Electronics Laboratory
(1944 to 1993)

The E-Lab beginning

`The Syracuse General Electric Electronics Laboratory began in Schenectady, in September, 1944. It was established by Dr. W.R.G. Baker as a component of his Electronics Department, and its first manager was Larry M. Leeds. Larry Leeds had begun his career with General Electric, in 1934, in radio development. In 1940, he was in charge of television transmitter development in the Radio Transmitter Engineering department in Schenectady. As GE received its first orders for radar equipment in 1941, Leeds was put in charge of the radar engineering work (the first radar transmitters built were very similar to the television transmitters of that time). His radar engineering organization had grown with increasing radar orders by mid-1943, and Leeds had gained a reputation as a radar expert. In 1943, he was called to serve as a radar consultant in the Office of the Secretary of War in Washington, D.C. Upon his return to General Electric a year later, he convinced Dr. Baker that a laboratory to develop new electronic products was essential to the company's continuing electronics business, and the Electronics Laboratory was born.

For historical completeness, it must be noted that an Electronics Laboratory Division had briefly existed in Dr. Baker's Radio, Television and Electronics Department when it was established in 1942. That organization was led by W.C. White, who had formerly headed the Vacuum Tube Engineering department in Schenectady. Although much of the work of that Electronics Laboratory had been concerned with vacuum tubes, H.W. Lord was listed for radar circuits, and J.E. Keister; had a few engineers working on radar systems. Two other well-known members of that laboratory were Simon Ramo, who later became the "R" of TRW, and John Whinnery, who became a professor at the University of California at Berkeley. By the time the RT&E Department became simply the Electronics Department in 1943, however, the Electronics Laboratory Division had been discontinued, and Jim Keister and Dick Longfellow; were sharing responsibility for the radar engineering organization originally built up by Larry Leeds.

The new Electronics Laboratory grew slowly at first, but Leeds was joined in Schenectady by Harry Marvin, from the General Engineering Laboratory, Dr. H.W. Anderson, from the Tube Division, and Walter Hausz and Burton Brown, who had both worked in Transmitter Engineering. Burt Brown only stayed briefly, however, before going back to a teaching assignment of the University of Vermont. In December, 1945, Larry Leeds moved to the Thompson Road plant in Syracuse, in anticipation of the opening of Electronics Park in Syracuse, which would be headquarters for Dr. Baker's Electronics Department and for the Electronics Laboratory.

In April, 1946, Dr. Baker announced that the new manager of the Electronics Laboratory (E-Lab) would be George Metcalf. Metcalf had joined General Electric with a BSEE from Purdue University in 1928 and had become Manager of special developments in Vacuum Tube Engineering by 1940. He had then gone into the Army Air Corps, becoming the Colonel in charge of the Aircraft Radar Laboratory at Wright Field by the war's end. Dr. Baker clearly felt George Metcalf was a better man for the job than Larry Leeds, but Leeds was extremely disappointed that the job was taken away from him. Although he went to a consulting position in commercial electronics and stayed with General Electric for the rest of his career, he never forgave Dr. Baker for relieving him of his Electronics Laboratory position.

In a statement of purpose issued by Metcalf, shortly after returning to GE, he noted that the primary function of the Electronics Laboratory was to develop new products, and that secondary functions were to maintain relations with government laboratories and to coordinate with the operating division engineering organizations. Most of the E-Lab personnel were still in Schenectady at that time, working under three project engineers: Walt Hausz, Harry Marvin, and Dr. Anderson.

Hermes telemetry and guidance

In the fall of 1944, as Germany's surrender was anticipated to end the war in Europe, the U.S. Army was interested in learning about the German missile program headed by Dr. Werner von Braun. The Chief of Research of Development for Army Ordnance requested General Electric to undertake a program of rocket research and development. The contract, signed in November, 1944, called the program Hermes. Dr. Richard Porter of the Marine and Aeronautic Engineering Division of the apparatus Department was assigned to lead the effort, and he assembled a team of experts to begin the effort.

Among these was Walter Hausz, from the new Electronics Laboratory, to cover the electronics control and guidance aspects of the program. Walt had earned a MSEE degree at Columbia University and joined General Electric in 1938 to go on the Advanced Engineering Program. At that time, Dick Porter was the supervisor of the A-Class. After a few rotating assignments, Walt had gone to work on communication transmitters within Transmitter Engineering. With the coming of wartime radar orders, Walt worked on the SC and SK series of 200 megaHertz radar transmitters, becoming the project engineer of the SK-1M version for the Marine Corps.

In March, 1945, Dr. Porter took four of his team, including Walt Hausz, on a mission to Germany to work with the Army Ordnance technical intelligence people to learn all they could about the German program. The team first studied captured documents in England, then visited Peenemunde, which had been the German test site, and Nordhausen, where the V-2 missile;s had been built in an underground factory. With Germany's surrender in May, 1945, they made contact with Dr. von Braun, who had escaped from the German military. Plans were made to begin the Hermes program by test firing captured V-2 missiles at White Sands, New Mexico, which was established as a U.S. Army missile test site.

Back in Schenectady at the Campbell Avenue Plant, Walt Hausz began some team building of his own to pursue Hermes telemetry and guidance development, as the first large undertaking of the E-Lab. Dr. Lou Neelands, Jack MacAllister, Don Arsem, George Kirkpatrick and others joined him over the next two years to work on the Hermes program. The initial development work by Walt Hausz and Lou Neelands was the telemetry equipment to be used on test firings of the captured V-2 missiles. The system used was a time-multiplexed system which sampled each of 28 input channels at 30 times per second.

George Kirkpatrick joined General Electric after graduating from the University of Illinois in the spring of 1941. After initial Test Program assignments at Bridgeport, he went to Schenectady in December, where he heard about the Japanese attack on Pearl Harbor at the Schenectady YMCA where he was staying. His initial assignment that winter was in the Research Laboratory where Dr. Pahl was heading a project to build a radar transmitter using the S-band magnetron, which had been developed in England. George worked with Siegfried Hansen on the pulse modulator, which was to use a thyratron being developed by Louis Tongs. His next assignment was with M.W. Scheldorf, working on an FM transmitting antenna which was tested at the Sacandaga reservoir. He was accepted for the Advanced Engineering Program in the summer of 1942 and began the A-Class that fall. In the summer of 1943, he went on the Engineering General payroll as a continuing member of the Advanced Engineering Program and began a series of somewhat longer rotating assignments.

On the first of these, George Kirkpatrick was introduced to monopulse radar by John Blewett. Monopulse is angular position measurement within a microwave-radar beam on an individual pulse basis. The radar was to be used for anti-aircraft searchlight direction. The initial Research Laboratory approach had been an optical radar with a pressurized spark-gap as a high-power pulsed light source. It was mounted in the focal plane of a 60-inch search light with several photo-detector tubes built by Smitty in the Research Lab. The optical tracker had been abandoned, however, because it could not track through haze or clouds.

The new project used a four-aperture phase-monopulse antenna, conceived by Siegfried Hansen, and operated on a mount previously developed by Aeronautic and Marine Engineering for the conical-scan APG-3 B-29 bomber defense radar. Siegfried Hansen did not think of monopulse as a new concept, but rather as a straight-forward extension of radio-frequency direction-finding techniques. At about the same time, H.T. Budenbom at the Bell Telephone Laboratories was also translating his earlier direction-finding concepts to microwave-radar tracking.

George Kirkpatrick’s following assignment, beginning in January, 1944, was concerned with a power supply used in electromagnetic isotope separation at Oak Ridge as part of the Manhatten Project, although George had little knowledge of its application at the time because of the tight security on the program. This assignment continued into 1945, the 1944-5 C-Class being postponed because of wartime urgencies. George supervised the A-Class while taking the Electronics C-Class in the 1945-6 season and supervised a B and C-Class in 1946-7. In the spring of 1947, he interviewed Walt Hausz for a permanent assignment. After the interview, he received a firm offer by telephone from George Metcalf, the E-Lab manager, whose office was in Syracuse.

Walt Hausz was working at the Campbell Avenue Plant in Schenectady on the Hermes missile A-1 missile development. The A-1 was to be a 30-50 mile ground-to-ground missile. GE was developing the rocket motor, with the design work at the Campbell Avenue Plant and test firings at the Malta Test Station, north of Schenectady. The A-1 was to reach apogee in free-flight mode, following which a modified SCR-584 radar would track a missile-borne beacon and command guide its descent to the target. George Kirkpatrick’s assignment was as project engineer for the guidance development. The SCR-584 radar was a van-mounted, anti-aircraft, fire-control radar built in quantity by Westinghouse and General Electric during the war. It was modified for its guidance role by substitution of an 8-foot dish for the original 6-foot dish, and by the addition of a command-guidance transmitter. A proportional-guidance system was used as an improvement of previous on-off missile-guidance systems.

George Kirkpatrick went to White Sands, in 1949, to prepare for the test flight of the Hermes A-1 missile guidance. Pappy White was the GE field service man in charge of the installation at White Sands, and Pappy required that the missile-borne electronics all be thoroughly tested on a shake table before they were actually flight-tested. George’s beacon passed the shake table test all right, and they got ready for the missile firing. During this test, they locked onto the missile immediately after launch and provided a few seconds of successful proportional guidance, but a missile malfunction caused it to break control and head upward. When all the tracking dishes, used to instrument the test, were found to be pointing straight up, the test crew sweated out the possibility that the missile would come straight back down on them. Fortunately, the missile landed between 2 and 3 miles away.

There were many jurisdictional disputes over the missile work in those years, between the Army and the Air Force, and between various development facilities of each service. George became soured on missile work when the Army decided to put future development of his guidance system at the Jet Propulsion Laboratory of Cal Tech. Cliff Cumming came to GE from JPL to learn all about the GE system. This system was then utilized on the Corporal E missile by JPL, with the missile itself built by Aerojet General. George doesn’t remember whether GE bid on manufacture of the guidance equipment, but Firestone and Motorola did produce parts of it.

Walt Hausz wanted George to work on guidance for the Hermes A-3 missile, and he made a trip to Convair, at San Diego, to observe their interferometer system. Ground tests in their hanger indicated it could measure the position of a car on a track to an accuracy of one inch, at a distance of two miles. When it was decided by the Army, at Huntsville, that GE would develop the A-3 guidance, Lou Neelands took over the work in the E-Lab and built up a group to do it. Since Lou was more of a creative engineer than an administrator, Nels Cochran was assigned to do all the administrative chores.

New E-Lab organizations

In May, 1948, George Metcalf was appointed General Manager of the Specialty Division of the Electronics Department. Lyman (Tiny) Fink was named the new manager of the E-Lab, a position he held for just two years, as he became Manager of Engineering of the Receiver Division in May, 1950. At that time, Dr. Lloyd T. DeVore was appointed manager of the E-Lab. Dr. DeVore came to GE from the University of Illinois and, like George Metcalf, had also been at Wright Field from 1943 to 1946, during the war. He was highly respected at the University of Illinois, and as a result, a number of good people from the University of Illinois later joined the E-Lab.

The E-Lab was reorganized by Dr. DeVore into three principal groupings with an organization breakdown listed as follows:

Government------------------------ W. Hausz
    Radar---------------------------------- G.M. Kirkpatrick
    Missile-guidance-------------------- Dr. L.J. Neelands
    Antennas------------------------------ A.E. Smoll
    Devices Development------------- J.P. Jordan;
Commercial------------------------- B.R. Lester
    Television Systems---------------- I.C. Abrahams
    TV-2 Transmitting Equipment- H.A. Samulon
    Communication Systems-------- J.F. Wilcox
    Microwave Systems---------------- H.B. Marvin
    Miniaturized Systems------------- R.F. Shea;
Materials----------------------------- R.N. Gillmor
    Electrical & Instruments---------- V.T. Burkett
    Chemical Inorganic---------------- G.W. Cavanaugh
    Chemical Organic------------------- J.R. Lampman
    Metallurgical------------------------ J.A. Miskelly
    Welding------------------------------ H.C. Wolfe

The Materials group supported current problems of the Syracuse operating divisions. Miniaturized Systems was concerned with the application of the recently invented transistor. By early 1951, Jordan and Samulon were appointed consultants to the E-Lab Manager for solid-state physics and communication theory, respectively, and Charlie Wayne was appointed responsible for digital-data handling, reporting to Walt Hausz. Dr. DeVore announced in May, 1951, that the E-Lab building was to be expanded from 33,000 square feet to 101,000 square feet.

In 1953, the organization was restructured as follows:

- Physical Electronics----------------- J.P. Jordan
  - Semiconductors--------------------- J.S. Saby
  - Thermionics------------------------ C.G. Lob
  - Magnetic Materials----------------- P.N. Russell
  - Dielectric Materials----------------- H.M. Sullivan
  - Magnetic Devices------------------- B.G. Walker
  - Dielectric Devices------------------- C.A. Rosen
  - Solid State Physics------------------ W.C. Dunlap
  - Solid State Comps. Anal.--------- J.S. Schaffner
- Electronic Techniques-------------- W. Hausz
  - Information Detection Techs.--- G.M. Kirkpatrick
  - Antenna Techniques-------------- A.E. Smoll
  - Coding and Modulation---------- A.D. Arsem
  - Video Display Techniques------- J.B. Russell
  - Recording and Memory---------- J.F. Wilcox
  - Solid-state Circuits----------------- A.P. Stern
- Advanced Products---------------- B.R. Lester
  - Television--------------------------- I.C.Abrahams
  - Microwaves------------------------- H.H. Grimm
  - Computers--------------------------- C.R. Wayne
  - Communication-------------------- C.R. Wayne (actg)
  - Radar and Sonar-------------------- E.W. Ernst

Mike Evans was named Manager of Auxiliary Operations, expanding the general support he already provided to the E-Lab. Bob Gillmor's group was set up as a separate Materials and Processes Laboratory of the new Laboratories Department.

By the end of 1953, both Burt Lester; and Walt Hausz had left the E-Lab, Walt Hausz becoming Manager of the GE Advanced Electronics Center at Cornell. Dave Pinkerton took over Burt Lester's position as Manager of Advanced Products Development and Don Arsem took over Walt Hausz's position as Manager of Electronic Techniques Development.

Dr. DeVore left General Electric in June, 1955, his position as E-Lab Manager being taken by Harris Sullivan. Mr. Sullivan removed the top layer of management and had about eight Sub-Sections reporting directly to himself, as noted on the E-Lab Management Chronology chart at the end of this chapter. In January, 1957, an Advanced Semiconductor Laboratory reporting to the Semiconductor Products Department was set up in the E-Lab building. Harris Sullivan was named Manager of the new Laboratory, and Dr. John Russell was appointed Manager of the Electronics Laboratory, which then reported to Dr. Haller as Manager of the Defense Electronics Division (DED). At the same time, with the dissolution of the Laboratories Department, Bob Gillmor's Materials and Processes Laboratory again reported into the E-Lab and C.G. Talbot;'s Flight Test Operation was transferred to the E-Lab from Aeronautic and Ordnance Systems in Schenectady.

Dr. Russell had come to the E-Lab a few years earlier from Columbia University where he had been a professor. In his new position, he divided the former E-Lab activity, which now included about 400 employees, into two Laboratories, the Electronic Equipment and Systems Laboratory under George Kirkpatrick, and the Electronic Components and Applications Laboratory under Art Stern. An E-Lab Accounting operation was set up under Jack Osborne, an Application Engineering operation was set up under Joe Berkeley, and Bob Mark was named Manager of Administration, which provided many of the E-Lab services.

George Kirkpatrick's Electronic Equipment and Systems Laboratory consisted of three subsections, Antennas & Microwave under Lloyd Krause, Communications & Radar under Bill Bartley, and Computers under Bob Beckwith. Also reporting to George were two consulting engineers, Chuck Norton for mechanical and Frank Dickey for radar.
Art Stern's Electronic Components & Applications Laboratory of the late 1950's included four subsections: Advanced Circuits under Jerry Suran; Advanced Components and Networks under Dr. Hal Katz, Electron Devices under H.J. Evans, and Solid State Materials under Dr. P.N. Russell. Also reporting to Art Stern were two consulting engineers: Dr. George Chafaris;for Electronic Storage & Displays, and Dr. Nat Schwartz for Solid State Physics. When Art Stern left GE in 1961, his position was taken by Jerry Suran.

By 1963, George Kirkpatrick felt his career at GE was somewhat stifled. He was not likely to become the E-Lab manager, and he felt he had stayed at the E-Lab too long to move to an operating department. He talked to Longacre; and Rodems at the Syracuse University Research Corporation, and in June, 1963, he left the E-Lab to join them.

Radar techniques development

Prior to the setting up of the new E-Lab organization in 1950, Walt Hausz; had won a contract from Wright Field to develop a concept known as Monopulse Resolution Improvement or MRI. The idea was to develop a monopulse azimuth-error signal with an azimuth-rotating antenna, and to use the error signal to laterally deflect the beam sweep of the display, so as to concentrate what would otherwise be a beam-width wide blip for each point target. Allen Smoll initially worked on this project, but as he took over the antenna group in the new organization, the MRI work was continued by Bob Thor under George Kirkpatrick.

Kirkpatrick wrote a proposal to Jack Slattery in the Signal Corps and won a contract to develop a technique called Angular Accuracy Improvement, in which the mount angular position of a monopulse-tracking radar was corrected by the monopulse-error signal, which became known as the Electrical Correction Signal (ECS). This gave a quicker response to maneuvering targets and a more accurate measure of target positions off the boresight axis.

MTI (moving target indication) problems on the CPS 6b radar led to another Signal Corps contract called Anti-Clutter Improvement. The CPS 6b MTI had been built by the Laboratory for Electronics Company (LFE) and utilized a mercury acoustic delay line. Frank Dickey and Major Johnson began their work in Syracuse on this project near the end of 1950. It began with ways to get a better match between the delayed and undelayed channels, but also led to looking for better match between channel pairs for the application of MTI to monopulse systems. That was investigated on the ALSTAR (Altitude Layer Surveillance Terminal Area Radar) study led by Burt Brown in Government Engineering (later HMEE). The GE approach to ALSTAR was to use a stacked-beam height finder and competed with an elevation frequency-scanning approach (VOLSCAN) by another contractor.

Other projects, on which Kirkpatrick's group worked, included multiplier circuits for the SPS-2 radar Range-Height-Indicator, monopulse theory and receivers for the TPQ-5 radar, and an analog electronic range-tracker for the TPQ-5. The TPQ-5 range tracker used a high-feedback linear-sweep generator, which gave an accuracy of one part in 10,000. The electronic approach was necessary for the TPQ-5 to provide a higher slew rate than permitted by the previous two-speed electromechanical range trackers.

As a result of requirements of HMEE's missile-detection radars, and after the application of a rather complex, Lincoln Laboratory coded-pulse system to the FPS-17 in 1955, Bob Thor, Earl Wingrove, and Herb Ramp in George's group also carried out a long series of analyses and developments of FM-chirp pulse compression. The initial E-Lab development of linear FM pulse compression, on an Air Force contract for the FPS-17, was followed by other developments, including stepped-chirp approaches, which were applied not only to various missile-detection radars but also to the SPS 30 radar. Work was also done for Jack Schultz on pulse compression for airborne-surveillance radar, and Steve Tehon built dispersive-acoustic-wire delay lines for this purpose on the suggestion of Bob Thor.

Work by Frank Dickey, on the MRI project for the Signal Corps, led to the use of a monopulse antenna to achieve electronic angular beam displacement for compensation of the antenna-beam rotation between delayed and undelayed MTI channels. When Frank began looking at MTI improvement for airborne radar, he conceived of the displaced-phase-center antenna (DPCA) concept, in which a monopulse antenna feed was utilized to laterally displace the antenna phase-center to compensate for the forward motion of the aircraft between successive pulses. In order to provide the proper compensation, it was necessary to know the forward ground-speed of the aircraft, rather than the air-speed, which was provided by the aircraft's instrumentation. This led Frank Dickey to think about a way to automatically adjust the phase-center displacement for best MTI performance, without previously knowing the ground-speed. In turn, this led Dickey to the possible use of a radar with parallel downward-looking antenna beams and offset phase-centers, as a ground-speed measuring system. Correlation of the separate antenna returns with varying time-delays provided an alternative to the Doppler radar measurement of ground-speed being investigated by the GE Advanced Electronics Center at Cornell (Ithaca) on the Fighter Automatic Navigator (FAN) Program.

The Doppler system employed multiple slanted beams which observed the ground return. The beam slanting required for a measurable Doppler offset reduced the return signal and required a larger power-aperture product for the system. Consequently, Dickey's new approach had a distinct implementation advantage. The FAN project at Ithaca was never persuaded to use Frank Dickey's correlation technique. However, Dr. Haller, who was an amateur pilot, was intrigued with the idea. He persuaded Harry Mayer, when he was managing the Advanced Electronic Center at Ithaca, to fund a demonstration. The demonstration was carried out in a Piper Tri-Pacer flown by George Kirkpatrick, who was also an amateur pilot. Dickey's correlation technique was further developed by Light Military Electronic Equipment (LMEE) after it was established in Utica. It became known as the Correlation Air Navigator (CAN). Frank also proposed that the correlation approach would be superior to the Doppler-sonar navigation approach. However, the Doppler sonar program being pursued by Gene (E.H.) Peterson in HMEE required too rapid an implementation schedule for the correlation approach to be considered. Many years later, however, in the 1970's, Frank Dickey revived the notion of using the correlation concept for a sonar navigator, and it has been applied to both military and commercial systems.

Development of a DPCA demonstration system at the E-Lab was carried out by Don Kuhn at the E-Lab during a period when Frank Dickey left GE and went to work for Melpar. A displaced-beam antenna, to compensate for azimuth scanning in an .MTI radar, although conceived initially by Frank Dickey, was not pursued by the E-Lab, but was further investigated at the GE Advanced Electronics Center at Cornell.

During the 1950's, electronically-steerable array antennas began to be considered for radar. These required controllable phase-shifters for each individual radiating element of the array. Herb Rothenberg built up a ferrite phase-shifter effort which provided important support of an HMED proposal for the SPS-33 shipboard radar. Rothenberg was later joined in this work by Hugh Hair, who had been hired into the E-Lab from Scotland by George Kirkpatrick to work on antenna & microwave efforts. Further E-Lab ferrite phase-shifter developments by Hugh Hair around 1960 became the basis of HMED's ASMS proposal and were initially applied on their Hardsite radar development. Hugh Hair won a GE Cordiner Award in 1964 for his ferrite phase-shifter development. Hugh Hair left GE to join the Syracuse University Research Corporation for a time, and then, together with Carl Gerst, another E-Lab alumnus, established Anaren, a company which became a successful supplier of electronic counter-measures equipment in the Syracuse area.

Atlas missile guidance

In October, 1954, General Electric received a letter from the Secretary of the Air Force inviting attendance at a pre-negotiation meeting on the Atlas guidance system in Los Angeles. The Atlas intercontinental ballistic missile (ICBM), which was highly classified at that time, was being developed by Convair for the Air Force as an answer to intelligence that the Russians were developing such a missile. It was to carry a nuclear warhead, based on recent developments which permitted a practical combination of lethal radius and physical size and weight. The responsibility for the General Electric radio guidance effort fell to Tom Paganelli, then Manager of Marine and Ordnance Radar Engineering (MORE) in HMEE. Paganelli appointed a GE delegation, led by Len Barker, and including Whit Reed, a GE sales representative, and Lou Neelands and Nels Cochran of the Electronics Laboratory.

At the meeting, the background of the program was disclosed as well as an analysis by Ramo Wooldridge of the system error allocation. The 5500-mile trajectory was given an overall impact error of only 2 to 3 miles. Of this total error, one mile was allotted to each of the three principal contributors, re-entry, ballistic flight, and initial powered-flight guidance. Ramo Wooldridge (RW) had postulated two possible radio trajectory-measurement approaches, a long-baseline (50 to 200 miles) system and a short-baseline (1 to 10 miles) system. The short baseline system was preferred for operational reasons, but there were many static and dynamic uncertainties in propagation which made its performance questionable.

Back at home, GE assigned two groups, one to analyze each of the two RW concepts. The Electronics Lab (Lou Neelands) was assigned the short-baseline concept and the Advanced Electronics Center at Cornell (Omar Jacomini) was assigned the long-baseline concept. To help in evaluating the propagation uncertainties, Dr. Bill Gordon, of Cornell University, was retained. As a nationally recognized expert on the subject, his help was invaluable for the analysis and for the later proposal presentation.

After a second Ramo Wooldridge meeting, and before returning home, Lou Neelands indicated to Len Barker that he had begun to perceive of a basic equipment configuration he believed could do the Atlas guidance job. It consisted of separate but integrated subsystems. The first was a monopulse-tracking radar which, with a lightweight beacon on the missile, could measure the missile position. The second, a rate subsystem using a second missile beacon, would measure the components of the missile's velocity. These two pieces of information would be used by a ground-based guidance computer to calculate guidance instructions for transmission by the tracking radar to the missile through its beacon receiver. Lou proposed separate position and rate subsystems because an interferometer baseline long enough for sufficient position accuracy appeared to have too much ambiguity for practical resolution.

The resulting GE proposal was well thought out, and the team was rewarded by an Air Force telephone call on the 15th of February which indicated that GE had won the development contract. To guide the program, a GE Steering Committee was also set up. This was headed by Electronics Division General Manager, Dr. Baker, and included HMEE Manager Jack Farrell, Dr. George Haller, the Electronics Division Laboratories Manager, Dr. Lloyd DeVore, the Electronics Laboratory Manager, and others.

Manning up for the development effort began with a transfer of Lou Neelands to HMEE, as had been initially promised, but additional manning came harder. However, Dr. Baker approved further active recruiting of Electronics Laboratory people by Tom Paganelli. As a result, Jack Records, Ben Walker, Bob Hill, and Ed Gibbons from the E-Lab shortly joined the program at HMEE. The program went on to be very successful, due in a large part to the contributions of Lou Neelands and others from the Electronics Laboratory.

Commercial developments of the 1950's

Transistors and circuits

The invention of the transistor at Bell Laboratories in 1947 was the beginning of semi-conductor electronics developments at many companies, including General Electric. Work on semi-conductor electronics in the Electronics Laboratory began about 1950. The initial device work was done by J. P. Jordan and shortly thereafter under Bob Gillmor, while the initial circuit design work was done by Dick Shea under Walt Hausz. Some of the early E Lab devices were unijunction transistors made by Arnie Lesk and Vern Mathis about 1952, the year Jerry Suran joined the Electronics Laboratory. Jerry went to work for Dick Shea, who had a tri-services contract "to advance the state-of-the-art of semi-conductor circuits." In the fall of 1952, a general strike at GE in Syracuse forced any work to be done outside the GE plant at various engineer's homes. At that time, Dick Shea got permission for his circuits group to spend the time organizing and writing a book on transistor circuits. The one month duration of the strike gave them a head start in what became a race with an RCA team under Art Lo, and the resulting book, Principles of Transistor Circuits, was published about three months ahead of the RCA book in 1953.

Following the completion of the transistor-circuits book, Jerry Suran was assigned the development of transistor circuits to perform digital logic. In this effort he initially worked with the unijunction transistors developed at the E-Lab, but the work soon employed the rapidly improving transistors available from various sources. Applications for which the E-Lab developed transistor circuitry included the depth finder for the Polaris submarine sonar, and telemetry for the Apollo & Nimbus satellite programs of the GE Missile & Space Vehicle Department. A transistor control system was also developed for Nimbus under Henry Putschi in the E-Lab. Putschi later left the E-Lab and joined the Space Division, where he contributed for many years.

On Project Redman for the National Security Agency, the E-Lab first broke the 10-megaHertz speed barrier in a competition with IBM, RCA and Sperry Rand.

Integrated circuits

The first General Electric integrated circuits were designed and built in the E-Lab in 1957. The project involved Jerry Suran, Nat Schwartz, and some of the people in the devices area. In the mid-50’s, there were several different major approaches to integrated circuits. At that time, only Westinghouse and Texas Instruments were following the eventually standard approach, that is putting everything on silicon. IBM believed that the computer of the future would be based on cryotrons, operated at extremely low temperatures, and that was then their major approach to integrated circuits. A west-coast GE group also had a big program in cryogenics. Bell Labs was following a hybrid-integrated-circuit approach using individually-mounted transistors and thin-film interconnection and passive components. The E-Lab took the Bell Labs approach initially, but then tried to go beyond Bell to do everything with thin-film metals.

Jerry Suran investigated what he called a hot-electron amplifier. It was a thin-film amplifier structure using a tunnelling effect. The Esaki diode had been invented shortly before, and some of the E-Lab physicists thought that the same tunnelling might be duplicated by thin metals and dielectrics and controlled by grids. Although they could never modulate the tunnelling amplitude, they did design and build a few devices that seemed to switch. So they decided that to go after an all-metal-and-dielectric system for integrated digital circuits. However, accurate replication of the small dimensions needed were beyond their ability, and the devices were never very reliable.

Silicon technology began to take off around 1960 with the discovery of the planar transistor and the work that Noyce and Gordon Moore did at Fairchild. The planar epitaxial transistor concept really put over integrated circuits, and from then on there was no challenge by any other approach. The E-Lab switched over to silicon around 1961 and gave up the thin metal devices.

As the result of an agreement in March, 1961, between Division Manager, George Haller, and Art Stern, Manager of the Electronics & Applications Laboratory, Jack Raper, who had led most of the E-Lab microelectronics developments, was appointed Manager of Integrated Electronics Development in an attempt to establish an internal integrated-circuits facility for the Division. It was a forerunner of the later Solid State Applications Operation of the Research Laboratory, except that it was a Division-based operation. The idea was to have an internal source of supply for military silicon integrated circuits. In order for this facility to continue, Art Stern had asked Haller to make sure that it have a guaranteed production base. This meant that the various Departments had to commit in advance to using that facility for production devices. It fell apart when Herm Konig;, who had been Manager of the Light Military Electronics Department from its beginning, refused to go along with that premise. He insisted on maintaining all make-or-buy decisions strictly on the basis of cost and availability of components, and he was not going to commit to an internal facility. If the internal facility could compete, fine. If not, then he would go outside. Interestingly, Light Military added silicon integrated-circuit production to their own thin-film hybrid-integrated-circuit facility in the following year.

Color television

During the war years, Dr. Baker looked on television as the principle electronics business of the future, and it became a key part of the planning for Electronics Park; in Syracuse. In 1950, color television was the leading television frontier, and Dr. Baker organized an ad-hoc industry committee to review the current state of color television in the United States. Following that initial review, the National Television Standards Committee (NTSC), representing all the concerned U.S. companies, drew up a color television signal-transmission standard and petitioned the Federal Communications Commission for its national adoption in July, 1953. This standard was approved in December of that year, and color television broadcasting on this standard was authorized in January, 1954.

In support of the NTSC, a fundamental investigation of colorimetry principals for television was undertaken in the Electronics Laboratory by Paul Howells under I.C. Abrahams, with support by Sidney Applebaum, J.S. Kerr and Henry Samulon. Paul's work was published in two papers in a special issue of the IRE Proceedings in January, 1954, and was later recognized by his election as Fellow of the Institute of Radio Engineers in 1960.
In parallel with Paul Howells' work in the E-Lab during the NTSC standard development, Bob Dome, in Dr. Baker's Receiver Division, investigated several alternatives to color television signal transmission, but the final standard was based on the system developed by RCA.

Following the establishment of the NTSC standard, the E-Lab also undertook the development of a color television picture-tube. This tube became known as the Lob tube, after Chester Lob who was the project leader. Other workers on the Lob tube development included Joel Almasi, Gunter Wessel and Bill Leyshon. The Lob tube was in direct competition with the Apple tube being developed by Philco and described by them in the September, 1956, issue of the IRE Proceedings. The Apple tube used a single wide-bandwidth electron gun, vertical color phosphor stripes on the screen and a servo system to synchronize the gun video with the color stripes. The Lob tube was a post-acceleration tube with three in-line guns and a vertical set of closely spaced wires about one centimeter behind the picture tube face. The colors were laid in vertical stripes to be aligned with the wire grid. Unfortunately, this alignment proved to be too difficult, and the Lob tube was never carried to a production design. Chet Lob left the E-Lab to join the GE Microwave Laboratory when it was established in Palo Alto, and later joined Varian when they bought that Laboratory in 1965.

Another E-Lab television development of this period was magnetic-tape TV recording;. The project was undertaken by Jim Wilcox and was based on dividing the required video bandwidth into several parallel frequency channels for recording by separate heads on the tape. This effort included the development of wideband ferrite read-write heads and suitable magnetic tape. The head work was done by Bill Chynoweth and the tape development was done by another young PhD Dr. DeVore had brought to the E-Lab from the University of Illinois. Although the tape development was very successful, the E-Lab TV recording system lost out to the spinning-head development of Ampex, and the project was discontinued in 1955. Dr. DeVore, the E-Lab Manager at that time, tried hard to interest various GE departments in the tape development, but found no interest in manufacturing it. The men who developed it in the E-Lab then took it to Minnesota Mining and Manufacturing where they and their magnetic tape found a home.

Cardiac Pacemakers

Work on the cardiac pacemaker began in 1959 in an accidental way. Ernie Stern, one of the E-Lab microwave engineers, had married a girl from New York who was related to Adrian Kantrowitz, the Chief of Cardiovascular Surgery in the Downstate Medical Center. Ernie Stern met him at a family party, where Kantrowitz commented that it would be great if they were able to miniaturize pacemakers with transistors and implant them completely inside the body. The Massachusetts General Hospital had invented the cardiac pacemaker concept about five years before that time, but their system used big electronic boxes outside the patient's chest with wires running through the chest wall into the heart. As many patients were lost as were saved, as a result of infections that usually developed around the wires. When Kantrowitz asked Ernie Stern whether or not he thought it would be possible to build a completely implantable device, Stern referred him to Jerry Suran, who was Manager of Advanced Circuits in the E-Lab at that time.

It sounded like a fascinating idea to Jerry Suran, so he spoke to Kantrowitz on the telephone, and then, on a trip to New York on another matter, met with him at his hospital. As a result of that meeting, it was decided to get together a medical group and an engineering group to try to specify a suitable implantable pacemaker. To provide the answer to many questions of design requirements, Kantrowitz agreed to wire some dogs and bring them up to the Lab in Syracuse, so that suitable measurements could be made. Although Jerry had no money to pursue such a project, he persuaded a few engineers to work on the project in their spare time and on weekends. The E-Lab engineering team overrode the dogs' natural heart-triggering pulses and sped their hearts up with external circuitry to see how much energy it would take. Kantrowitz soon got impatient with the dog experiments, and said, "Look, there are people dying, we need to do this with people."

At this point, Suran began to get concerned about what the general attitude of General Electric Company might be to all of this. Art Stern, his boss, set up a briefing for Division Manager, George Haller. Haller was interested, but he consulted with his Division Counsel, Stu MacMackin, who advised against pursuing it because of the financial risk of legal suits. However, Haller overrode that objection. The E-Lab then contacted the Medical Systems Division, who had little interest. Haller was still intrigued and gave the E-Lab a qualified go ahead. He instructed Stu MacMackin to provide guidelines to make sure that the Company had the least liability.

Suran then put together a team to design a pacemaker for human use. He still had no source of project money, but they proceeded on Laboratory overhead when they had to. Kantrowitz guessed that the heart-triggering pulse energy for a human should be greater than for a dog in proportion to the increased heart weight. It actually took less than this amount, but that gave them a first design. The first human patient was a woman in the Downstate Medical Center who had used one of the external pacemakers. She was fairly young, in her mid-forties, but she was so incapacitated by the external unit that she volunteered to be the first patient on the implantable one. So the team worked with her. She already had wires implanted and they ran out through her chest to an external pacemaker. One of the first experiments run was to connect to her to see how much energy it would take to trigger a human heart. The advice from the attorneys to the GE engineers was: don't even be in the same room. Let the surgeons run that experiment. So Jerry Suran and his team set up their equipment in a back room, with cabling in between the patient's room and the oscilloscopes and other test equipment. In the experiment, the doctors first turned the external pacemaker power down to a threshold level where the heart would momentarily stop, and then they turned it back up. Then they did the same thing with the pulse width. That experiment provided, at least, an energy fix on one person. Jerry always remembered the first time when the pacemaker was turned down while they were watching the EKG pattern on the oscilloscope, and the heart stopped. For that moment in time, they had killed a person! Of course, the doctors quickly turned it back up and everybody was relieved when the heart restarted after what seemed to the GE team like a year, but was probably just a second or so.

The first implanted pacemaker was designed for this woman in the Downstate Medical Center, and the implantation was done in March, 1961. The surgical team had the engineering team there behind the table just to offer advice if the doctors needed it. Everything on that first operation went fine, and the woman survived it well. And as far as Jerry Suran knew, she lived a long time afterward. The E-Lab team got a very nice letter from her, thanking them.

One of the concerns about the design was that the medical team wanted the heart trigger rate to be controllable from outside the body. Under the trauma of recovering from an operation a person's heart rate is normally a lot higher, and the doctors felt that the the pacemaker had to be speeded up to increase the blood flow and increase the patient's recovery chances. So the GE team put a in coil which could be magnetically triggered by an external control device. It was very carefully designed so that it wouldn't be triggered by stray fields. The approach was to design it in such a way that it would trigger only on very sharp impulses. The pacemaker was tested to make sure that fields in the New York City subway would not trigger it, even though breaks in the third rail generated very strong fields.

The heart-rate control turned out to be very practical. This first implant patient was given an external control so she could speed up her own heart, and she found that it was very useful when she went to events where she got a little excited. At the normal rate she would feel kind of faint or weak, but when she sped up her heart to get the right blood flow she felt fine. She could exert herself, go dancing, or do whatever she wanted.

Soon after the success of the initial pacemaker, and after more marketing studies indicated that there was a fairly large number of people who could use pacemakers, the Company decided that it was probably a profitable business, and the risk didn't look too high (before the coming age of greater litigiousness.) A lot of these people were basically terminal cases. Without the pacemaker they would die. So that made a difference in the liability encountered. The GE medical business in Milwaukee took over the design of the pacemaker in 1962. They went to a more producible, printed-board design, but used essentially the same circuits as the E-Lab model.

It is interesting that the E-Lab used Minuteman missile components designed for extreme reliability and figured that the electronics had a life of about a thousand years. On this basis, with a market of 50,000 cases a year, there would be about ten failures a year. Although this meant there might be 49,990 people who were doing well, there might be ten who wouldn't, and those ten represented a substantial liability. It turned out that eventually the Medical Systems people felt that the liability was too high, because the GE pockets were very deep from the lawyers point of view. The liability extended beyond the Medical Systems business to the General Electric Company as a whole. The country had become more litigious, and more suits were filed on things that one would think were absurd. After 5 or 6 years, they decided to get out of the pacemaker business and sold it to a foreign company.

The E-Lab Pacemaker project was unusual in that it was always an extracurricular project. The E-Lab never got funds for it. The team worked on it on spare time and on weekends. Both Jerry Suran and his engineering team donated their weekends. They generally met with the doctors on weekends. It wasn't until the first human experiment that they decided to put together a team during the day, because they needed to pull together many more disciplines. But it was still a "Swiss Navy" project. The E-Lab carried it on its overhead.

Another, lesser known, medical electronics effort was a proposal by Steve Tehon and others at the E-Lab to develop an ultrasonic PSI (Pulse Scatter Imaging) system for medical diagnostics. In principle, it operated in a similar manner to the CAT scanner but did not require the use of X-rays. The GE Medical Systems people were not then convinced, however, that ultrasonic imaging would ever find clinical use. Later on, they changed their mind and bought a small California company which had developed a hand-held unit. The E-Lab proposal did lead to their sponsorship of the doctoral thesis of Larry Nadel at Ohio State University which resulted in a successful demonstration unit but no further commercial development.

Other military developments of the 1950's

Computers

In 1950, the Air Force Office of Air Research was interested in an "automatic calculator" to aid in their efforts. Burt Lester, who headed the E Lab Advanced Products group, led a proposal effort for such a development and won a contract for what was designated OARAC, the Office of Air Research Automatic Calculator. The responsibility for the development of OARAC within the E-Lab was given to Charlie Wayne, who's team included Kurt Cockburn, Ben Geyer, Walt Wakefield, Art Sears and George Johnson. In 1951, when Burt Lester left the E Lab, Charlie Wayne's activity became the Digital Data Handling section, reporting to Walt Hausz, and Kurt Cockburn was designated the project engineer.

The OARAC design was based on the use of vacuum-tube flip-flop modules, running at a clock speed of about 200 kiloHertz, together with a rotating magnetic-drum memory. Since Charlie Wayne knew Howard Aiken, who was building the Mk 4 digital computer at Harvard, Charlie arranged for the use of the Mk 4 digital-drum aluminum casting design. the OARAC drum was therefore 22" in diameter and 30" long. It was to operate at a speed of 3600 rpm. When the drum was first given a magnetic coating and brought up to speed, Ben Geyer found that the heads cut into the magnetic coating because the drum expanded by about 8 milli-inches at its center as a result of the centrifugal force generated at operating speed, and the head clearance was only 2 milli-inches. The solution was to remachine the drum at operating speed and recoat it.

The completed OARAC computer was assembled and tested in Building 15 at Electronics Park. It was installed at Wright Field by Ben Geyer and given its final checkout during the 1952 GE Syracuse strike. The system was accepted by the Air Force in early 1953. Although George Hobbs had built another electronic digital computer in A&OS in Schenectady shortly before, OARAC was the first GE digital computer delivered to a customer.

While Geyer was installing OARAC at Wright Field, Kurt Cockburn, George Johnson and Bob Berlin began work on the SPA-13 for the Navy. This was a carrier traffic-control system to handle 200 aircraft via data-link for scheduled blind landings by the SPN-10 blind-landing system;. The SPA-13 was unique at that time in its use of two separate computers. One of these was a programmed serial-function machine, while the second was a hard-wired parallel machine. Rather than flip-flops, these used pulse amplifier and delay-line modules running at a one-megaHertz clock rate. A magnetic-drum memory somewhat smaller that OARAC's was also used. The system worked well, the principle operational test problem being to get enough aircraft in the air at once to properly exercise it. The project was completed about 1956, but the Navy never carried it further. It could have been a good system for either military or civilian air traffic control.

In September, 1955, Charlie Wayne transferred from the E-Lab to the Heavy Military Electronic Equipment Department to set up an Advanced Engineering subsection. In January, 1956, he was joined by Ben Geyer, who put together a computer programming group in Charlie Wayne's new subsection.

Communications

In 1951, Dr. John Costas; was interviewed by Electronics Laboratory Manager, Dr. Lloyd DeVore, for a position at GE. Dr. Costas had received his ScD(EE) degree from MIT earlier that year and had spent a brief period at BTL working for Bode and Darlington. At the E-Lab, he initially reported to Henry Samulon, who headed the Engineering Analysis group, and later joined the Communications subsection. Here he investigated amplitude modulation detection in the presence of interference and applied analysis of I & Q (in-phase and quadrature) samples following his thesis work. The need for a carrier reference for implementation of this approach led to his considering the use of the I & Q channels to generate a phase-locking signal for a local oscillator and resulted in the so-called Costas-loop, for which he received a patent and became very widely known. Consideration of his phase-locked receiver led to comparisons with single-sideband systems which had been developed and evoked much interest and no little controversy within the communications engineering community. The Costas receiver was first reduced to practice on the CCDL project of the E-Lab for the U.S Air Force, who consequently held the patent rights.

The frequency-division Command and Control Data Link (CCDL) project was originated in the Electronics Laboratory by Ralph Bolgiani and later project engineered by Dick Fye; in a unit headed by Len Maier. It's aim was to utilize the previously unused space between channels of an existing voice-radio system to carry digital data. It placed 25 subcarriers, each carrying 100 bits per second, between each voice channel. During 1953, the development of the CCDL was transferred to Frank Reynolds' Communications Engineering unit in HMED. In 1954, Len Maier moved from the E-Lab to HMED to set up a Techniques and Computers Engineering unit, reporting to Howard Earls, who then headed the Communication and Indicators Engineering Subsection. This unit included the GPA-37 and CCDL work, and Dick Fye also transferred to that unit. In later years, Len Maier became a GE vice-president.

In 1956, Dr. Costas headed a communications unit in the E-Lab for a brief period before following Charlie Wayne and others to join Advance Engineering in HMED, where he pursued the used of his detectors to a spread-spectrum communication system named Phantom. Interestingly, that effort led not to GE communications business, but to the GE over-the-horizon radar development.

Near the end of 1957, E-Lab engineers, under the direction of Bill Bartley, monitored signals for the USSR's Sputnik I.

Low-noise amplifiers

In support of microwave communications work, the E-Lab also undertook the development of low-noise microwave receivers. Both parametric diode and maser amplifie (microwave amplification by stimulated emission of radiation) amplifiers were developed. The maser work was done by Dr. Gunter Wessel, who also demonstrated ruby laser operation in the E Lab.

Sonar developments

In 1958, the Specialty Electronic Components Department transferred its LeMoyne Avenue Specialty Devices Operation to the Defense Systems Department. Their Electronic Ceramics shop, which manufactured sonar transducers for Heavy Military, was attached to the Electronics Laboratory under Art

Stern from late 1958 until late 1960, when it became part of the Heavy Military Electronics Department. Polarizing and assembly of transducers was done in Building 7 of Electronics Park during this period.

The HMEED development of the SQS-26 sonar used individual transmitter amplifiers behind each transducer of a large array. In order to simplify the transmitter amplifier design, which originally used vacuum-tubes, Dick French, in the E-Lab, was asked to develop a solid-state design in 1959. A breadboard was completed which used SCR (silicon-controlled-rectifier) amplifying elements to build a 800-watt transmitter module. The production design was completed by HMEED and became the basis of all future SQS-26 transmitters.

In 1955, Paul Howells and Sid Applebaum of the E-Lab worked with HMEED's sonar engineering group to develop a GE version of a sonar array beamforming technique originally developed by the British. The system used a broad transmit beam and a scanned narrow receiving beam. Instead of using phase shifters for each array element signal, it used a set of phase locked local oscillators and mixers to introduce coherent frequency shifts between the element signals before they were summed. The result was rapid beam scanning at the element frequency-offset rate. The technique was applied to the CXRP sonar and SQQ-14 mine-hunting sonars. In 1956, when Howells and Applebaum transferred from the E-Lab to Charlie Wayne's Advance Engineering subsection in HMEED, this technique also became the basis for what became known as MOSAR (modulation-scanned array radar).

Signal processing

General Electric work with OTH radar first began as a result of pioneering work at the Naval Research Laboratory (NRL) in the 1950's. An important need of OTH radar is removal of strong clutter-return signals, and this is generally achieved by high-dynamic-range Doppler-frequency filtering. This filtering requires a clutter rejection band only a few Hertz wide. The NRL workers felt that magnetic drum storage, as used for digital computers of that era, would be a good way to achieve suitable filter time responses. The GE Electronics Laboratory in Syracuse had developed a good magnetic storage drum for the Air Force OARAC computer, and the result was a contract in June 1955 for the Electronics Laboratory to develop a magnetic-drum-based Doppler processor for NRL. It was titled MADRE for Magnetic Drum Recording System and became the basis of a complete MADRE OTH radar which NRL put on the air in 1961. This beginning later led to other OTH signal-processing developments by HMED for the Navy.

Shortly after World War II, Electronics Department General Manager, Dr. Baker bought the rights to a Swiss developed projection television system called Talaria. The Talaria approach made use of an optically-flat glass substrate with a thin film of oil squeegeed over a deposited transparent conductive coating. This film was then raster-scanned in a vacuum by an electron beam which was modulated by a video signal as in a standard television picture tube. The electric field in the oil film between the deposited electrons and the conductive coating result in a decreased oil film thickness, the effect being more pronounced where a greater number of electrons were deposited. By mounting this disc in a Schlieren optical system and shining a light through the scanned image on the oil film, the thickness variation on the oil film was converted into a variation of light intensity so as to project a bright television image on a screen. The properties of the oil used were adjusted so its image decayed in the time between television frames in the same manner as the luminescent decay of a picture tube phosphor. The Talaria principle was developed by a General Electric commercial business into a successful line of television projectors for theater or other large screen use. An attempt was also made to produce a low-cost design which could be used for large-screen home television receivers, but the cost goals were never met, and the project was abandoned.

In the late 1950's, the Electronics Laboratory adapted the Talaria principle as a means for signal processing. The two-dimensional optical image could directly produce two-dimensional Fourier transforms by the use of appropriate optical elements, and the apparent simplicity of this method was appealing for the increasing Doppler-signal processing and array-antenna beamforming requirements of radar systems. The work was carried out by Bob Horsch from about 1958 to 1962, with sponsorship by the radar departments. The E-Lab continued to push this approach on their own for another decade, but with the complexity of the Talaria vacuum system and the necessary reconversion of the output optical signal to electrical form, the approach was eventually overtaken by the rapidly developing digital-signal-processing art.

Work was continued on acoustic-wire-delay lines throughout the late 1950's and into the 1960's. When the Specialty Devices Operation came into being at LeMoyne Avenue, these lines were made a commercial product, with a number sold for data storage in the European 412L system. To meet the specifications for that application, Lou Zakraysek, a metallurgist at the E-Lab, carried out metal research and found a particular alloy, NiSpanC, met the specs when properly heat treated. An open ended oven was set up and wire was run through it for several weeks to build up a sufficient supply of appropriate treated wire. On a contract from the Air Force Rome Air Development Center, fused quartz was investigated for delay lines and was obtained in wire form from the GE Nela Park operation.

Some time later, Steve Tehon got a request from HMED for a very long (about 1000 foot) wire delay line for over-the-horizon radar. NiSpanC wire was wrapped in coils in large walk-in-size cabinets, but the line was found to very noisy when continuous signals were used. With help from a number of people, including Lou Zakraysek, it was found that the noise was caused by scattering reflections from microscopic grain boundaries at the surface of the wire. Further investigation by Zakraysek found a way of reducing these reflections by 40 dB by a combination of cold work and annealing of the NiSpanC wire.

Reporting and organization changes

GE President Cordiner's decentralization drive, in the 1950's, raised questions about the proper place for the E-Lab in the organization. Dr. Haller went to one of the first decentralization-management classes and came back to be General Manager of the Defense Electronics Division in June, 1956, as Dr. Baker neared retirement. In January 1958, the E-Lab was made part of the Defense Planning and Development Operation under Brig Gen. (Retired) Haywood Hansell. This arrangement was not very successful, and when DP&DO was discontinued in October, 1958, the E-Lab reported to HMED under Jack Farrell. Two years later, in October, 1960, the E-Lab again reported directly to Haller as General Manager of the Defense Electronics Division. With the establishment of the Command Systems Division under Dick Shetler in 1962, the Electronics Laboratory reporting changed again, this time to Dick Shetler.

The early 1960's saw a decline in military business that particularly hit the advanced development contracts on which laboratory operations subsisted. Aerospace and Defense Group Executive, Jack Parker, wondered whether both the Electronics Lab and the Advanced Electronics Center at Cornell were needed. He sent Mike O'Brien, one of his consultants, to review the programs of the two laboratories. Not long after that, the word came down the management chain that one of the two labs would be discontinued and folded into the other. E-Lab Manager, John Russell and AEC Manager, Harry Mayer, both prepared position papers and tried to convince Gerry Hoyt, the Defense Electronics Division Manager now responsible for both, that their lab should continue. Gerry's decisions were that the Advanced Electronics Center should be folded into the E-Lab at Syracuse, and that Harry Mayer should lead the combined laboratory.

At the time of the merger in 1964, the combined population of the two laboratories had already been reduced to 600 people from a total of about 820, and the pressure for further reduction brought the population down to about 500 in 1965. This pressure, together with the program combination of the two laboratories, led to an entirely new organization under Harry Mayer. In the new organization, Jerry Suran continued as Manager of the Electronic Applications Laboratory, Bob Gillmor continued as Manager of the Materials and Processes Laboratory, Jack Osborne continued as Manager of Purchasing and Finance, and R.V. Lang continued as Patent Counsel. Don Beilman became the Manager of the Electronic Systems Laboratory, Chuck Schnorr was Manager of the Chemical-Biological Defense Laboratory, Dave Ferguson was named Manager of the Electro-optics Laboratory, and Abe Dunn was named Manager of the Laboratory Support Operation. Also reporting to Harry Mayer was Ed Herzog, formerly Manager of Engineering of HMED, who was named a Senior Consulting Engineer.

In the fall of 1966, the Chemical-Biological Defense Laboratory and the Electro-optics Laboratory were combined under Chuck Schnorr, and Dave Ferguson was appointed Manager-Technical Planning. In 1967, the E-Lab was honored for their work in two areas when they were designated by the the Research and Development Center as GE "Centers of Research" for Advanced Logic Circuits and for Pattern Recognition.

Electro-optics

Optical engineering

The infrared sensor, display, and optical-processing system developments underway in the E-Lab in 1964 involved a significant optical component content. The talent in this field from the two predecessor laboratories and from the discontinued Scranton Operation of the Ordnance Department was combined into an Optical Engineering group under Dick Sparling, and their facilities and capability was further expanded during the mid-1960's. This included not only laboratory optical and electronic equipment, but optical-design programs which could be run on the GE-415 computer of the Electronics Laboratory.

This capability was applied to programs of the E-Lab and to many programs of other GE organizations. In 1966, they assumed responsibility for updating and publishing the sixth edition of an Optical Engineering Handbook which had been originally put together by the Ordnance Department's Scranton plant. An important project undertaken for the Ordnance Department was a shipboard periscope for alignment of the missile-borne guidance equipment of the Polaris system. The system was further upgraded to serve for the Poseidon missile system. Another project was a head-up display feasibility model for the Office of Naval Research which was completed by the end of 1966. In this model a four-inch-square image was expanded to a 25-degree field of view at infinity focus distance on a reflective surface inside the aircraft cockpit windscreen. A further product, designed and built in 1967-8, was a gunner's periscope for the Army Cheyenne helicopter on a contract of the GE Avionic Controls Department in Binghamton.

The optical engineering group designed many unique components for the GE laboratory system developments including optical systems for Talaria and thermoplastic thin-film projectors and signal processing, scanners and germanium windows and lenses for IR sensor systems, prisms, mirrors and laser components.

Recording and displays

Considerable display work was carried on in the E-Lab under George Chafaris. Work toward thermoplastic recorder-displays had been begun at both Syracuse and Ithaca. The thermoplastic recording (TPR) technique had been developed as a means of permanent signal storage by Dr. Glenn;in the GE Research Laboratory, and was first announced in 1960. It was based on the Talaria principle with the substitutions of a high-melting-temperature tape for the glass optical flat, and a thin thermoplastic film for the oil film. In the E-Lab a complete system was developed by Wayne Holden on a U.S. Air Force contract begun at the Advanced Electronics Center in 1963 and successfully field tested in mid-1966. It could store and then project a strip map based on inputs from airborne radar, IR or other electro-optic sensors. Recording was implemented by a scanned electron beam in a vacuum, followed by heating of the thermoplastic film to allow distortion by electrostatic forces generated by the varying electron charge on its surface. A 70-millimeter-wide thermoplastic tape was used for the storage of 8000-pixel lines across the tape, and 5000 lines were projected at a time on a rear projection screen by a Schlieren optical system. The design was such that only a few milliseconds elapsed between recording and projection of the image of each line.

Another TPR display built by the E-Lab was completed by the end of 1967. This display, built for the U.S. Electronics Command, projected an 8 x 8 foot image of 3000 x 3000 pixels written on thermoplastic tape using TIRP (total-internal-reflection prism) optics. Although a single picture could be written in less than one-half second, it could be projected for as long as thirty minutes, and details of the picture could be changed without rewriting the entire picture.

Improvement of the commercial light-valve (Talaria) projector produced by the Visual Communications Products Department was also undertaken by George Chafaris' group on a contract for the Defense Communications Agency. The improvement was aimed at improving its reliability to 1000-hours mean-time-before-failure with a 90% confidence level. Two elements of the system were modified using developments of the GE Research and Development Center to achieve this performance, a new long-life thin-film fluid, and a new electron-emitter cathode. Delivery of the modified and tested projector was made in the spring of 1969.

Chemical-biological detection

Pursuit of this technical area was an extension of that begun at the Advanced Electronics Center and involved a number of technologies and programs:

Detection and discrimination between a number of strains of bacteria was based on analysis of the chemical by-products of bacterial metabolism by gas chromatography. A program, begun in mid-1964 by John Gould of the E Lab and Dr. Martin Alexander of Cornell on an Air Force Office of Scientific Research contract, investigated 32 separate bacterial strains and found clear differentiation was possible between all of them even though many were very similar. The equipment used was further developed over the following two years and won an IR-100 Award in 1968.

Another program, begun in 1966 with the U.S. Army Ballistic Research Development Laboratory, was based on the detection of ammonia developed by microorganisms in contact with certain substrates. This could be used to monitor the bacterial count of the atmosphere as an indication of the presence of other life.

The basic approach to chemical detection systems was the use of infrared spectrometry, and the work in this period was led by Dick Sharman. Detection of nerve gas in the atmosphere was the aim of the SHOPAIR (Short path infrared); program which had been begun in Ithaca. An infrared spectrometer was developed for the U.S. Army Edgewood Arsenal using a 20 long folded optical path within a 4 x 6 x 17 inch portable unit.

A passive LOPAIR (long path infrared) airborne system, developed on a U.S. Air Force contract by Larry Snowman, performed a similar function using normal background radiation as the illuminating source. A further application of LOPAIR was seen as the detection of leaks in natural gas pipelines. The Air Force LOPAIR contract was completed in 1969. A related airborne sensor developed in this period was a helicopter borne personnel detector.

Consideration of the needs of IR spectrometry led Dr. Hal Bowers at the E-Lab to propose that mixtures of carbon and oxygen isotopes used in a CO-2 laser could produce a fairly uniform spread of spectral lines across the wavelength region of interest. This was proven experimentally by Gordon Jacobs in what became for him a long period of investigation of CO-2 lasers for various applications.

Another device developed on internal development funds in this period had a more everyday application. It was an Intoxograph which would analyze breath samples to measure the degree of intoxication of the subject.

The chemical-biological detection business was transferred from the E-Lab to the Ordnance Department in Pittsfield in 1967, but some new equipment development continued in the E-Lab. One of these developments was the ILAMS (infrared laser atmosphere monitoring system). This was further modified in 1973 on a joint contract with the Ordnance Systems Department for the U.S. Environmental Protection Agency to monitor ozone concentration over a one-way path up to two-kilometers in length.

Spectral discrimination

Another area of investigation stemming from the AEC experience was that of multi-spectral image analysis. In 1964, an internal development was begun by Howard Heydt to investigate the possible discrimination of targets or camouflage by a dual-optical-band television system. Two narrow spectral bands were used to generate two separate TV images which could be combined in different ways to accentuate certain image features. The system was successfully field tested by the U.S. Air Force in the fall of 1966. The technology was of interest to the GE satellite business in Philadelphia, and Apollo 9 multi-band photos of the earth were analyzed by the E-Lab in 1969. Howard Heydt later moved from the E-Lab to GE, Philadelphia.

Computed-image generation

One of the most important programs of the Electronics Laboratory, as it was reconstituted in 1964, had originated many years earlier at the GE Advanced Electronics Center in Ithaca. In 1954, Walt Carel, a psychologist, was engaged in studies of instrument landing of aircraft on the Joint Army-Navy

Instrumentation Program (JANIP). He suggested that what the pilot needed was a graphic perspective representation of the airport he was approaching. A small group, called the Contact Analog Unit, which included Joe Gala, John Breyer, Gene Gilliland, Rod Rougelot and Bob Schumacher, had been formed to pursue this development, which was aimed at visual simulation of the ground terrain as seen from the cockpit of an aircraft. In 1962, they had won the JANAIR contract with the Navy to simulate carrier landings and with NASA to simulate space rendezvous and docking. Later they simulated space station assembly. The development was led in the Electronics Laboratory by Joe Gala under Chuck Schnorr, after the Ithaca Lab was discontinued in 1964. The JANAIR system was delivered to the Navy Missile Center at Pt. Mugu, California in April, 1966. A new NASA contract to provide greater capability than the first system was begun in 1966 and delivered to Houston by the end of 1967.

The E-Lab also pursued civil applications for computed-image simulation, particular its use for highway design and driver training. A study contract of this application was received from UCLA for the Department of Transportation in the fall of 1968, but further business in this area never came to pass.

Starting in 1967, both the Apollo Support Department in Daytona Beach and the Avionic Controls Department in Binghamton began application of these techniques to flight simulation and training. A Visual Environment Simulator System was delivered to Binghamton for use in their laboratory in mid-1969, but the market for further Binghamton projects never materialized. However, the computed-imagery work became the foundation for most of GE Daytona's business in the 1980's. Rod Rougelot, Bob Schumacher and Gene Gilliland were actively recruited by the Apollo Support Department. Because the Apollo Support Department offer was not satisfactory to Rod Rougelot, he and Bob Schumacher left GE to join Evans and Sutherland, which later became a significant competitor in the computer-generated-image business. Gene Gilliland did transfer to the Apollo Support Department in 1969.

In the continuing computed-image generation (CIG) work in the E-Lab for NASA, an approach was developed to type in alphanumerics for titling their computer-generated movies. This led to use of the NASA CIG system to produce slides for a presentation to their NASA customer. When Heavy Military Electronic Systems General Manager, Tom Paganelli, saw what they had done, he got interested in its possible application for making slides for general business presentations. The system required for that purpose could be much simpler than required for animated films or simulation. When Paganelli first suggested the idea to his Division Manager, Dr. Roy Beaton, he was negative. He thought it would be too costly. So Paganelli had a development plan prepared and submitted it as a plant appropriation which would save $100 thousand a year. After having Finance review the plan carefully, Dr. Beaton signed the appropriation, and an auto-chart facility was begun. Chuck Schnorr and Werner Sharp moved from the E-Lab to HMED engineering in 1972 to carry out the project, initially designated as Kinegraphics, but shortly changed to Genigraphics.

Guidance techniques

Under this title within the Electro-Optics Laboratory was an organization headed by Fred Reibert. Their effort, which was highly classified, covered several decades and was devoted to a continually renewed program with the U.S. Air Force Foreign Technology Division. Their function was to analyze the operation and determine expected performance of foreign missile and sensor systems. In this endeavor, they often utilized consulting help from experienced engineers in these fields from other GE and outside organizations. In 1967, the subsection was more appropriately moved under the Electronic

Systems Laboratory, which was then headed by Don Uren, Don Beilman having transferred to a position in Heavy Military Electronic Systems.

Electronic Applications & Devices

Microelectronics

In the mid-1960's it was clear that the wave of the future for digital implementation was silicon integrated circuits. At that time, this was thought to be heading to a few thousand transistors per chip and applications and design approaches for chips of this complexity were just beginning to be worked out. Silicon arrays were being considered as an approach to custom designed circuitry. Significant building of silicon devices in the E Lab awaited the construction in 1967 of an expanded microelectronic facility which was devoted as much to opto-electronic as to digital devices.

An approach to memory design pursued in 1965-6 was the use of a thin magnetic film, in a sort of integrated-circuit approach to magnetic-core memory.

In 1967, the mounting and interconnection of integrated-circuit chips on a larger substrate became the aim of a program known as STD (silicon on thermoplastic on dielectric). The rationale of the approach was based on the limited size of integrated circuits at that time. It was aimed at more compact mounting and a batch process for lower-temperature interconnection instead of using the tedious manual operation of gold-bond flying leads. The substrate design allowed the batch fabrication of passive components as well as interconnecting leads, and the leads had a controlled impedance which was suitable for frequencies up to microwaves. The approach was patented, and the development was continued on internal funds until 1968, when a NASA contract was received. However, it was never really accepted by any of the GE operating departments. Jerry Suran signed a three-year mutual STD development agreement with Toshiba in 1974.

In 1969, the E-Lab began the development of MOS-FET transistor circuitry in their new Advanced Microelectronic Facility. This was also extended by the addition of a metal layer to build MNOS non-volatile memory chips. By 1970, the E-Lab was building 1024-bit memory chips and took a contract from the U.S. Air Force Avionics laboratory to build a Megabit Memory (10^6 bits).

Microwave solid-state

The mid-1960's saw a number of E-Lab investigations into solid-state power generation at higher frequencies. An internal development program of 1966 successfully demonstrated a power module at 200 megaHertz which was seen by Heavy Military Electronic Systems as a possible means of building a solid-state transmitter for the Perimeter Acquisition Radar (PAR) being proposed to the Bell Telephone Laboratories. When the PAR radar was switched to 400 megaHertz in 1967, the E-Lab demonstrated a 400 megaHertz power module. Although BTL considered this approach too risky for generating the transmitted power of the PAR radar, solid-state exciter circuitry based on the E-Lab developments was used.

Ways of pushing this accomplishment to microwaves, using devices which could be built at that time, were also investigated. Under Earl Mullen, Gunn-effect and avalanche-diode oscillators were both built and demonstrated in 1966. Although these were low power and could only be operated as oscillators, there were applications for which they were suitable. One of these, investigated in 1968 for the GE Armament Department, was as the RF source for a proximity fuze in artillery shells. It was also felt that they could be phase-locked to serve as elements of an array-radar transmitter and this was investigated. Microstrip circuitry was developed as a means for implementing microwave modules. By 1970, John Schenck was investigating PIN diodes as phase-shifter switches, low-noise transistors for microwave receiver amplifiers, and Schottky-barrier FET transistors as microwave power amplifiers.

Opto-electronics

An opto-electronics unit was established in the Electronics Laboratory in 1964, under Tom Bray. The unit was dedicated to the development of optical detecting and display devices and the associated circuitry. Initial detection developments included silicon-avalanche photo-diodes with detection response down to wavelengths of 1.06 microns and gallium-arsenide-phosphide light-emitting diodes. Development was soon initiated on a one-quarter-inch long linear array of 50 indium-arsenide infrared-detector diodes which was used in an infrared (IR) camera completed in 1968 for NASA.

Several image-producing means were also developed under Tom Bray during this period. A one-inch-square magneto-optic display incorporating 40 x 40 picture elements, was completed in 1966 on a contract for the U.S. Army Electronics Command. The device could be directly viewed or projected by reflected light, with its surface reflectivity modulated by the local magnetization. A larger, 5 x 5-inch, magneto-optic unit was completed in 1968 on company funds as a possible image source for an airborne head-up display.

Electroluminescent (EL) cells were also developed. An eight parameter, linear bar-graph display was completed for the Apollo Support Department in early 1967. Each individual bar-graph consisted of 100 electroluminescent cells. Following this, a combination bar-graph and alpha-numeric fuel consumption display was completed in 1968 for the Aerospace Electrical Equipment Department in Wilmington, Massachusetts. This was used as a replacement for the previous mechanical moving-tape indicators.

The work on electroluminescent cells was closely followed by E-lab work on matrix arrays of light-emitting diodes (LED’s). One variation developed was called a light-emitting switch because each element of the matrix had its own memory and needed only to be switched on or off. LED arrays were developed for applications by the GE avionics departments at Utica, Binghamton and Wilmington.

The E-Lab capability to build various semiconductor devices was significantly augmented by the 1967 completion of an expanded Microelectronics Facility. It was directed by Dick Stewart within Tom Bray’s organization. This facility was not limited to opto-electronic devices, but fabricated various types of semiconductor devices and integrated circuits. When Tom Bray left the E-Lab in 1970, Dick Stewart was promoted to take his place, and Man Jin Kim took over direction of the Microelectronics Facility.

Working toward development of solid-state camera tubes, the E-Lab developed integrated two-dimensional silicon-detector arrays with charge-injection-device (CID) readout. For IR detection they worked with various materials. In 1969, lead-tin-selenide and lead-selenide-tin-telluride were used to build 8 to 14-micron detectors on a contract with the U.S. Army Night Vision Laboratory. In 1970, Man Jin Kim began to work with indium-antimonide as an IR-detector material which could permit fabrication of integrated detector arrays. (Indium antimonide is often abbreviated by its chemical formula, InSb, which can be pronounced “insbee”.) InSb detectors work up to IR wavelengths of 3 to 5 microns, an important atmospheric window. In 1972, a contract was won from the Air Force Wright-Patterson

Avionics Labs to develop InSb detector arrays, and in 1973, a contract was won from the Army Night Vision Lab to develop CID (charge-injection diode) readout of InSb arrays. These developments caught the attention of Bob Boerschig and Dan Friedman in HMED, who were developing IR-detection-system techniques for the Navy.

Financial support for the E-Lab opto-electronics work at this time became difficult to maintain, and Jerry Suran, who became the E-Lab manager in 1972, went looking for a new home for the group. As a result, he arranged to transfer Dick Stewart and the opto-electronics work to the Visual Communications Products Department which was primarily interested in TV cameras. The transfer was primarily administrative as the group continued to work in the E-Lab's Bldg 3 of Electronics Park. Work continued on both visible and IR detector arrays, but funding support continued to be less than needed, even though Dick Stewart tried hard to find support from both inside and outside General Electric. In 1975, Jack Welch, as Components and Materials Group Executive, directed Don Perry, General Manager of the Electronic Components Division, to get rid of the Opto-electronics Operation (OEO). When the engineers working on electro-optic systems in HMED heard about this, they were very concerned, as the InSb detector developments were seen to be key to future military systems. Ed Balian and Paul Teich of HMED brought the matter to the attention of Electronic Systems Division General Manager, Tom Paganelli. Paganelli looked into the work of OEO for both HMED and the Space Division and decided it should be saved. Dick Stewart looked into the OEO prospects for the coming year and concluded they could just about break even. Paganelli asked Group Manager, Mark Morton if ESD could take over the group. Morton said it sounded good, but wanted to check first with Bob Norwood, his Finance Manager. Paganelli called Don Perry and asked what he thought about his taking over the operation. Perry was very happy about the possibility. He thought the work was important, but he had to get rid of it. In the meantime, Norwood determined that they'd have to transfer about $40,000 of book value to ESD. Paganelli was told this was too much negative cash flow. Although this seemed a small concern, further discussion with Mark Morton was to no avail.

Paganelli had also talked with Bob Pry of Corporate Research and Development, who had been involved with some OEO work, and who thought it would be very good for Paganelli to take it over. When Paganelli called Pry to tell him the bad news, he had an idea. He said work for him in the E-Lab could use the equipment so that he could accept the cost. When that was confirmed, Morton approved the transfer, and the Opto-electronic System Operation was added to the Electronic Systems Applications Operation in April 1975. As with their previous transfer, OEO continued its operation under Dick Stewart in Bldg 3 of Electronics Park.

Control and instrumentation

Bill Sollecitto was appointed Manager of the Control and Instrumentation subsection in 1961. Some of the specialized instrument developments in the mid-1960's were a fluidic digital accelerometer and a laser gyro by Gordon Jacobs.

In addition to the instrumentation programs mentioned above, the subsection developed a pattern recognition technique, starting in 1964, called Frequency of Binary Words (FOBW). An application of this technique was made to the sonic analysis of GE J-79 aircraft jet engines for early diagnosis of various malfunctions. This work was complementary to on-going work in this field by Corporate Research and Development in Schenectady. As the decade moved on, the Control and Instrumentation subsection attention turned more and more to the use of digital computers as direct control system elements because of the advanced control algorithms they could implement.

Strangely, an effort in the mid-1960's by Jim Elliott to find applications of electronic instrumentation to the work of the Syracuse Police Department led him instead to propose alternate police operational strategies. His suggested application of "Crime Control Teams" was found effective by the Syracuse Police Department and was widely heralded, but led to no further GE business.

Signal and image electronics

In 1968, Ed Nielsen's subsection developed a four-channel microwave satellite TV converter for NASA's Lewis Research Center. It could operate with satellite signals at 12 gigaHertz, 9.45 gigaHertz and two modes of operation at 2.25 megaHertz.

The late 1960's also saw a multi-year development on HMED funding of a 10-megaHertz, 10-bit, analog-to-digital converter for radar :signal processing use. Unfortunately, the task proved too difficult at the time, and full performance was never realized.

Piezo-electric devices

Working with Bill Sollecitto;'s group in 1963, Steve Tehon invented the VYRO (vibration rate gyro), a gyroscope based on a vibrating bar with piezo-electric actuating and sensing elements, which was further developed and flight-tested by the Avionic Controls Department in Binghamton for use on the A-10 attack aircraft. Several thousand units were manufactured for that program.

Steve Tehon left GE for about a year between 1966 to 1967 to work for Al Katz at the Tecumseh Research Laboratory at Ann Arbor. During that time, he worked in their optical research group on time-exposure holography of vibrating objects in which reconstructions showed by fringe patterns the profile of vibration amplitude from point to point. On Tehon's return to the E-Lab, he worked as advisor to Bill Penn and Don Duffy on their holography; work, which was used to analyze the vibration modes of sonar transducers.

When a 1969 E-Lab program to develop a CO_2 laser rangefinder for the GE Armament Department needed a way to provide a rapid spiral scan for target acquisition, a piezo-electric-element-supported-mirror scanner was developed by Gordon Jacobs. It provided 40 spiral scans per second with the instantaneous scanning speed adjustable to provide equal angular increments between successive laser pulses.

In the late 1960's, Steve Tehon and Steve Wanuga began working with surface-acoustic-wave devices, which could provide electronic signal delay and filtering. By 1974, the techniques were developed sufficiently that a pulse-compression/expansion filter was completed and delivered to the Aerospace Electronic Systems Department in Utica.

Electronic Applications Center

In 1967, Art Bueche, Vice-president of the Research and Development Center in Schenectady, felt there must be a way to transfer some of the electronics technology developed for the GE aerospace businesses to GE's commercial businesses. To put this idea into action, he set up a task force of people from R&DC together with Larry Wechsler as a representative from the E-Lab. The task force visited the various commercial electronic businesses to find if they might have any interest in pursuing some kind of a venture along these lines. Most of the businesses visited were interested, especially if it meant that their investment would be augmented by additional funds from R&DC. As a result, the task recommendation was that an organization should be set up in the E-Lab which could serve in a program-office mode to define, together with the commercial businesses, programs which should be undertaken and could draw on the engineering talent in the E-Lab and other Aerospace Group organizations to implement those programs. This recommendation was implemented at the beginning of 1968 as the Electronics Applications Center (EAC) in the E-Lab, led by Larry Wechsler. Two other engineers from the E-Lab joined Larry at the establishment of the EAC, Bill Peil, who became the technical driving force behind their many projects, and Bob McFadyen.

Art Bueche initially committed enough financial support from R&DC to support the work of 6 to 8 engineers on EAC programs. The money could not be spent on any project, however, unless the money for the project from R&DC was matched by money provided by an interested commercial department and unless that department had also made the outcome of the program a part of their business plan. The EAC activity went on for many years with an annual review by Art Bueche, his R&DC staff, and the Vice-president of the Commercial Electronics Business Division.

Many different projects were undertaken by EAC over the years, most being concerned with the development of microelectronic chips to implement the functions required for the various product lines. One of the first and most extensive was the development of a series of chips for television receivers. These included chroma and audio-processing chips which became a part of GE's standard TV receiver line. EAC also developed a new synchronous-detection receiver for TV which worked well but never went into production. The most successful project of EAC was a complete microelectronic radio receiver which was introduced as the Great Awakening clock radio and became the heart of the complete GE home radio line.

Electronic Systems

Information systems

Herm Lintner's Information Systems subsection covered a number of areas in the mid 1960's. An important area was that of digital machine design. Included were a register-transfer language (RTL) for logic design and checkout, and automated component layout and interconnection for printed-circuit boards. The results of these program were utilized both in the GE Information Systems Group and in Heavy Military Electronic Systems. Other efforts ranged from the esoteric, such as intelligent machine approaches, to hardware like the TRADAR (transaction data recorder), a cash register integrated into ISIS (integrated store information system) developed by the GE Internal Automation Operation in Schenectady. The latter development proceeded successfully but was discontinued before completion.

Late 1960's efforts with P-3C sonobuoy signal analysis for the Aerospace Electronic Systems Department in Utica also served to train Andy Rasi and John Breyer for work on HMES's Improved Digital Narrowband Acoustic (IDNA) systems proposal Both men later transferred to HMES. Jack Williams also worked on multiping active sonar detection algorithms.

In 1970, Sam Craig of the Signal Processing subsection completed development of another digital hardware equipment, the Remote Radio Computer Terminal system for the Information Systems Department.

Radiation systems

This subsection was concerned with antenna and propagation problems. From 1964 to 1968, it was managed by Erm Ferris. In 1968, it became the Electromagnetics subsection under Bill Nester. 1966 programs of this subsection included satellite and decoy antennas for GE's space businesses along with HF-antenna-groundscreen analysis and ionospheric propagation for HMES's OTH radar program.

Len Humphrey and Clayton Roberts, who did most of the E-Lab propagation work, worked with the GE Missile and Space Division in this period to plan experiments in Venus atmospheric propagation. Their suggestion that there might exist a very reliable long-range "Whispering Gallery propagation" radio-propagation mode under the earth's ionospheric D-layer led to an Air Force Cambridge Research Laboratory contract in 1971, which confirmed their theory.

In 1968 the subsection designed and tested antennas for the Armament Department artillery-shell proximity-fuze project. In 1969, the subsection built and delivered to NASA's Electronics Research Laboratory, an antenna array-phasing unit based on the MOSAR principle that Paul Howells and Sid Applebaum had pioneered many years before.

Signal processing

The Signal Processing subsection was led from 1964 to 1967 by Bill Penn, at which time Bill specialized in optical signal processing. From 1968 to 1972, the subsection was led by Erm Ferris.

Radar pulse-compression work, begun by Thor and Wingrove in the 1950's, continued on into the 1960's. In 1966, a 6 to 0.1-microsecond biphase coded system was delivered to the U.S. Air Force for the improvement of an existing radar. In 1968, Steve Tehon, of the Electronic Applications & Devices Lab, developed dispersive-acoustic-wire delay lines for use in HMES' PAR radar development. In 1969, a digital linear-FM pulse-compression system was built as an internal development.

Adaptive processing was investigated by the E-Lab in 1966 for both radar electronic-counter-countermeasures and torpedo sonar. Optical holography was also used that year as a means for the classification of fingerprints. Between 1968 and 1970, Sam Craig developed a speech-privacy system for the Communication Products Department. This equipment could provide over 55-thousand possible security codes using five control dials.

Serious problems and a new start

As 1970 got underway, Electronics Laboratory support began to fall off sharply. Within GE, support dwindled in general, and Heavy Military became the primary source of funds with a little coming from the Ordnance Department. Part of the cause of this difficulty was felt to be that most departments had established advanced engineering groups and were doing their own development work. Outside contracts also fell off, perhaps for similar reasons within Department of Defense organizations. The total E-Lab employment, which was about 500 between 1965 and 1969, had to be cut to about 370 in 1970. 1971 and 1972 brought no relief and by the end of 1972, the employment had to be cut below 200. A review of the E-Lab in 1972 by Division and Group management reaffirmed the importance of the Electronics Laboratory, but the way it should be continued was not clear. Harry Mayer was tired of his position and asked his boss, Electronic Systems Division General Manager, Dr. Beaton, that he be replaced in the assignment. Dr. Beaton responded by doing two things. First, he looked for a suitable replacement, finally settling on Jerry Suran from the E-Lab, itself, and second, he scheduled a special ESD Staff meeting in September, 1972, at Hershey, Pennsylvania, to review the E-Lab problems and to give Jerry Suran some guidance on how he should proceed as the new E-Lab manager. (Harry Mayer, himself, joined HMES' ESAO to work on computed-image simulation.)

As a result, Jerry Suran's plan for revitalizing the E-Lab had five principle elements:

1. Streamlining the organization
2. Going after a broader Company support commitment
3. Effectively raising the E-Lab overhead rate
4. Aiming at longer range technology programs
5. Increasing the average size of department sponsored programs

The reorganization eliminated many activities that lacked sufficient continuing support, such as the electro-optic work which had been built up over the years. The new organization had only three principle sections: Information Technologies, headed by John Buchta; Electromagnetic and Circuit Technologies, headed by Don Uren; and Technical Services, headed by Dick Moeller. Also reporting to Jerry was Technology Marketing, headed by Eldon Fox. Legal, relations and financial services were obtained from other division organizations. The Information Technologies Section included Information Analysis, Fred Reibert's FTD work, and Information Processing, headed by Jim Geyer. Electromagnetics and Circuit Technologies included Advanced Circuits, headed by Jack Raper, the Electronic Applications Center, headed by Larry Wechsler, and Electromagnetics and Acoustics, headed by Erm Ferris. Technical Services included the former Materials and Processes Lab. functions plus facilities, the library and office services.

Jerry obtained a broader internal support commitment by agreement of Dr. Beaton and serious talks with other division managers. Charlie George was his first concern, but talks went well, and Jerry decided that he needed a full-time internal-liaison man to carry on a continuing dialog with Charlie's and other departments. He gave Dick Moeller this assignment, which became official with other E-Lab management changes in 1974. Agreement with Dan Fink of the Space Division, took a little longer when Jerry talked to him about a division support commitment. Dan objected to having any "tax" put on his division. However. he finally agreed to a certain level of support by his departments for work that Dan felt was worthwhile for the E-Lab to do. Jerry also got E-Lab work from commercial GE departments. One of these was development of the display controller for the CR&D CAT scanner program. He arranged for Henry Lehmann of HMED to bid to Milwaukee on production of the unit, but they went outside GE, instead. Discussions on the CAT scanner program were used by Jerry as a springboard for further discussions on how the E-Lab could best work in a complementary way with CR&D, rather than unfortunately crossing paths as had often happened before.

The overhead rate was a tough problem! Gerry Hoyt had held the E Lab at a 100% overhead rate since he had come to the division. When Jerry Suran complained about this to Dr. Beaton, he was challenged to present what it really would take to make the E-Lab financially viable. He consulted with the HMED Manager of Finance, Bill Anger, who suggested that he could raise the effective overhead rate by direct charging more things, such as vacations and holidays, while keeping the "billing overhead" the same for psychological reasons. Jerry took this course, with Dr. Beaton's approval. In spite of dire predictions, it turned out to have no adverse affect on winning new contracts, and it relieved the financial bind the E-Lab had fallen into.

Jerry Suran's concern about department sponsored programs was based on recent E-Lab experience in which the bulk of the orders were short term efforts of less than $20 thousand. He contrasted this with the substantial annual funding commitment for the Electronic Applications Center which was expected to run for many years. Aiming for longer range developments and larger individual program efforts was a matter of Jerry's firmness in the annual E-Lab technical program planning. It required a change of thinking on the part of the various department planners who worked with the E-Lab, but substantial improvement was made. Altogether, Jerry's program was a successful one, and it turned around the E-Lab morale problems which had developed in the crisis period.

In 1974, John Buchta left the E-Lab for Heavy Military to head Sonar Engineering. At that time, Jerry Suran moved Dick Moeller from Technical Services to perform the E-Lab (internal GE) Technical Liaison function, and moved Don Uren from Electromagnetics and Circuit Technologies to head Technical Services. Jerry then brought in two new managers from outside the E-Lab: Charlie Hearns, from the Space Division in Valley Forge, to head Electromagnetics and Analysis Technologies; and Al Belle Isle, from the Ordnance Systems Department in Pittsfield, to head Information and Circuit Technologies. In 1975, the Electronics Applications Center, under Larry Wechsler, was also elevated to section status, reporting directly to E-Lab Manager, Jerry Suran.

1970's programs

Advanced design programs

Infrared Laser Atmospheric Monitoring System (ILAMS): Larry Snowman was the principal investigator on this Environmental Protection Agency contract which had Ordnance Systems Department sponsorship.

Solid-state TV for surveillance: A joint project with the Imaging & Display Devices Operation (IDD) of the GE Tube Department, this system used a solid-state camera developed by IDD to record a low-resolution picture for transmission over telephone or field-radio links. Bob Glusick and Martin Fine were the E-Lab electrical engineers.

Automatic inspection equipment: Working with HMED, Joe Chovan developed equipment which would digitally analyze information from an optical sensor, such as a TV camera, to check conformance of parts from a high-volume production line.

VYRO (vibration rate gyro);: This device, which was flight tested in the 1960's by the Avionic Controls Department, was being improved by E-Lab project engineer, Cleo Stearns, for application on the A-10 aircraft.

Multiplexed data communicators: Aimed at reducing inter-unit wiring in complex systems, these devices were aimed at high-data-rate digital buses. Chang S. Kim, N.T. Yang and Dominick Colangelo were the principal E-Lab contributors to a program based on a microwave approach in the mid-1970's. That approach gave way in 1977 to a three-year fiber-optic-bus investigation by G.B. Harrold and others, which was sponsored by the ABG Advanced Development Council.

Turbine-blade vibration sensor: This system, for the Aircraft Engine Group at Lynn, Mass., monitored turbine-blade vibration on a running gas-turbine engine using a laser Doppler sensor. Gordon Jacobs was the principal investigator.

Solid-state kilowatt power supplies: This program of the Electronic Applications Center for Corporate Research and Development used active devices and ferrites available from the large-volume television market to deliver modulated high-power voltage pulses.

Advanced Integrated Modular Instrument System (AIMIS): Bob Glusick and Martin Fine, of the E-Lab, worked on cathode-ray-tube cockpit displays for this program, begun in 1970, with the Aerospace Instruments and Product Support Department of Wilmington, the Ordnance Systems Department of Pittsfield and the Aerospace Electronic Systems Department of Utica.

Remote fusing: Joe Kinsel and Myron Egtvedt worked on rocket-artillery fuses which could be set by a signal from the ground after they had been fired. Tests were being run in 1975 to determine the signal loss in propagation through the rocket plume. This work, with Armament Department sponsorship, was done on a contract for the U.S. Army Picatinny Arsenal.

Optical tracking radar;: A complete 10-micron-wavelength radar; was built for HMED during 1971-2 using a 100-watt CO_2 laser transmitter. Such a radar could potentially provide not only more accurate tracking than a conventional microwave radar, but could also provide an image of the target for identification. This development was led by Bill Penn, and field tests proved its features using light aircraft and Army helicopter targets. To provide greater range capability, a higher-power CO_2 laser was developed by Gordon Jacobs in the E-Lab during 1975-6.

Optical rangefinding;: In the latter half of the 1970's, Mike Chun of the E-Lab worked on several laser rangefinder transmitter programs for Aerospace Control Systems Department in Binghamton. These included the development of a CO_2 waveguide laser and analysis of the face-pumped configuration of glass and garnet lasers.

Optical sonar components: 1978 saw E-Lab activity in this new area. With UEPD support, a Navy contract was received in 1978 to build a demonstration optical sonar beamformer which was referred to as a PHAST (Photo-acoustic space-time) processor. Various PHAST techniques had been previously developed by Syracuse University, and one had been conceived by Frank Dickey of the Heavy Military Electronics Department. The particular technique used here was based on the modulation of a set of light-emitting diodes (LED's) by the individual elements of a hydrophone array. The LED signals were then transmitted by optical fibers to a scaled replica of the hydrophone array configuration which was mounted against a plate of photo-optic material such as quartz. The edge of the plate was acoustically modulated by a suitable local oscillator. This modulated in turn the light signals from each element which were then optically summed and detected by a photodetector. The varying delay of the local-oscillator acoustic wave to each element of the optical array provided the appropriate phase shift for beamsteering, with the beam angle steered according to the local-oscillator frequency. Development was also undertaken on 1978 and 1979 IR&D funds from UEPD of two separate approaches to optical-signal-modulation hydrophones.

Array antennas: Antenna work in the 1970's was almost entirely aimed at various phased-array antenna applications. For HMED, in 1978 and 1979, Bill Nester undertook a study of hardened radiating elements. For AESD in this period, he also investigated approaches to the design of array elements to be mounted in aircraft wings for airborne-early-warning radar. For RESD, Joe Kinsel investigated array antenna designs for reentry-vehicle radar-altimeter antennas.

Theoretical studies

Algebraic formulation of the FFT: The Fourier transform is the basis of most array beamforming and coherent signal processing. Economical digital implementation of the Fourier transform is therefore very important to these endeavors. The fast-Fourier-transform (FFT) initially described by Cooley & Tukey is only one of many possible. A study was undertaken by Dr. Helene Nelson in the E-Lab to investigate other formulations which might be advantageous.

D-layer propagation: Continuing experiments of the “Whispering Gallery propagation” mode of propagation were conducted by Clayton Roberts and Len Humphrey in the E-Lab with the Air Force Cambridge Research Laboratory which confirmed the advantage of this propagation mode just below the ionospheric D-layer at about 37 miles above the earth’s surface.

Circuit technology

Work in circuit technology in the mid-1970’s covered two principal areas: design and production of surface-acoustic-wave (SAW) devices and design of large-scale-integrated (LSI) circuits. SAW work in the latter half of the 1970’s led to new devices such as resonators for the design of highly stable oscillators, a SAW pressure sensor for jet engine control, and the revival of the ultrasonic delay-line as a radiation-hardened memory device. LSI designs undertaken in latter half of the 1970’s included the following:

Sonar signal processing: Under sponsorship of the Undersea Electronics Programs Department, Dr. Noble Powell developed a monolithic integrated computational element (CE) chip for the implementation of the fast-Fourier-transform. A related LSI chip design project was undertaken by Fred Schlereth to develop two chips, an external delay (ED) chip, and a digital-filter (DF) chip. Chips of these two types could be combined to provide economical implementation of many types of digital filters for signal processing. Following the successful demonstration of these chip designs in 1975, projects were undertaken by Noble Powell to build complete fast-Fourier transform processors for HMED and on two Navy contracts. Work continued on this effort up to 1980, with Scott Rice as a later project leader.

Al Moyer began a project in 1975 to build a CMOS-on-SOS matrix inversion processor for the Aerospace Electronic Systems Department. The application of this processor was to an adaptive communications system. The development was carried up through 1979 by Dave Rollenhagen. A CMOS-on-SOS array multiplier for the Electronic Systems Division was developed over 1977 to 1979 by Nick Schmitz.

Programmable LSI modules: From 1973 to 1976, Jack Lunden led an E Lab effort, sponsored by Dave Greer in HMED, to develop an associative-logic chip (an extension of the programmable logic array concept of others), which could be produced in quantity and programmed as needed to suit various digital logic applications.

Integrated injection logic (I^2L) technology was investigated by Y.C. Hwang and Lou Ragonese in 1976 for Space Systems and Reentry Systems because of its potential for low-power and radiation hardness for those applications. Later work in 1979 by Dave Dening showed that I^2L devices could be designed to operate at the high temperatures required for on-engine control circuitry for jet aircraft.

High-speed multipliers: HMED and AESD jointly sponsored this development in CMOS-on-SOS technology for adaptive signal processing which was led by Dave Rollenhagen. The initial thin-film module was essentially a 5 bit by 8 bit multiplier so implemented that multiple modules could be interconnected to realize any size multiplier. A second module developed was a high-speed 32-input adder. This adder could provide the final addition needed in a 16 bit by 16 bit multiplier operating at a multiply rate of 30 megaHertz. 1976 saw the beginning of single chip implementations of these functions, and a complex-multiplier chip was developed between 1977 and 1979.

Synchronous detection: In the continuing program of the Electronic Applications Center, Bill Peil developed synchronous-detection radio receivers which could be economically implemented by analog LSI chips.

Information processing

Coherent optical processing: Milt Noble utilized the commercial GE display-light-valve tube in a two-dimensional coherent optical processor.

Bipolar computation and control circuitry: John Irwin developed the architecture of a special control processor to meet the needs of the GE Aircraft Engine Group.

Organization of LSI digital processors: Investigations of the optimum application of commercially available microprocessor chips to implement various digital-processing requirements began in 1973. Jack Williams undertook 1976 investigations of the processing required for computed-image generation programs of the Ground Systems Department in Daytona and flight-control programs of the Aerospace Controls and Electrical Systems Department in Binghamton. Jim Fawcett studied correlation tracking and control processors of interest to the Aerospace Electronic Systems Department in Utica, as well as control processors for the Reentry and Environmental Systems Division in Philadelphia. The latter effort continued on through the rest of the 1970's. Bill Straub studied LSI hardware macroprocessors of interest to the Heavy Military Electronics Department and the Ordnance Systems Department. In 1978 and 1979, Tran Thong investigated algorithms and architectures for visual simulation systems of interest to the Simulation and Control Systems Department (formerly Ground Systems Department). In 1979, W.W. Knight investigated for the Aerospace Control Systems Department the architecture and LSI implementation of multiprocessor systems of the ACSD MCP-701A class, while John Irwin began a program to define and evaluate spacecraft electronics architectures for the Valley Forge Support Department.

Reentry-vehicle fuzing: Between 1976 and 1977, work was led by G.B. Harrold in the E-Lab to analyze, design and breadboard arming-and-fuzing processors for the Reentry and Environmental Systems Division.

Digital control and servo design: Jim Fawcett, Nick D'Antonio, Bob Glusick and John Irwin developed digital control circuitry for a number of applications: (1) an antenna-director digital controller for the Ordnance Systems Department, (2) a control digital processor and all-digital motor drive for the Armament Systems Department, (3) image correlation tracking for the Aerospace Controls and Electrical Systems Department, and (4) non-linear instrument-servo compensation for the Aerospace Instruments and Product Support Department.

Low sensitivity digital filters: Fred Schlereth and Al Moyer developed a new digital-filter topology, analogous to the analog LC ladder filter topology and known as a digital-leapfrog filter, which was relatively insensitive to input analog-to-digital conversion drifts. The work was sponsored by the Undersea Electronics Programs Department.

Sample-data for power-system analysis: George Pfeifer used the sonar data-processing experience of USPD to undertake some very sensitive measurements of 345-kilovolt power transmission lines in conjunction with the GE Electric Utilities Engineering Operation work for two New England power companies.

Computer program development

As the years went by, computer programming became an increasing part of the E-Lab work as it did with most engineering organizations. 1970’s active computer program developments included the following:

Pattern recognition: Bob Berlin and Bill Whyland were principle contributors to this work, which included applications to component inspection, vehicle detection and classification, measurement of pollutants and signal detection.

Digital system modeling and simulation: Two systems tools were developed by Bill Purdy and Fred Pfisterer under sponsorship of Ordnance Systems and HMED. These were a processor system modeling (PSM) system at the subsystem block level and a general-purpose logic simulator (GPLS) at the logic level. PSM was developed and applied to problems of several ABG departments by the E-Lab over the period of 1973 to 1976. Work on GPLS began in 1975 and proceeded at the E-Lab for several years following.

Software design verification system (SDVS): The increasing complexity of software programs led to the need for this program which was begun in 1977 under the joint sponsorship of a number of ABG departments and was continued up to at least 1980. The development was led by Fred Pfisterer in the E-Lab.

Distributed firmware: This program was sponsored by the Ordnance Systems Department and the Aerospace Electronic Systems Department, who were both concerned about creation of the increasing amount of coding stored in distributed read-only-memory chips in their systems. It was begun in 1978 and led by Bill Purdy.

Electronic Systems Analysis: This covered the broad scope of computer programs developed by Fred Reibert and his people in their work for the Air Force Foreign Technology Division.

Automatic analysis of interferograms: On a Navy contract, the E-Lab developed a means of deriving amplitudes of vibration of sonar transducer elements from holographic interferograms.

Custom LSI simulation: John Kislinger undertook the development of a simulation program for design verification of LSI chips using the E-Lab Honeywell 635 computer.

Testing digital systems: Sheldon Akers and Dick Heckleman embarked in 1973 on a continuing study of the complex problems of testing systems to find if they could properly perform the full range of computations for which they were designed and to isolate faults which might occur. By 1979, they had conceived a means of analyzing such systems in terms of “binary decision diagrams”. They also considered the design of self-testing LSI processing systems.

Computer aided circuit design: Gordon Danielson extended the BELAC program, initially designed by Cal George of AESD and widely used within GE. The extension of Danielson permitted the inclusion of distributed transmission lines which are important in microwave circuitry.

Cross-compiler system: It is often desirable to develop and check software when the target minicomputer is not available. A Fortran cross-compiler was developed in 1975 by Philip Gray for HMED and AESD to permit use of a Honeywell 635 to develop assembly language code for the Navy standard AN/UYK-20 computer;. A high-order-language (HOL) compiler was developed by M.C. Lew over 1977 to 1979 for the ACSD MCP-701A control processor.

Technical services

Mid-1970’s work in this area included: (1) pollution and hazard analysis, (2) materials and process applications, (3) instrument calibration for industries in central New York as well as GE departments, (4) environmental testing and stress analysis, (5) mechanical engineering, particularly thermal stress analysis, and (6) electronic component reliability studies. A significant program for the Ordnance Systems Department in cooling of Navy Standard Electronic Modules was carried out by Fred Wenthen. Electronic component reliability studies were led by Bob Warr, utilizing two scanning-electron-microscopes (SEM’s) with X-ray microprobe capability, an Auger analyzer and other supporting instrumentation.

Management changes after 1978

In 1978, Charlie Hearns left the E-Lab to return to the Space Division. Erm Ferris acted in his place for a time, and in 1979, Manny Ares came over from HMED to lead Electromagnetic & Analysis Technologies, an organization which was shortly to be renamed the Electronic Systems Laboratory.

In 1978, the General Electric Company was organized into four principal Sectors at the corporate level, Technical Systems and Materials (which included the Aerospace Group), Power, Industrial and Consumer. Each Sector was to have a Sector Technologist, who would insure that his Sector Executive recognized the technology driving forces for his business and would be incorporated into the strategic plans of his Sector and the Company. The Sector Technologist was also expected to insure that the research of the various Company laboratories were consistent with those strategic plans.

When Ed Hood, the Technical Systems and Materials Sector Executive, invited Jerry Suran down to Fairfield in September, 1978, to interview for his Sector Technologist position, Jerry went. During the interview, Hood offered Jerry the job on the spot. There had often been complaints within the E Lab about how the Company had made some very inappropriate moves in electronics, and this seemed to to be a challenge to do something about it. Jerry surprised himself by immediately accepting. Jerry had also just been elected President of the Institute of Electronic and Electrical Engineers, with his term starting at the beginning of 1979, so he made sure that it would be all right with Ed Hood if he spent about half of his time at that job. Hood said that should help him do a better job for GE. What Jerry very soon found out was that instead of spending half of a 40-hour week on each job, he would really spend about 40-hours on each job every week. Jerry shuttled back and forth between Fairfield and Syracuse for about four months, until his replacement at the E Lab was appointed. Jerry stayed in the Fairfield position until the end of 1981, when Jack Welch became GE President, immediately streamlined the Fairfield staff, and eliminated the Sector Technologist positions. Jerry was offered a job managing the new Microelectronics Center in Raleigh, North Carolina. However, he felt Welch would not continue it in the way Jerry thought it should go, and he elected early retirement. Having gotten a taste of teaching as an adjunct professor at Syracuse University, he wanted to finish his working career that way, and he got offers from several universities. He accepted the offer from the University of California at Davis, where he taught both engineering and management courses.

In 1974, Tom Paganelli had become Vice-president and General Manager of the Electronic Systems Division to which the Electronics Laboratory reported, so it was up to Paganelli to find a replacement for Jerry Suran. The two leading contenders on his slate of candidates for the position were Dick Kashnow, who had been Liaison Manager for Corporate Research and Development, and Al Belle Isle, who was at the E-Lab. Both were very young, and both were very bright. After interviewing the two of them, Paganelli felt that Kashnow would become a better manager, and offered him the job, which he accepted, becoming the E-Lab Manager on the first of February, 1979. A fallout of this choice, however, was that Al Belle Isle left the E-Lab in 1979 for a job outside of GE.

Dick Kashnow replaced Al Belle Isle with Jim Geyer to head the Information Systems Laboratory of the E-Lab, and in 1980, he established a separate Integrated Circuit Systems Laboratory, headed by Dave Rollenhagen. Another change of 1979 took place when Don Uren retired as head of Support Services. He was temporarily replaced by John Mills, and then by Mike Fitelson. Dave Guinther, who had led E-Lab development of electronic appliance controls, also merged his programs into the Electronics Applications Center in 1979 and became the EAC manager. In 1980, Dave Guinther left, and EAC was managed by Paul Scott for about two years, at which time the organization was folded into the Integrated Circuit Systems Laboratory.

In August, 1979, Dick Kashnow had a new boss. Reporting of the E-Lab was changed from the Electronic Systems Division to the new Aerospace Group Technology Development Operation, headed by Don Beilman. Beilman had been hired back from the Major Appliance Business Group by Aerospace Group Executive, Dan Fink, just before he had moved up to corporate planning in October, 1979. Fink was then replaced by Lou Tomasetti. The change in E-Lab reporting was viewed as recognition that the E-Lab was truly an Aerospace Group laboratory.

Dick Kashnow was not destined to stay at the E-Lab very long. Soon after he came, Sector Executive, Paul VanOrden, called on him to become his Sector Technologist. Kashnow interviewed with VanOrden, but didn’t want a staff job. He told him that he would really like to aim toward running a business. In 1981, when Paul VanOrden came back to Kashnow with an offer to make a business out of a new lamp development, known as Halarc, he felt compelled to take the new job. Incidentally, the Electronic Applications Center had contributed to the development of the in-base electronics required for the Halarc lamp.

When Dick Kashnow left, Manny Ares was designated acting-manager of the E-Lab, a position which he filled for about a year. During that period, Don Beilman had become primarily involved with the establishment of the new Microelectronics Center in Raleigh, North Carolina for Technical Systems Executive, Jim Baker, but continued to be responsible for the E-Lab. In 1982, Don Beilman left GE to work for the state of North Carolina, and the E-Lab reported for a time to the new Manager of the Microelectronics Center, Dr. Mark Barron. From 1979 to the spring of 1981, Barron had been Manager of the Solid State Applications Operation of Corporate Research and Development, which was located in Building 7 of Electronics Park in Syracuse. When Mark Barron left SSAO, its new Manager was Dr. Walter Butler, who came up from CR&D in Schenectady.

The function of SSAO, development of integrated circuits for commercial applications, was similar to work performed by the E-Lab during this period. As a result, an agreement between the Aerospace Group and Corporate Research and Development merged SSAO into the E-Lab. Walt Butler, the former SSAO Manager, became Manager of the E-Lab in 1982. In another change, the infra-red sensor work which had moved from the E-Lab to ESAO in the Electronic Systems Division in 1975, came back in 1982. When the Microelectronic Center was transferred out of the Aerospace Group to the Semiconductor Business Division in 1983, responsibility for the E-Lab was given to Chris Raber, who led the Strategic Defense Initiative Program Office on the Group staff.

Under Walt Butler, the E-Lab activity was focused more closely to ABG needs, and the organization was streamlined. The total of the E-Lab and SSAO populations was about 460 in 1981, but the combined laboratory was reduced to 260 in 1982, and 205 in 1983, with a number of people leaving, many to Electronic Systems Division organizations in Syracuse. The refocus of activity, combined with a new emphasis on winning Department of Defense (DOD) contracts, changed the E-Lab customer funding distribution. In 1979, the distribution was about 40% for ABG, 15% for DOD and 45% for other GE businesses. In 1984, it was 65% for ABG, 25% for DOD and only 10% for other GE.

In the new organization, Manny Ares continued to lead the Electronic Systems Laboratory. Software systems work was de-emphasized and that organization of the E-Lab was discontinued as Jim Geyer transferred to the Microelectronic Center in North Carolina to develop their integrated-circuit design capability. The E-Lab integrated-circuit design work was assigned to an IC Design Center under John May, and a new Microwave Integrated Circuits Laboratory was established under Linus Cordes, both of these managers having come over from SSAO. Management of the Technical Services section was taken over by Larry Wechsler, as Mike Fitelson moved over to the Undersea Electronics Programs Department. Butler acted in the position of Technology Marketing, with Dick Moeller continuing the Technical Liaison and Eldon Fox continuing the Aerospace Sales.

1980’s developments

Two areas of development received increasing emphasis as the 1980’s began, the development of both monolithic microwave integrated circuits (MMIC) and infrared sensor focal-plane arrays. These areas, together with very-large-scale-integrated (VLSI) circuit design and high-speed digital circuitry, became the primary emphasis of the E-Lab technical program. Focus on these areas was formulated by Walt Butler, after consultation with the Aerospace Group Advanced Development Council and the ABG departments, as a means to make the greatest contribution to the Group for the cost.

Monolithic microwave integrated circuits

The E-Lab began MMIC development, in 1978, on a small IR&D program sponsored by HMED's Advanced Development Engineering. This initial work was based on silicon technology and gave them enough of a start to bid on L-band module work under the Air Force STRAM program, aimed at space-based radar. In 1979, RADC let four STRAM development contracts. GE and Raytheon won silicon L-band (~1-gigaHertz) developments, and Raytheon and Texas Instruments won gallium-arsenide (GaAs) X-band (~10 gigaHertz) developments. The E-Lab program was led by Bill Perkins, an alumnus of HMED's ADE and Solid-State Radar Engineering. In the second phase of STRAM, the same contractors turned their attention to S-band (~3 gigaHertz) modules. In 1981, Grumman, on their PALDEM (Phased-array lens demonstration), awarded the E-Lab a contract to build 500 L-band phase-shifter modules.

With the S-band work indicating the shortcomings of silicon at the higher frequency, the E-Lab began internal work on gallium-arsenide devices. An arrangement was also made by the E-Lab to work with Cornell University, who had good GaAs experience and facilities. MESO chose C-band (~3 gigaHertz) as the frequency to pursue for future tactical radar. An Aerospace Business Group IR&D program for GaAs MMIC's was established in 1982, with sponsorship by MESO, AESD, and the Space Systems Division. Because of MESO's earlier definition of C-band module requirements, these received initial emphasis. Reaching the required 10-watt power with a pair of output transistors proved to be most difficult, but was finally achieved in 1985.

In parallel with the internal MMIC work, two supporting developments were also bid and won from RADC. The E-Lab won a contract to design and build an integrated module-signal-controller to provide module phase and amplitude control using previously stored values of the element location in the array, along with the commanded frequency and beam-steering direction. MESO won a 30-watt module contract based on the addition of a discrete output-amplifier to the basic E-Lab module assembly.

The initial C-band module development was followed by E-Lab development of modules for the Space Systems Division, to transmit at 20 gigaHertz and receive at 30 gigaHertz, and finally by wideband (8 gigaHertz) modules of interest to the Aerospace Electronic Systems Department.

Infrared-sensor arrays

E-Lab work in IR sensors had begun with the development of indium-antimonide (InSb) devices by Man Jin Kim in 1970, as previously noted. The interest in these sensors by both HMED and AESD in 1977 led to the formation of an intra-group IR&D program for more intense E-Lab work. As a result, a 64-element linear InSb sensor array was developed to meet needs of HMED, AESD and AC&ESD, and a two-dimensional InSb 128x128-element array was developed for an AESD requirement.

In 1982, an interest developed within several ABG departments for the use of mercury-cadmium-telluride (MCT) as an IR sensor material, various government agencies having pushed its application earlier. Corporate Research and Development did basic MCT material work during 1983 and 1984. In parallel with this, the E-Lab established a working relationship with North Carolina State University, which was quite successful. To further this work, the E-Lab hired Steve Jost and then Fenner Milton, who took over management of the electro-optics work.

VLSI design

A significant capability in VLSI circuit design came from SSAO and was organized in the E-Lab under John May. One of their successful efforts was the design of 1.25-micron chips for HMED's Military Computer Family (MCF) program for the Army, and they also provided design capability to AESD and SCSD.

High-speed digital electronics

The use of GaAs material made possible not only microwave integrated circuits, but also promised the development of digital circuitry operating at much higher speeds. E-Lab activity in this area was crystallized in 1982 by the establishment of an intra-group IR&D program to develop a fiber-optic multiplexed bus for digital system interconnection. This aimed toward the complete integration of both the required digital and optical devices on a single chip.

Conclusion

Since its establishment in 1944, the Electronics Laboratory has survived many variations in its reporting, direction, recognition and financial support. Twice other company laboratories and their management were completely absorbed along with major cutbacks in personnel. In spite of these obstacles, the Electronics Laboratory has continued to provide key products, technology and technical personnel to the electronics businesses of the General Electric Company. These accomplishments are a tribute to the spirit and dedication of the scientists and engineers who have constituted the Electronics Laboratory since its beginning.

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