam turbines, but to no avail.

George Haller sympathized but was powerless to help. I was devastated by this development and considered it a crippling blow to the program. I made a rough calculation of the added cost of fulfilling the ERMA contract if the headquarters and manufacturing facility were remote from the development engineering group, and the estimate turned out to be several million dollars. I thought this would tip the scale, but was informed by the site selection people that this extra start-up cost was considered minimal compared with long term labor savings. I would not win this particular battle. In recent years I have tried to imagine what would have happened to the GE

Computer Department if the company had accepted the original proposal and had permitted us to locate astride what later became Silicon Valley, the home of Apple, Intel, Hewlett-Packard (HP), Beckman Instruments, Sygnetics, and the rest. An intriguing speculation!

The site selection experts were from Schenectady. They were anxious to locate the Computer Department in Nashville, Tennessee because of the low labor costs, the favorable tax rate, and the accessibility to railroad transportation. We were able to shoot that down on the issue of lack of attractiveness to high grade professional people. After a number of trips and false starts, we were able to negotiate a compromise. Phoenix, Arizona had a favorable business climate, and the way of life was generally attractive to professional people, though hardly on a level with the San Francisco Bay Area. Also, I knew there'd be a day of reckoning when GE's ERMA engineering development program in Menlo Park was complete and we tried to persuade the key technical people to move to Phoenix. (Note: The ERMA engineering development program was housed in a World War II hospital building on SRI's Menlo Park campus. Menlo Park and Palo Alto are adjacent communities, so there would have been no future personal dislocation if the Computer Department had been established in Palo Alto.)

Early years at Menlo Park and Phoenix

Bob Johnson and George Jacobi had put the initial cadre together by drawing on staff from the Electronics Laboratory in Syracuse, the GE Advanced Electronics Center at Cornell in Ithaca, and the General Engineering Laboratory in Schenectady. John Paivinen was soon attracted from Burroughs, an important acquisition because he had just finished the design and construction of a medium size main frame computer. His ERMA design group included Gerry Allard, an expert on semiconductor circuits who was to make a number of important contributions to the Computer Department. An important addition was Joe Weizenbaum, a programmer who had finished an operating system for a small machine at Bendix, and heard about the ERMA project. "I went to San Francisco and presented myself to, I think, Bob Johnson and a Mr. Green. "They didn't know what I was talking about and so they hired me—very smart of them! Very smart of me! It all worked out."[3] Jay Levinthal, of the GE Advanced Electronics Center at Cornell, headed up the systems group and Bob Hagopian, a GE veteran, headed up the Document Sensing and Handling Group.

George Jacobi bore the brunt of a number of technical disagreements with SRI concerning the need to abandon SRI's hard wired computer approach in favor of a flexible stored program computer. His strong recommendation to which Bob Johnson subscribed, was quite unpopular with the SRI computer group, as it completely by-passed much of their prior work. However, it was the right decision and it was eventually accepted. George Jacobi had by this time made himself unpopular with SRI management because of the persistence of his arguments, and SRI virtually demanded his removal. George moved to Phoenix to head up the Computer Department Advanced Development Section, and to become an unsung hero of the ERMA program. One major contribution he made before leaving Menlo Park was to persuade the General Engineering Laboratory in Schenectady to undertake the development of a transistorized version of the magnetic ink character reader, perhaps the most critical element in the ERMA system. Al Zipf of the Bank of America had, by mid-1956, obtained acceptance of MICR as the common language for the computer input of bank checks[4], receipts, and other numerical information, but the huge vacuum tube system developed by SRI was expensive, temperamental, and in no shape to produce and install in banks. Zipf was delighted when the General Engineering Laboratory system was received, installed, and tested. It was accurate, stable, and relatively inexpensive to produce.

Bob Johnson was appointed project engineer/Manager when Jacobi departed. The group jelled under Johnson, and the core members remained as the group grew and expanded. There still exists today an ERMA Fellows Society spearheaded by Johnson, an indication of the esprit developed during this extremely difficult engineering project.

The work on the design of ERMA proceeded in Menlo Park. Meanwhile, having moved my home to Phoenix, I was faced with a number of interesting problems. It was necessary to create in Phoenix a computer manufacturing facility with sufficient technical competence to support ERMA manufacturing under the assumption that few of the Menlo Park ERMA development staff would relocate to Phoenix. This was a costly procedure, acknowledged by 570 during the site selection process but somehow forgotten during budget time.

We needed substantial dollar sponsorship from other than GE coffers, and fortunately we negotiated a contract with National Cash Register for completing development and production of a limited quantity of a computer which existed in prototype form at the Hawthorne Laboratory, itself a recent acquisition of NCR in its efforts to break into the computer business. We had previously subcontracted the check sorter and high speed printer to NCR, though this was not a quid pro quo.

Chuck Keenoy, NCR vice president of engineering, had visited me while I was in Syracuse, and we had shown him the automated television production line. He figured we could show him the mysteries of electronic manufacturing. In addition, Keenoy believed, and I agreed, there was an opportunity to establish a long term relationship between the two companies. We thought even Mr. Cordiner could not object, because we would not be selling directly to business machine customers except banks.

We consummated a $30 million contract with NCR in mid-1956, calling for the product design and production by the GE Computer Department of a quantity of NCR 304 computers. Thus financed, we rapidly built up our Phoenix engineering staff with emphasis on manufacturing and engineering capability.

Our manager of manufacturing was Ray Barclay, a young but quite experienced graduate of GE's Advanced Manufacturing Program. Ray very quickly put together his manufacturing team, organized temporary facilities in Phoenix for the entire department, and began training local technicians in the basic manufacturing functions. Our manager of engi-

3. Private Communication, 31 July 1993, from Joe Weizenbaum to Barney Oldfield.

4. See the accompanying article by James McKenney on this aspect of the development of ERMA.

neering was Ken Geiser from the General Engineering Laboratory. Ken's experience in engineering management had involved applications of network analyzers and associated analog devices to manufacturing and utilities, and to other process control problems. We badly needed that type of expertise to guide our process control development program. In the digital area, Ken was backed up by Bob Wooley who took over the NCR 304 design project, and by Arnold Spielberg, newly recruited from RCA's BIZMAC project group.

One of my longer term projects, during this early period in the history of the Computer Department, had to do with developing a mutually useful relationship with Arizona State College. President Grady Gammage, encouraged by Motorola, which had preceded GE in establishing a substantial plant in Phoenix, had upgraded the Electrical Engineering Department in terms of providing and supporting both staff and facilities, as a phase in upgrading the college to university status. Actually, the new Technology Building was virtually complete when we arrived in Phoenix, but the college would not be ready to make full use of it for a couple of years. The space was ideal for engineering offices and laboratory space, and we quickly made a deal to lease the space to house our engineering group. It was a fortuitous start to our relationship with Gammage.

In mid-1956 we were joined by Herb Grosch who had previously established a substantial computer center for GE's Aircraft Gas Turbine Division in Evendale, IL. With him came a huge IBM 704 and a group of programmers familiar with the application of the machine. The 704 and supporting staff were to be installed as an addition to the engineering building on the Arizona State College campus. It was an ambitious venture which we hoped to support by performing computer services for outside customers, and which hopefully would improve our overall competence in computer programming. It was also supportive of our desire to help Arizona State College in its struggle to earn university status. The project was partially successful, but it turned out to be impossible to obtain enough computer service business to cover the expense. Grosch left GE at the end of 1957 to rejoin IBM. However, he had made a contribution by exposing GE to the computer services market which was to blossom in future years.

Grinding out ERMA

During the latter part of 1956 and through most of 1957, we pursued three missions in particular. The most important was, of course, the continuing development and design of the ERMA system at Menlo Park, with the associated liaison with major subcontractors such as National Cash Register, Pitney Bowes, and AMPEX. NCR was a key player in implementing MICR. While not a part of the initial contract, NCR had the job of modifying their standard proof machine so the checks, already imprinted with bank and customer number, could be imprinted with the dollar amount in magnetic ink as a by-product of the proofing operation.

It was no simple task to ensure accurate registration and a crisp character font with a printer mechanism to be heavily utilized in a bank environment. Success of the program depended also on the development of a high speed computer printer by NCR, on the completion by Pitney Bowes of the development of the high speed sorter, and on completion of improved magnetic tape units from AMPEX. At that time there was no established peripheral equipment industry; every new computer project lacking the IBM imprimatur had to involve upgrades and modifications to existing peripheral devices and their controllers.

The second mission, to develop a manufacturing facility with competence in computer manufacturing, was facilitated by the fact that the key manufacturing people were all experienced in the assembly and testing of complex electronic equipment. John Paivinen and Ray Barclay had established a training program for the manufacturing people so they would be familiar with the types of special problems they would encounter at each step in the production cycle starting with the incoming inspection of components and proceeding through assembly, cabling, unit testing, and system testing. We had leased 50,000 square feet of open space on Peoria Avenue, Phoenix, and Barclay moved immediately to set up parallel assembly lines for ERMA and the NCR 304.

In late 1956, Arnold Spielberg was assigned to head up the Process Control Engineering Section. His eldest son Steven was to make movie history many years later....

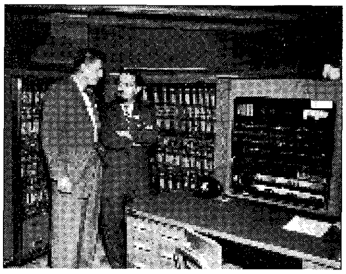
One of our major problems was establishing a sufficient supply of computer grade germanium transistors—silicon devices were available only in experimental quantities and required a military priority. Raytheon was the only reliable source, and even they found it difficult to produce a sufficient quantity of devices which met the tolerance standards established by GE engineering.

Much of 1957 has spent designing automatic test equipment for incoming inspection, and then accumulating a reasonable backlog of transistors for the initial systems. Gradually the factory took shape, and we began to produce modules for testing by John Paivinen's group. Bob Johnson was elated by the high quality of the factory output, and a real feeling of teamwork was developed between the groups. This teamwork was to stand the test of time and, much to the amazement of both 570 and our friends at IBM, the entire complement of ERMA systems would be delivered and accepted within the contract delivery schedule.

In addition to ERMA and the NCR 304, we had a commitment to develop a position in the process control market. At the time that the Computer Department has established, the only GE process control products were the numerical machine tool directors of the Specialty Control Division, and a series of analog computers developed by the General Engineering Laboratory in Schenectady. These were transferred to the Computer Department at a time when analog techniques were still favored for most industrial applications.

We assembled and marketed a small quantity in Phoenix while awaiting the emergence of our digital computer line. The first of these was the GE 30Z "slide rule," a small device used to determine the optimum economic allocation of power generation in an electric utility. This led to a series of increasingly larger analog computers, the GE Model 307 A-C Network Analyzer, and the GE 308 Economic Dispatch Computer that could deal with multiple power grids.

Another analog device was the GE 306 PRODUCTRON for production scheduling, materials explosion, and work station impact calculations. We sold a few of each of these computers, and the experience was educational in terms of probing the industrial and manufacturing markets.



Herb Grosch discusses computer design with actor Ronald Reagan. As a television star, Reagan was a spokesman for

Process control

In late 1956, Arnold Spielberg was assigned to head up the Process Control Engineering Section. Spielberg had come to GE from RCA where he had worked on the RCA BIZMAC Computer, first in basic circuit development, then logic design, and finally real-time, on-line applications. This experience was what Geiser had been looking for. Spielberg liked what he saw in GE, and in early 1957 found himself on the way to Phoenix with his wife Leah and his four children. (His eldest son Steven was to make movie history many years later with films such as *Schindler's List*, *E.T.*, *Jurassic Park*, and *The Color Purple*.)

Spielberg's first task was to familiarize himself with GE's many products for industrial control applications such as steel mills, aluminum foundries, cement plants, utilities, and the like. The Industry Control Department in Salem, Virginia, was an eye opener in terms of degrees of "hardening" required to withstand the shock, vibration, temperature variations, and environmental pollution associated with industrial processes. This was very educational and useful for Spielberg, and our early products used heavy duty switches along with heavy sheet metal panels and racks, and were designed for high reliability under adverse conditions.

Our first process control product was to be what we termed a "data logger" for the inspection of a Jones and Laughlin (J&L) high speed tinplate line. There was a trend developing in industry to produce tinplate in large coils rather than in sheets, resulting in economies for both the steel mill and the customer. This involved the development of new inspection techniques, as it was no longer possible to inspect each sheet separately. This required the development of a technique for inspecting the tinplate line while it was being processed at speeds up to 3,600 feet per minute. J&L had put out a bid request for such a system, and the Computer Department was anxious to bid on the job. Spielberg was hard at work on the technical proposal when we received word that Industry Control Department in Salem had lodged a protest with 570, claiming this was an invasion of their territory. Thus began the great "Product Charter" battle.

Ralph Cordiner's guru at 570 on organization philosophy and professional management was Harold Smiddy, a client and disciple of Peter Drucker. Smiddy was masterminding Cordiner's massive decentralization program, one key of which was GE's Advanced Management Center at Crotonville for the creation of "professional managers" and the other was the establishment of detailed "Product Charters" for each operating department.

In theory, this was a method for eliminating duplication between departments and permitting precise measurement of each general manager's performance. There were detractors who thought this inhibited cooperation between departments, and such was obviously the case between the new Computer Department and the mature and highly profitable Industry Control Department.

The procedure for establishing product charters and resolving conflicts was covered by a two-inch thick management manual. We decided to follow every prescribed procedure in the book, culminating in a product charter meeting in Phoenix attended by Harold Smiddy, our own people, and a delegation from Industry Control.

It was apparently the first time anyone had followed the entire procedure as Smiddy had set forth, and he was ecstatic. We had prepared carefully for the debate, and our opponents had not, so the Computer Department won the decision hands down. I remember the western barbecue we held after the meeting; it was there we got the radio message that Russia had placed the first satellite in orbit.

Industrial products

The GE 302 Data Accumulator was our first industrial product. While it was digital in function it was hard wired to solve the specific tinplate inspection problem. X-ray thickness gauges, pinhole detectors, coating thickness gauges, footage tachometer, and shear operate signal were all fed to a cabinet containing logic circuits and a magnetic drum which accumulated data captured from every foot of tinplate. The resultant data—total number of feet in the coil, number of prime feet, number of waste feet, number of feet of each type of defect and total number of pinholes—were printed out at the end of each run.

The next step in the process control program was to design and construct a general purpose stored program digital computer to industrial process standards, with the input-output capabilities suited for application problems of gas and electric utilities, steel mills, and other metal processing plants, cement, petroleum, chemical, and petrochemical industries. It was labeled the GE 312 and eventually commanded a good market.

Probably the most exciting application of the GE 312 was to the hot strip mill of McClouth Steel Co. in Michigan. It was a difficult design inasmuch as each step in the process had to be varied on the basis of the measured values of the previous step. This required continuous high speed feedback to set the five different hot stands, with absolute accuracy and reliability being essential; an error at one point could be magnified at the next, causing the entire process to go out of control. Fortunately, the GE 312 met the challenge. (At a later date, Spielberg replaced the drum with a core memory, turning the GE 312 into the more powerful GE 412. A non-hardened version with different peripherals became the GE 225, the Computer Department's most profitable product long after I had departed from the scene.)

Quiet exit from General Electric

By mid-1958 the first ERMA computer had been delivered from Ray Barclay's production line in Phoenix and was installed in the San Jose branch of the Bank of America. The entire system was not scheduled to be put together and operated with customer checks until the end of the year, but we felt we were well on our way. There was a subtle change in our staff meetings as we began to make plans for life after ERMA.

Clair Lasher, our manager of marketing, was a firm believer in detailed product planning. He had previously, in 1954, participated in a corporate study headed by Vice President George Metcalf which investigated the markets available to GE in the electronics field. Lasher had handled the computer market and had recommended GE invest the funds necessary to compete with IBM across the spectrum of small and large computers. Cordiner had rejected the recommendation, but the ERMA contract presented an opportunity to raise the issue again.

Lasher considered process control to be a specialty market of minor importance. My belief was that we should first capitalize on the two-year lead ERMA would give us in an important segment of the banking market by developing a complete and continuously updated banking product line, perhaps in cooperation with NCR, and in parallel invest heavily in process control. My thinking about process control was not shared by many, but I believed it had great value in linking the Computer Department together with the rest of GE.

My wife, Sofia, settled the debate by becoming seriously ill during the extra-hot summer of 1958, and imploring me to move the family back to the Boston area where her family and family doctor were located and where, she was confident, she would recover.

Unknown to me she had asked her brother-in-law, the manager of Raytheon's HAWK missile plant in Andover, to mention my name to Hal Geneen, Raytheon's executive vice president, who was bringing in fresh talent in his drive to transform Raytheon from an overgrown family business to a modern profit-oriented corporation. Geneen had contacted me during one of his swings to the west coast, and I was impressed with his dynamic vision of the future of Raytheon and with the intriguing career opportunities. I enjoyed the encounter, though he didn't offer me a job, and I had no intention at that time leaving Phoenix. later, as the pressure to leave Phoenix intensified, I was grateful for the contact.

The first ERMA system was accepted by the Bank of America in December of 1958. Almost coincidentally, I left Phoenix with my family and settled in Weston, Massachusetts, not far from Raytheon's Wayland Laboratory, home of their equipment Division. Clair hasher had been appointed acting general manager of the GE Computer Department, and I lost touch rapidly as I went about the process of finding a job within Raytheon. It had been a sad parting from the Computer Department but I was too concerned about my ailing wife to dwell on the disappointment.

At this point I would like to refer to George Snively's *Annals* article entitled "General Electric Enters Computer Business." George wrote this in 1987 after his attempts to locate me had failed, so his flattering article was based, in a number of cases of intuition, hearsay, and guesswork. One of his guesses related to President Cordiner's visit to the Bank of America during the dedication ceremony for ERMA held in mid-1959. According to Snively, "Cordiner took one look at ERMA and said, 'My God, we're in the business machine business! How did we get here?' He fired Barney on the spot...." This was not a very good guess on Snively's part, because, at that point, I was already a Raytheon employee and not eligible for firing by the president of GE. I almost wish George's apocryphal story had been correct because it would have been a grand event to be fired by the president of GE in the presence of the president of the Bank of America and Ronald Reagan, future President of the United States.

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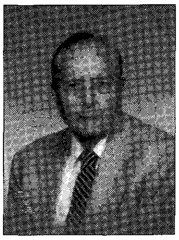

Homer R. (Barney) Oldfield received his BS and MS degrees from MIT in 1938 and 1939 in Aeronautical Engineering (Instrumentation). After two more years of graduate study he was called to active duty and spent most of World War II in the application of microwave radar. After the war he joined the General Electric Company's Electronics Division, originally as a salesman and then as a laboratory manager. His 13 years with GE culminated with his appointment as general manager of the GE Computer Department. He has devoted the last 30 years to the field of hospital information systems and automated multiphasic health testing. Now a consultant and occasional author, he regained contact with the GE Computer Department Alumni Association in 1993, and discovered the exciting nature of events which took place within GE after his departure. Assisted by the recollections of literally hundreds of former GE employees, Oldfield has recently completed a book covering GE's 14 year adventure in the computer market.

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