

RAIL TRANSPORTATION

Rail Transportation in the Delaware Valley History of SEPTA

Stanley Sandler

TROLLEY CARS

In 1892 electric trolley cars were introduced in Philadelphia. They were immediately successful and trolley lines soon spread throughout the city. Philadelphia's trolleys reached their apex in 1911 when 4,000 streetcars operated on eighty-six routes.

SEPTA's City Transit Division owns and operates 260 Presidential Conference Committee (PCC) cars and 112 LRVs (Light Rail Vehicles). There are twelve trolley routes running from three districts that stretch over approximately 194 track miles throughout the city.

The PCC cars were built in the 1940s and operate on a track gauge of 5'2 1/4". The earliest PCC cars were equipped with air controls for brakes, wipers, and sanders, while the newer PCC cars were manufactured with electric controls. Although air control PCC cars are being phased out of service, the best of all-electric PCCs are being rebuilt to add approximately eight more years of service life. New Light Rail Vehicles replaced Presidents' Conference Committee (PCC) cars on the lines in 1982.

The LRVs were built in the early 1980s and were the first new trolleys to be used in Philadelphia since the 1940s. Among the many new features of the LRVs are: air conditioning, acceleration controls, air suspension and public address systems.

The LRVs operate over SEPTA's five subway-surface routes that connect West and Southwest Philadelphia and Center City and on the Suburban Media and Sharon Hill Line.

The two and one-half mile long subway-surface tunnel connects West Philadelphia with Center City Philadelphia. Built at an approximate cost of ten and seven-tenths million dollars, it serves streetcar routes 10, 11, 13, 34, and 36.

Ground was first broken for the subway-surface tunnel at the junction of 23rd and Market Streets on April 6, 1903. Streetcars on the Market 63rd Vine Streets route began using the tunnel on December 15, 1905. At this time the tunnel was completed only to 15th Street. In December, 1906 three more trolley routes were diverted into the tunnel the Lancaster-Haddington route (route 10), the Darby route (route 11) and the Angora route (route 34).

In August 1908 the subway was extended to the Juniper Street Station after the station was constructed. By 1933 the subway was completed between 24th Street and 32nd Street. In 1947

new plans called for extending the subway westwards to 36th Street with cars surfacing at the junction of 36th and Ludlow Streets. As construction work progressed it was decided to extend to 40th Street between Baltimore and Woodland Avenues.

The new tunnel opened for eastbound cars in October 1955 and in November for westbound cars. New stations were opened at 22nd, 30th, and 33rd Streets and also at 36th and Sansom Streets and 37th Street. Routes 11, 34 and 36 entered the tunnel at 40th Street. Route 10 entered at 36th and Ludlow Streets. Route 13, which operated between West Philadelphia and Center City, was diverted into the subway-surface tunnel in September, 1956.

In November, 1971, a completely renovated 15th Street West-bound Station was opened featuring tiled floor and wall, improved lighting and structural improvements. In the spring of 1975, the Juniper Street Station was renovated at a cost of over two million dollars.

SUBWAY ELEVATED LINES

The Market Street Subway Elevated was opened between 69th Street and 15th Street in 1907 and was extended to 2nd Street in 1908. An extension was also built to South Street via Delaware Avenue in 1908, but this was discontinued in 1939. The original line operated as an elevated between 69th Street and the eastern bank of the Schuylkill River and as a subway east of the river. The subway tunnel was extended from 23rd Street westward to 45th Street in 1955. This line was constructed by SEPTA's predecessor, The Philadelphia Rapid Transit Company.

The Frankford Elevated Line was constructed by the City of Philadelphia and opened for service in 1922. This addition provided uninterrupted service between 69th Street and the Bridge Street Terminal.

SEPTA currently owns the Market-Frankford facilities between 69th and Arch Streets. The City of Philadelphia owns the portion of the line from Arch Street north to Bridge Street and the Subway-Surface tunnel west of 30th Street.

The Market-Frankford Subway-Elevated line is a two-track system with two additional tracks used by subway-surface cars between City Hall and 40th Street. Planning is now underway for an extensive rehabilitation of the Frankford Elevated portion of the line.

The Market-Frankford cars operated by SEPTA were purchased in 1959 from the Budd Company. Approximately one half of these cars are owned by the City of Philadelphia and one half are owned by SEPTA. The track gauge on this system is 5 feet, 2 1/4 inches with 600 Volt D.C. power supplied by bottom contact to a parallel third rail.

There are two types of cars: single cars and coupled or married cars. Single cars have controls at each end and can be operated by themselves or in combination with coupled cars. Coupled cars must be mated such that cars with motor generators are coupled to cars with air compressors. They have controls at one end and cannot be operated except as a coupled pair.

The Broad Street subway was opened for service in 1928 extending from Olney Avenue to City Hall. In 1930 the subway extended to South Street and in 1938 to Snyder Avenue. Northern service was extended to the Fern Rock Terminal (10th and Nedo Streets) in 1956. In 1973 the subway was extended south to Pattison Avenue. The Ridge Avenue Subway Spur was opened in 1932.

The Broad Street and Ridge Avenue subways are owned by the City of Philadelphia. The facilities are operated and maintained by SEPTA personnel. The subway is equipped for four-track operation between the Erie and Walnut-Locust stations with two track operation through the rest of the system.

TRACKLESS TROLLEY

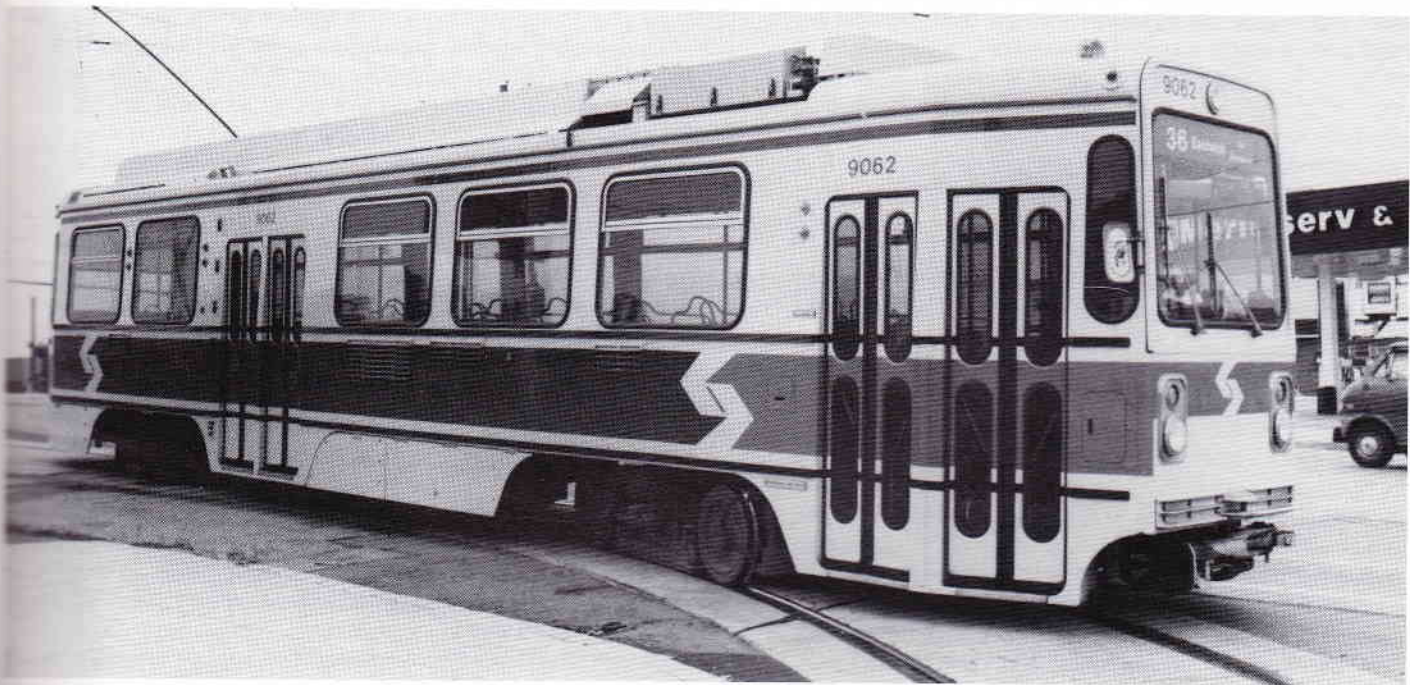
Trackless trolleys were introduced to Philadelphia on October 24, 1923, along Oregon Avenue (Route 80). Today SEPTA operates 110 trackless trolleys over five routes. These vehicles are dispatched from two districts and cover forty-two miles within the city.

SEPTA has operated four basic types of trackless trolleys. By 1980, the AM General replaced all older trackless trolleys. Philadelphia's first trackless trolleys were Brill 'Rail-less' Cars, built in 1923 for Route 80. They were patterned after the street cars and had solid rubber tires.

SUBURBAN LINES

One of the country's few remaining inter/urban trolley systems, the Media and Sharon Hill Lines, link Upper Darby's 69th Street Terminal and the Delaware County towns of Media and Sharon Hill.

The two suburban lines were opened in stages between 1906 and 1917 by the Philadelphia and West Chester Traction Company, which in 1936 became the Philadelphia Suburban Transportation Company (PSTC). PSTC then adopted the Red Arrow symbol that remained until SEPTA purchased the lines in 1970. Although the Media and Sharon Hill Lines are not grade-separated like the Norristown-High Speed Lines, they are mostly double-tracked and operate primarily on private right of way.



Light Rail Vehicle

In October, 1982, the picturesque old trolley fleet of Brilliners, St. Louis's and No. 80 cars were retired and their duties assigned to twenty-nine modern high-speed, air conditioned, Light Rail Vehicles. SEPTA's Suburban Transit Division operates twenty-nine double-end LRVs on its Media and Sharon Hill Lines.

One of the country's last interurbans, Norristown High-Speed Line, covers a 13.5 mile run between Upper Darby and Norristown.

Opened in 1907, the high speed line, then known as the Philadelphia and Western Railway Company, operated between 69th Street in Upper Darby and Stratford — a distance of 10.6 miles with a construction cost of four hundred thousand dollars a mile. The original stations were 69th Street, Beechwood Park, Ardmore

Junction, Ardmore Avenue, Haverford, Bryn Mawr, Rosemont, Garrett Hill, Villanova, Radnor, Ithan, St. Davids, Wayne and Stratford. During the next five years, a new portion was constructed between Villanova and Norristown at a cost over one and one-half million dollars.

On August 26, 1912, the first P & W trains operated between 69th Street and Norristown. Express trains made the thirteen and five tenths mile run in twenty-six minutes. Fare was twenty-five cents.

The new portion included the terminal at Norristown and the stations at Bridgeport, Gulph Mills and DeKalb Street (later changed to King Manor). On March 23, 1956, the Villanova to Stratford portion of the line was abandoned because of dwindling ridership.

Railroad & Transit Electrification

Harry Rappaport (LS '81)
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During the last few years, many articles have been written, many studies performed, and many U.S. Engineers have toured, overseas high speed, electrically operated railroad and transit installations.

Among the electric railroads toured was the French TGV, which moves their trains in an excess of 135 mph; the Japanese, Shinkansen Bullet Trains and the British Intercity Traffic, moving electrically operated railroad cars at 130/125 mph.

Why go over the pond, when more than ten years ago U.S. technology designed and built equipment and performed tests on existing (upgraded) commercial rail-beds and fifty year old catenary, at speeds up to 150 mph. These tests were performed on what is now Amtrak's Northeast Corridor in New Jersey, U.S.A.

At this date, U.S. Northeast Corridor trains are travelling at speeds up to 120 mph, on existing Northeast Corridor right-of-way. This is not on a brand new railroad track or catenary system.

The New Haven (now a section of Amtrak's Northeast Corridor) was the world's first A.C. electrified railroad, installing an auto-transformer 11kv, 25 Hz electric traction system, which the Japanese National Railroad adopted many years later, using 50/60 Hz at higher voltages.

A compound (3 wire) catenary system was designed and installed on the Northeast Corridor (Former P.R.R.) for high speed operation, over half a century ago, which was also used as an example for installation by overseas engineers along with their newly developed constant tensions.

In retrospect, the pioneer electrification in the U.S. was installed before the turn of the century by the B&O and the P.R.R. in 1895, followed by a Camden to Atlantic City run in 1906.

Shortly thereafter, in order to eliminate delays and slow movement via river traffic, the Pennsylvania Railroad (PRR) installed tunnels through the Hudson and East River. To permit their use by railroad traffic, a 600 volt-DC third rail system was installed in 1910. This system extended twenty five miles from Manhattan (Hudson) transfer, NJ, to Sunnyside (New York City), New York.

Alternating current was chosen even though direct current provided ideal motor torque characteristics for slow speed, the direct current could only handle low voltage along with its high currents, which necessitated close substation spacing and extremely large conductors. High voltage alternating current permitted much longer substation spacing and smaller conductors. Low frequency alternating currents (25 Hz) series-wound motors provided the low speed torque characteristics. This low frequency electricity used long HV transmission runs between the rotary converters, with minimum reactive loss in the catenary, permitting small size conductors.

After the PRR's initial experimentation with various types of direct current electric locomotives through the NY/NJ tunnels, the Pennsylvania selected alternating current as the more efficient and economical system. The AC system decided upon was a single phase, 25 Hz system for both locomotive and multiple units (MU) using a series wound AC traction motor. Although no suitable on-engine rectifying apparatus was available at that time (1915), 25 Hz energy was obtained through wayside rotary frequency-changers that were driven by 3 phase, 60 Hz motors and generated single phase 25 Hz at 13,600 volts.

In 1915, the PRR completed its overhead 12,500 volt electrification between Philadelphia and Paoli on its suburban commuter service and later in 1931 this 25 Hz was made continuous to New York.

The PRR continued expansion of its electrification with the 1935 electrification extension southward to the Capitol in Washington, D.C. The final stage from Paoli, PA and Perryville, MD to Harrisburg, PA was completed in 1938. This final electrification included wiring railroad distribution and storage yards at Washington Potomac Yard and Ivy City, along with Harrisburg-Enola and Sunnyside Yard.

The total electrification was 656 route miles and 2,350 track miles.

During the early days of railroad electrification there were no utility company interconnections by high voltage transmission lines and the railroad load at times exceeded the total generation of local power companies. In order to provide this large power demand,

the Pennsylvania erected its own high voltage transmission lines. These lines spanned the PRR system at 132,000 volt (now 138,000) single phase, 25 Hz, from step-up stations generating this power at 13,200 volts (now 13,600).

The Pennsylvania also initiated its own signal power transmission facilities. This provided a 100 Hz (+96.7) modulated signal used to provide the locomotive (MU) engineer with signal information regardless of fog or other masking of the distant wayside signal. The coded energy in the rails is also available for wayside signals, eliminating the need for line wires.

This signal power is generated at various substations through motor/generator sets that convert the single phase 25 Hz to single phase 100 Hz (96.7) which is transmitted at 6,900 volt, using space on existing high voltage catenary poles.

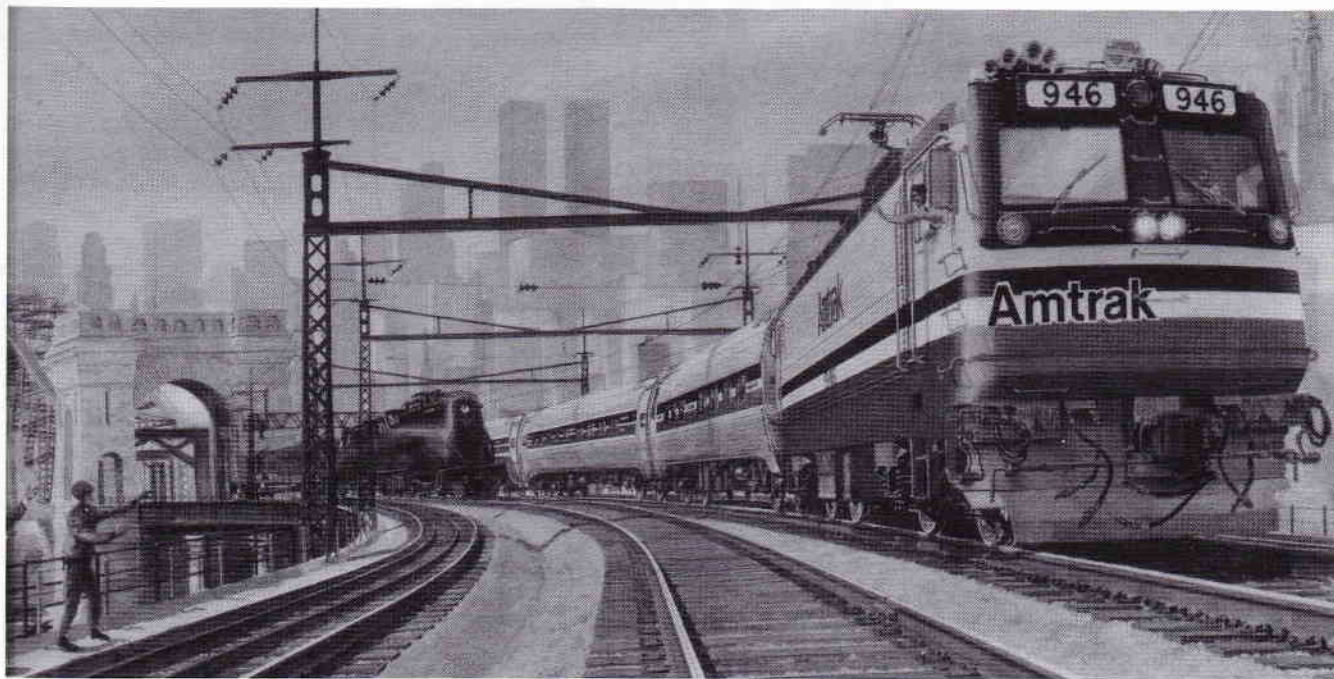
As indicated above, the 100 Hz is modulated and used as a carrier for the signal information provided to the engineer. On the Northeast Corridor this modulation is 75, 120, and 180 pulses per minute and is carried by the two rails in front of the locomotive (MU). Two pick-up coils are mounted on the front and are connected in opposition to induce currents in the same direction and to minimize electrical noise riding the rails created by the high level traction currents traveling along with the modulated signal carrier. This signal is then de-modulated, to energize the cab indicated signal aspect, simulating wayside conditions immediately in front of the locomotive.

Amtrak's Northeast Corridor has used several types of equipment. Many rail fans associate electric train operation with the famous GGI, the first streamlined electric locomotive in the world to pull railroad trains. For many years this locomotive was the world's most powerful locomotive, and with its twelve large drivers and eight ponys. The GGI has been retired after almost half a century of faithful service and its original prototype (4800) now rests at Pennsylvania's State Railroad Museum in Strasburg, PA.

During the early days of Amtrak's Northeast Corridor operation, the E60CP 6000 HP electric locomotive was gradually replacing the GGI's.

With Amtrak improvement of roadbed and switching points (interlocking), speeds have been gradually increased and metroliners were pressed into service to accommodate speeds up to 100 mph.

Metroliner (MU) type vehicles also have been gradually replaced by the more versatile AEM 7, which have the capability of operating on catenary frequencies of 25 or 60 Hz and voltages at 12,000 or 25,000. Hotel power (lights, heat, air-conditioning, food, etc.) for the AEM-7 trains is produced from the catenary via solid state converters that change the single phase traction power to three phase 480 volts double distributed throughout the coach's sleepers and diners.



1983 AMTRAK Calendar, illustrating an AMTRAK AEM 7 and GG 1 operating over the New York Hellgate Bridge.

When the NECIP (Northeast Corridor Improvement Project) was started, plans were developed to extend AC electrification from Hew Haven, CT to Boston, MA, at 25,000 volts, however, due to funding limitations this part of the NECIP has been on hold.

Some of the advantages of electrification of railroads:

- 1) Smoke abatement (during coal fired steam engine days)
- 2) Clean, pollution free operation to permit tunnel operation
- 3) Clean, pollution free operation, no oil spillage
- 4) No noise caused by propulsion
- 6) Fast acceleration
- 7) High torque at slow speeds
- 8) More power in smaller equipment since prime power generator is elsewhere



E60CP Locomotive

12) Can use regenerative braking

13) Overload capability

The main disadvantage of railroad electrification and the reason why U.S. companies have not installed new systems, is the initial cost of installation, with its accompanying high rate of interest.

This is not a problem overseas since, in most cases, the railroad is government owned and operated. As a result, railroad electrification is proceeding at an extremely fast pace.

A prediction — shortly the U.S. will wake up and find they are missing the train on this marvelous method of ground transportation and will take advantage of its quiet, efficient, economical and fast movement of people and goods, by installing many miles of railroad electrification.



GG 1 Locomotive

Chest Radiograph 1925-1943

S. Reid Warren Jr., (LF '53)

From 1925 to 1943 Professor Charles Weyl, Moore School of Electrical Engineering, University of Pennsylvania, and several of his colleagues worked on problems related to the making of X-ray films of the chest. The origin of this project, the methods of approaching and solving some of the problems, and some of the results are interesting from several points of view. First, there were elements of systems engineering in the project, although that name had not yet gained popularity. Second, there developed from the work on the project many lasting and rewarding professional associations and friendships among people in diverse occupations: physicians, engineers in industry, and faculty members. Third, there arose, spontaneously, opportunities in other areas: activities in professional societies, including AIEE; research and development in other fields of electromedical work; and opportunities for teaching courses in the Moore School and in medical schools.

What follows is a summary of an effort to improve apparatus and techniques for making and using X-ray films of the chest. The work was supported by grants from the National Tuberculosis Association (now the American Lung Association) and from several insurance companies and by contributions of the manufacturers of X-ray equipment who loaned apparatus for tests.

The initiation of the work in the Moore School in 1925 depended upon a series of events that appear, in retrospect, to be coincidences. F. Maurice McPhedran, M.D., a Canadian physician who later became an American citizen, contracted tuberculosis, cured at Trudeau Sanatorium, Saranac, New York. Subsequently, he engaged in research at the Henry Phipps Institute, University of Pennsylvania; his chief objective was to find out how to produce X-ray films of the chest that would display as accurately as possible signs by which physicians could diagnose diseases of the lung. Although there was no specific cure at that time for tuberculosis, accurate knowledge of the progress of the disease from physical signs and particularly from X-ray films was essential to decisions as to how to treat each patient.

In 1925 Dr. McPhedran asked Harold Pender, Dean of the Moore School, if some one on the staff might like to help him with the physical and engineering aspects of his problems. Professor Charles Weyl volunteered to work with Dr. McPhedran.

Weyl's first contribution was the development of the pulse relay which was designed to cause the X-ray exposure to be synchronized with a particular phase of the cardiac cycle. For this work Professor Weyl was awarded the Edward Longstreth Medal by the Franklin Institute in 1930. This pulse relay was initiated by the

pulse in the carotid artery. A time delay was inserted so that the X-ray exposure occurred in diastole, i.e., when the heart and vessels were nearly stationary. The use of the pulse relay produced stereoscopic films taken in the same phase of the cardiac cycle; all parts of the chest were perceived in three dimensions with minimum blurring (unsharpness).

Subsequently, Weyl organized a few faculty members and graduate students to develop methods for measuring the electrical characteristics and radiation output of apparatus used for taking X-ray films of the chest. They designed and built a laboratory with a wood cage into which high-voltage X-ray equipment could be installed or removed with ease; a bank of resistors to be used as a "dummy" load on each machine; a 100 megohm voltage divider to measure high voltage; a small darkroom with accurate temperature control for film processing solutions; and a variety of auxiliary equipment such as a densitometer to measure film densities.

Several manufacturers of X-ray equipment and of supplies such as film and intensifying screens had been asked to lend samples of their products for tests. They agreed and their contributions were essential to the success of the program. The staff proceeded to make comparative tests of most of the chest radiographic apparatus made in the United States during the decade 1930-40. Results of tests on specific equipment or auxiliary materials were given solely to the manufacturer. However, in the course of the tests, and in research and development projects associated with them, much important information concerning the process of making X-ray films of the chest were revealed. This formed the basis of papers in the radiological journals and the active participation of the members of the staff of the laboratory in the presentation of such papers—and the preparation and showing of exhibits—at national meetings of the National Tuberculosis Association; the American Medical Association; the Radiological Society of North America; and the American Roentgen Ray Society.

It became clear about 1932 that a major objective should be to find out how physicians in hospitals and tuberculosis sanatoria were producing X-ray films of the chest, what were the physical characteristics of those films, and how the equipment and exposure techniques could be modified to improve the quality of the films. This required the design and construction of portable equipment to measure high voltage, X-ray tube current, and other technical factors and particularly to measure radiographic results without excessive exposure of individuals to X-rays. The last requirement was satisfied by deductions from a series of X-ray films. Radiographs using several different techniques were made.

right chest of an individual and, simultaneously, of an aluminum ladder of eight steps from one-eighth inch to 1 inch. It was found that each of several areas in the chest corresponded in photometric density to the density beneath a particular thickness of aluminum regardless of the wide variations produced by the several different techniques. Therefore, it was not necessary to make chest films in each hospital or sanatorium; exposing the aluminum ladder provided the key information as to the density and contrast of chest films made at that institution.

Accordingly, physicians in hospitals and tuberculosis sanatoria were offered a consulting service. Members of the Moore School staff—usually two persons—would visit a laboratory, test the equipment and submit recommendations for improving radiographic results. Sometimes, physicians were able to obtain funds for new equipment. Therefore, the Moore School staff prepared specifications for such equipment and consulted on the choices among several bids. The specifications, incidentally, did not describe, in gory detail, the measurements of each piece of equipment and all the physical dimensions; instead, they described results that were to be achieved and outlined the methods for achieving them. This gave the bidder, and therefore the buyer, greater flexibility in the choice of new equipment. The consulting service was eminently successful. From 1932 to 1939 about 200 hospitals and sanatoria in about 30 states in this country and several provinces in Canada either were visited or were consulted by mail with respect to purchase of new equipment.

The work described above led to other activities which are not considered in detail in this summary. For example, there was extensive cooperation with the Air Hygiene Foundation of the Mellon Institute in Pittsburgh, under the auspices of Eugene Pendergrass, M.D., Chief of Radiology at the University of Pennsylvania

and development and presentation of courses in radiological physics to student X-ray technicians (now technologists), and residents in radiology in medical schools. In the latter case there resulted a cooperative venture among the several medical schools in Philadelphia whereby their staff members worked together on a program in radiological physics for all radiology residents in the several schools who wished to participate. There was extensive collaboration with the National Bureau of Standards, persons in particular research departments in industry such as Rex Wilsey at Eastman, persons in medical schools such as Ed Chamberlin at Temple, Otto Glasser at Cleveland Clinic, and persons in professional-society committees such as the Committee on Therapeutics of AIEE, which has evolved into the IEEE Society for Engineering in Medicine and Biology. Later, owing to publications and travel, there were valuable associations with persons with cognate interests in Great Britain, Germany, Netherlands, and Sweden. Finally, it should be noted that two books were published: a technical summary of the work in the Moore School entitled "Apparatus and Technique for Roentgenography of the Chest" in 1935; and two editions of a textbook entitled "Radiologic Physics" (1941 and 1951).

Work on chest radiography in the Moore School came to a conclusion early in the Second World War, when staff members chose to participate in activities directly related to that war. Furthermore, the basis for the production of high-quality chest films had been established not only in the work described above but by that in other laboratories throughout the United States and Europe, some of which are referred to above. Finally, thanks to antibiotics and other developments in biology and medicine, tuberculosis is no longer a major problem; many of the sanatoria visited during the 30s have been converted to other purposes or closed. Such is the fast-changing face of science and technology in the 20th century.

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Systems Engineering — A Formal Beginning

J. G. Brainerd, (LF '69)

Before World War II and ever since, Systems Engineering has been practiced in the Bell Laboratories and during World War II the field of operations research became prominent. It became evident to a few engineers that operations research was in most respects a part of systems engineering.

After several experimental seminars on "systems engineering and operations research", the Moore School of the University of Pennsylvania organized, through a national committee, a Workshop in Systems Engineering. This was held in 1959 on campus, with representatives from more than 50 institutions in attendance. There were extensive talks of what constituted the elements of systems engineering and examples of major applications. This workshop had a profound effect, with numerous specialized

courses and, finally, a curriculum in the undergraduate sense and a specialty in the graduate sense becoming broadly available.

It is believed that the Moore School graduate seminars which preceded the workshop were the first university courses in systems engineering, and that the workshop started the growth in systems engineering courses and curricula which exist in abundance today.

As an aside, we might mention that the workshop was attended by an officer of the Ford Foundation and it was from his discussions with members of the Moore School staff at that time that talks were initiated which led to the \$3 million Ford Grant for Engineering at the University of Pennsylvania.

Computer Development at the Moore School of EE

J.G. Brainerd, (LF '69)

The ENIAC, which was conceived, developed, designed and built entirely within the Philadelphia section, and specifically in the Moore School of Electrical Engineering of the University of Pennsylvania, was the world's first large-scale digital electronic general-purpose computer. The history of its inception and creation has been told in many articles and books, and the ENIAC has become a matter of historical importance. To summarize extremely briefly: a stimulating memorandum was written by John W. Mauchly, Assistant Professor, given to J. G. Brainerd, Professor and at the time, supervisor of other war research projects, then discussed with Herman H. Goldstine, liaison officer with the Army Ordnance Department, stationed at the Moore School, who effectively "sold" the idea to two superior officers. The result was that the University submitted a formal proposal and was awarded the contract for the R&D work.

Under the contract the project was the responsibility of the University, and within the University, by agreement of two responsible officers, Brainerd was placed in complete charge of the project, a position, as he afterwards said, he would not have taken if he did not know that he could transfer J. Presper Eckert, a brilliant instructor and graduate student, to the new project.

Eckert and Mauchly are usually given the credit for the technical development of the ENIAC, although engineers such as Kite T. Sharpless, Joseph Chedaker, Chuan Chu, and others were brought together on the project. The ENIAC began June 1, 1943 and the machine was dedicated February 1946. It was a huge affair containing 18,000 vacuum tubes, almost four times that number of resistors, and it had a frame about 80 ft. long arranged in the form of a 'U'.

The first paper ever written about large-scale electronic digital general-purpose computers was the description of the ENIAC which appeared in February 1946 in The Pennsylvania GAZETTE, the Penn Alumni magazine. The first article of potential application of large computers to business problems was written by Adolph Matz, Professor of Accounting in the Wharton School, University of Pennsylvania, and appeared late in 1946 in a professional accounting journal. That paper had an interesting short history in that it was rejected originally as too "ephemeral", but

apparently the publicity which accompanied the dedication of the ENIAC changed the editor's mind.

The Moore School went on to build a second computer, the EDVAC, which was larger mathematically but far smaller and more efficient physically, and had stored memory. It was not, however, the second of the big computers because Maurice V. Wilkes, Professor at the University of Cambridge, England, finished his EDSAC sooner. The EDSAC is a machine for which Professor Wilkes set up a project immediately after visiting the Moore School.

Later the Moore School produced the plans for the UFOFT—Universal Digital Operational Flight Trainer—under the direction of Professor Morris Rubinoff. This was at its time the most flexible such device ever designed. It opened the field to training with groups of planes simultaneously, rather than with just one. The UFOFT was built by a commercial organization to the Moore School plans.

The Moore School had been involved in the computing field for at least 10 years before the ENIAC. In this time it built small machines but its outstanding production was the construction in 1933-35 of the Differential Analyzer. This was a machine of about 50 ft. length and contained ultimately 14 integrators. It was based primarily on a development of Vannevar Bush of MIT. It was an analog machine and carried out many analog operations. It was originally intended to help with non-linear equations which had arisen in three or four branches of Moore School research. At the time it was built, the Moore School had virtually no funds for the project but great good fortune matched the idea to the times (curiously, since it was 1933-35) and a machine of about \$200,000 value in 1935 was achieved.

Editor's Note: A year earlier, Dr. Mauchly had met Dr. John V. Atairasoff, a professor at Iowa State College (now Iowa State University) at a meeting for the advancement of Science. Dr. Mauchly presented a paper at this meeting in which he referred to his ideas concerning development of an electronic computer. Since Dr. Atairasoff was building a computer, he invited Dr. Mauchly to visit the college and observe the computer project.

John W. Mauchly, Co-Inventor of the First Electronic Computer

An Historical Sketch

Abstracted from an interview with John W. Mauchly
by Marian F. Fegley

The circumstances which shape our lives are varied, often curious. One might often wonder what inspired the great inventions that change the course of many lives. John W. Mauchly related his story of one such invention, ENIAC, the first all-electronic computer, as the attainment of a long sought goal. Many factors had combined to inspire him to build a calculating machine which would do more and do it faster than any equipment then known. It did not happen in a flash, but required years of working toward the goal despite much discouragement from others. This work continued even after the ENIAC was completed.

John Mauchly attended public schools in Washington, D.C. where his father was head of the Section of Atmospheric Electricity of the Department of Terrestrial Magnetism of the Carnegie Institute of Washington from 1913 until his death in 1928. As a high school student he would occasionally help take measurements in his father's office.

With the encouragement of a high school teacher, John applied for a scholarship at the Johns Hopkins School of Engineering. After two years in the School of Engineering, he abandoned his Maryland State scholarship and was accepted as a New Plan student in physics. Under this plan he mixed graduate and undergraduate courses. In 1932 he earned his Ph.D. in electrospectroscopy without stopping for a bachelor or master's degree.

He remained at Johns Hopkins as an assistant in physics for another year, after which he was named professor of physics at Ursinus College.

Statistics began to draw his attention. First, he used statistics for a new problem, comparing his students with those in other American colleges and universities. Standardized tests, which were constructed and measured statistically, were available. Statistical studies and analyses were not generally applied to physics or chemistry in those days.

A second-hand oscilloscope purchased by Mauchly was used by physics students during the day, but at night was used to put together circuits to count pulses to make an electronic calculator. The idea seemed rather obvious to Dr. Mauchly as it was similar to the method then used to count cosmic rays. Thus the idea of an electronic calculator was conceived as Mauchly and his student

assistants processed some of the mass of geophysical data. He believed that all one needed was suitable inputs from keyboards or punched cards and outputs to punched cards or printers. He also realized that to be really useful the equipment must be able to store information and remember a set of instructions on what to do with the numbers.

About this time he built an analogue computer with 12 input knobs and one output knob. This was used to analyze the tide in the atmosphere as it is affected by the sun and the moon. Calculations, which required twenty minutes using a desk calculator, could be done in two minutes with the analogue computer and a reading meter. The results looked interesting, but so much more data needed to be analyzed before truly significant results could be obtained.

About 1940, Dr. Mauchly believed that he had to get the electronic computer program started. Since Ursinus College, PA did not have the funds for such a project, he considered industry, government service, and other academic institutions. At the same time he sought opportunities to learn more about calculating instruments already in existence or proposed. He spoke freely of his ideas hoping for both support and suggestions.

A graduate course on the theory of design of computing instruments at the University of Pennsylvania attracted his attention. Penn had a big calculating instrument, a differential analyzer—only two others existed. When Penn offered a summer defense training course in electronics in the spring of 1941, he was quick to apply, knowing that those completing courses would be considered hired in a defense industry.

He went to Iowa State College (now Iowa State University) to meet Dr. John V. Atanasoff, who was building a computer (far from completion) with the help of graduate students. While there, he heard that he had been accepted for Penn's summer course. Dr. Atanasoff and Mauchly had met at an American Association for the Advancement of Science meeting over a year earlier when Mauchly had presented a paper in which he mentioned his ideas for an electronic computer.

Since the laboratory work for the course was about the same as that which the Ursinus professor assigned to his senior physics

students, he spent much of these periods discussing with the laboratory instructor, J. Presper Eckert, Jr., the possibilities of building a computer. Upon completion of the course, Mauchly was offered and accepted a teaching position at Penn's Moore School of Electrical Engineering.

The Moore School's differential analyzer was being used by Army Ordinance to supplement its twin at Aberdeen Proving Grounds. Both were hard at work calculating tables for the Ballistic Research Laboratories. These tables were mostly firing tables, tables of the path along which projectiles travel when fired.

When Lt. Herman H. Goldstine, who was supervising the Aberdeen Proving Grounds contract at the Moore School, learned about Mauchly's ideas, he was fired with enthusiasm and asked Mauchly to submit a development proposal to the Army.

The proposal was made in early April and a contract for research into an electronic trajectory computer with the Ordinance Department of the U.S. Army became effective July 1, 1943. Mauchly and Eckert set to work on the design with a team of 12 engineers. The computer they designed was not like any previously described in print. It was essentially a repetition of many common parts, which would accept decimal numbers, give decimal output, and provide a decimal storage device. Every bit of circuitry was built to operate on the "all or none" principle. Many design principles were established at the start. Mauchly said (before his death), "I think of Eckert as being one of the first people who deserved the title of 'reliability engineer'." The actual value of resistors and the performance of vacuum tubes available in 1943 varied widely. Dr. Eckert designed the circuits so circuit performance would be independent of circuit current.

In December 1945 the monstrous machine was completed. The electronic numerical integrator and calculator, dubbed ENIAC by Army Ordinance, had a half million parts and over 18,800 vacuum tubes of only 10 types, 60 kinds of resistors, and 30 kinds of capacitors.

In mid-February 1946, various news media carried the announcement that the ENIAC, an electronic computer, had been invented by J.W. Mauchly and J. Presper Eckert, Jr and built at the Moore School of Electrical Engineering of the University of Pennsylvania.

The ENIAC, which required about 3 milliseconds for a multiplication, or did 5000 additions a second, promptly made relay calculators obsolete from the scientific viewpoint for they had a top speed of about 10 additions per second. During its first months at the Ballistic Research Laboratories, for a typical week of actual work, ENIAC was equal to 500 human computers working 40 hours with desk calculators. It was anticipated that this rate would double or triple as the operators gained experience. While designed primarily to calculate trajectories, the ENIAC was modified during the building to enable the machine to calculate a very wide class of problems. It had two major limitations: its storage capacity was at most twenty numbers (of 10 decimal digits each) and the instructions had to be set up thru a slow manual process of wire plugging or switch setting.

Although the ENIAC did not have a large storage device, the 1945 report gave a clear recognition both of the problems and of the advantages to be gained through the availability of such a device. Actually the realization that this was needed and could be included came in 1944. This was a crucial point as the ENIAC design was well under way. As there was so much skepticism about its ability to function as proposed, work was continued on the original design. The ideas were recorded and later were incorporated in the EDVAC, built at the Moore School, the UNIVAC designed by Eckert and Mauchly and subsequently produced by Remington Rand, and the smaller BINAC.

The application for a patent on the ENIAC was the longest ever filed up to that time, June 1947. No one in the patent office was then qualified to examine it. The patent was issued seventeen years later, nearly eight years after ENIAC had been dismantled following ten years of continuous operation at Aberdeen Proving Grounds.

History of Computer Systems Operations of Sperry Corporation

In 1946, two University of Pennsylvania engineers laid the foundation for the present Computer Systems operations of Sperry Corporation. In that year, the world's first all-electronic digital computer known as ENIAC (Electronic Numerical Integrator and Calculator) was completed at the University's Moore School of Electrical Engineering in Philadelphia for the U.S. Army Ordnance Department under the leadership and direction of J. Presper Eckert and Dr. John W. Mauchly.

ENIAC weighed 30 tons, used 18,000 vacuum tubes and occupied 1,500 square feet of space on the first floor of the Moore School. It was capable of performing 300 multiplications per second. By contrast, the fastest electromechanical devices at that time could only do one multiplication per second.

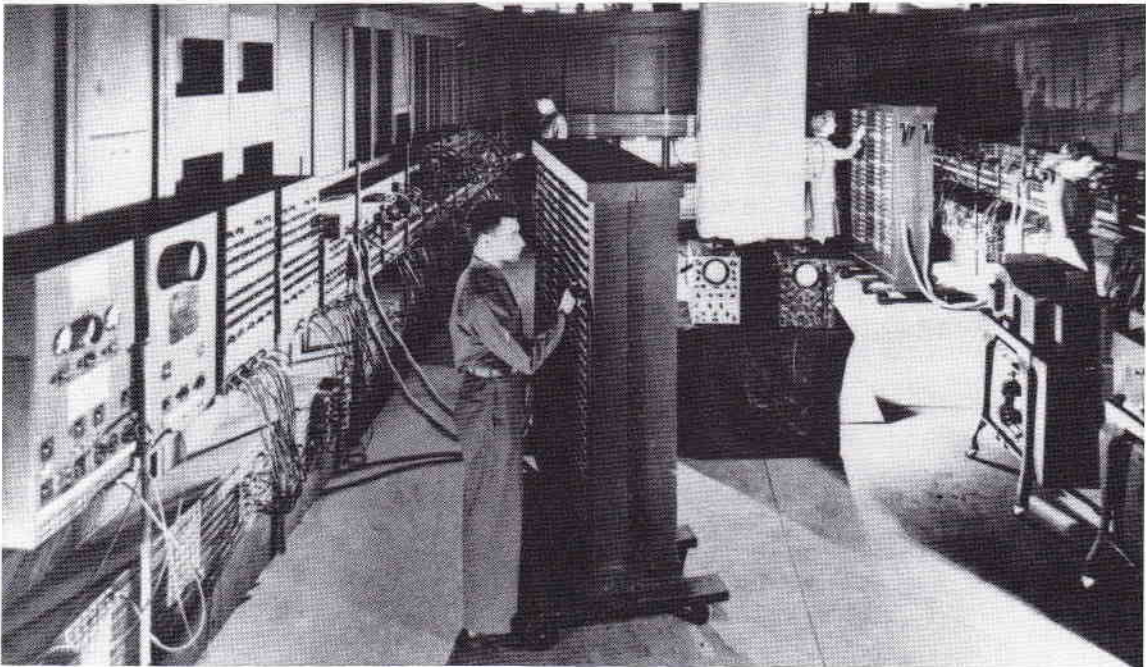
Soon after this development, these two engineers formed the Electronic Control Company, which subsequently became the Eckert-Mauchly Computer Corporation. In 1949, this company completed a computer called BINAC (Binary Automatic Computer), which was believed to be the first machine to be programmed by internally stored instructions. Designed for scientific applications, BINAC was built under contract to the Northrop Corporation, California.

The development of BINAC served as a test vehicle of plans Eckert-Mauchly had formulated for the UNIVAC® I (Universal Automatic Computer). UNIVAC I was the world's first, general purpose commercial computer able to handle a wide variety of applications.

An alpha-numeric machine, UNIVAC I made extensive use of peripheral equipment—card reader, magnetic tape units and printer. Another significant feature was that it was able to simultaneously read new information, compute information just read and record the output results.

Data and program instructions were all stored in a mercury delay line memory. Information could be recycled in the line in the form of acoustical pulses. After pulses traversed the length of the mercury, they would be read and automatically introduced again to the beginning of the line. This process could go on indefinitely while needed information could be accessed as fast as 200 milliseconds.

The Eckert-Mauchly Computer Corporation was acquired by Remington Rand, Inc. in 1950 and work continued on the UNIVAC I development. The first UNIVAC I was supplied to the United States Bureau of the Census in March, 1951.



ENIAC Computer

The UNIVAC I central processor weighed 16,000 pounds and used more than 5,000 vacuum tubes. It could perform about 1,000 calculations per second.

UNIVAC I became famous for its use in predicting the outcome of the 1952 Presidential election — the first time a computer was used for this purpose. The computer predicted that Eisenhower would defeat Stevenson by 438 electoral votes to 93. The actual count turned out to be very close to this — 442 to 89 in favor of Eisenhower.

In 1952, Remington Rand made a second acquisition in the data processing field by purchasing Engineering Research Associates (ERA) of St. Paul, Minnesota. ERA consisted of a group of mathematicians and engineers who, during World War II, had been active in the development of electronic cryptographic equipment.

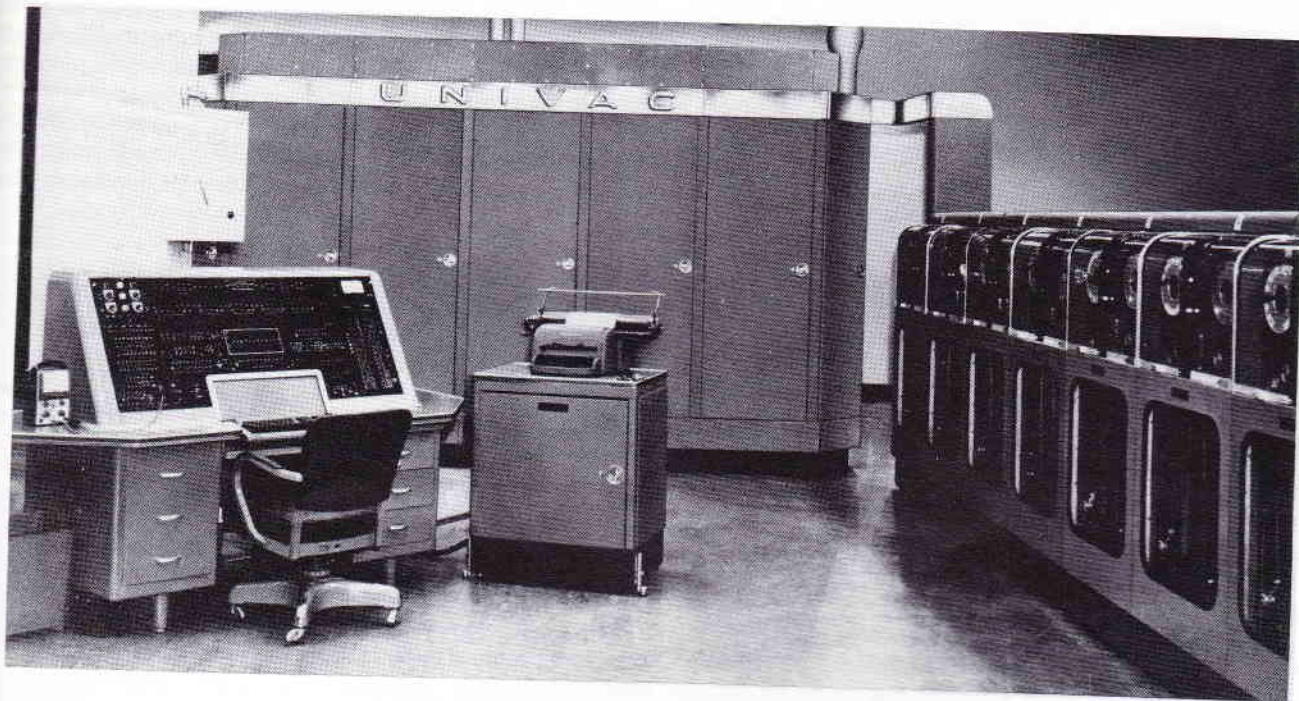
After the war, ERA entered the data processing field and, in 1950, delivered the first scientific computers in the United States to the U.S. Navy and Georgia Institute of Technology. Later known as the UNIVAC 1101, these machines were markedly different from the UNIVAC I.

In contrast to the UNIVAC I's mercury delay line memory, the UNIVAC 1101 stored programs and operating data on the surface of a rotating magnetic drum. This early work with magnetic drums proved to be an invaluable experience for subsequent development of on-line, real-time systems.

The 1101 is believed to be the first electronic computer that was used in a real-time, on-line mode. It was directly connected to the wind tunnel at the Wright-Patterson U.S. Air Force base in Dayton, Ohio. The analog information recorded by sensors in the wind tunnel was converted to digital form, transmitted to the computer, processed by the computer, converted again to analog form, and fed back to the wind tunnel to help control and adjust its performance.

In 1953, an improved version of the 1101 — the 1103 — was produced. This was the first commercial computer to be delivered to a customer with coincident current magnetic core storage. The UNIVAC 1103 was 2,000 times faster than the 1101.

During the early 1950's, following the installation of the Bureau of Census UNIVAC I, computers started to move out of the laboratory and into the business world. In 1954, the first system was delivered to a non-government customer, the General Electric Company at their Louisville, Kentucky facility.



UNIVAC I Computer

Concurrent with continuing developments in computing technology, were organization changes. In 1955, Remington Rand, Inc. and the Sperry Corporation were consolidated to form the Sperry Rand Corporation. Univac became a separate division of Sperry Rand in 1962. The division name was changed to Sperry Univac in 1973. In October, 1982, the name was changed from Sperry Univac to the Computer Systems operations of Sperry Corporation. (Earlier, in 1979, the corporate name was changed to Sperry Corporation.)

Simultaneously, there were several facility changes going on during this period of computer development in the Philadelphia area. After leaving the University of Pennsylvania, Eckert and Mauchly established their company at 1215 Walnut Street, in downtown Philadelphia. In 1948, they moved to Broad and Spring Garden Streets, also in the center city area. A year later (1949), the company moved to Ridge Avenue in North Philadelphia. Subsequently, after Remington Rand acquired control, the Eckert-Mauchly division was headquartered at three separate locations on Allegheny Avenue in North Philadelphia between 1952 and 1956.

In 1961, a Univac Engineering Center was established in Blue Bell, a suburban community about 20 miles northeast of Philadelphia, and gradually the company's personnel were relocated from North Philadelphia. The Blue Bell site became the world headquarters of the Computer Systems operations in 1966.

Sperry has pioneered many computer advances, originating or improving upon major historical developments in the field of data processing. These improvements have spanned every generation of computers from those in the era of vacuum tubes, to the introduction of transistors, and later to semiconductor integrated circuits. Main memory developments progressed over the years from mercury delay lines and magnetic drums to ferrite cores, plated wire and then to the present integrated circuit technology.

Progress in the development of peripheral equipment kept pace with improvements in the central processor. Through the years, refinements and new engineering techniques produced peripheral equipment with ever higher operating speeds and greater capabilities. Sperry offers a full line of data entry equipment, high-speed printers, magnetic disk and tape subsystems and optical character readers.

In more recent years, with the growth of data communications, production of both the printer and visual display type of remote terminal has become a major part of Sperry manufacturing.

Another area in which Sperry has excelled is in the development of real-time computers. Real-time means being able to find information or answer an inquiry virtually instantaneously in a period of time related to the urgency of the question. This contrasts with the batch-mode type of computer operation—represented typically by payroll processing. Although a payroll has to be produced

according to a set schedule and time frame, it does not have the immediate urgency of, for example, the confirmation of an airline reservation by a real-time computer.

A real-time computer can, at any time, deal with questions of immediate urgency, and quickly alert management as soon as it detects a situation calling for immediate action.

The development of one of the first operational real-time computers originated in 1954 when the United States Navy asked Sperry to help in the development of a system that would instantaneously and automatically accept, process and display vital tactical information in shipboard combat centers. Sperry subsequently designed and built a real-time computer that was known as NTDS (Naval Tactical Data System). One such system, which enables all the fighting and maneuvering of a task force to be coordinated from the bridge of one ship, is installed in the 85,000 ton aircraft carrier USS Enterprise.

The experience obtained in developing the naval system was later incorporated in the first commercial real-time systems introduced by Sperry — the 490 Series of computers.

Real-time systems, which were a prominent part of the Apollo (Man-on-the-Moon) program conducted by the National Aeronautical and Space Administration (NASA), are installed at control centers in the United States as well as on land and ship tracking stations throughout the world.

Sperry computers form the heart of the NASA worldwide communications network (NASCOM) centered at the Goddard Space Flight Center in Greenbelt, Md. In this network, the computers function as a message acquisition system to assemble, recognize priority, and route messages to the command computer where the data is compared with a pre-stored mission profile. Any resulting commands and messages are automatically sent back to the computers which assemble and re-route them to the proper destination.

In addition to the NASCOM network, several SPERRY 1218 model computers assist NASA operators in monitoring the astronauts' physical condition on missions, as well as the spacecraft's on-board systems during the six minute pass over the tracking stations. Other Sperry systems are used in the NASA facilities at Goddard, Slidell, Houston, and the Marshall Space Flight Center at Huntsville, Alabama.

Another NASA project in which Sperry computers are playing a major role is the Mariner program for exploration of the planets, conducted by the Jet Propulsion Laboratory at the California Institute of Technology in Pasadena. On the Mariner 9 mission, SPERRY 1230 computers processed photographs of Mars taken from a spacecraft at distances varying from 76 to 146 million miles from Earth.

In the military area, the Defense Systems Division (DSD) has supplied several Naval Tactical Data Systems (NTDS) to the U.S. Navy and to warships of other nations in the North Atlantic Treaty Organization (NATO). Micro-electronic computers and advanced computing equipment for the Polaris/Poseidon submarine navigation system and airborne computers for the anti-submarine warfare program are examples of other equipment furnished by DSD to the Navy.

Among other significant Sperry contributions to the nation's defense programs was the provision of more than 160 computers for the U.S. Air Force's Base Level Supply Inventory Accounting system, which were installed at bases in the United States and throughout the world in the early 1960s, and the installation of real-time computers for the Defense Department's AUTODIN (AUTOMATIC Digital Network) high-speed, worldwide communications system.

Early in 1983, the U.S. Air Force awarded Sperry a \$520 million contract (in its first stage), known as Project Libra-Phase Four, to update the Base Level Supply Inventory Accounting system.

At that time, this was considered to be the largest single commercial computer order of its kind on record. This contract award was followed by two more very large contracts from the U.S. Navy for specialized military type computers, bringing the total value of all three orders to \$1.5 billion.

Among the first non-military applications of Sperry real-time computers were systems supplied for processing airline reservations and for air traffic control by the Federal Aviation Agency. In these areas, the ability of the computer to supply facts and results, virtually without any time loss, was recognized to be a paramount asset.

A number of leading domestic and foreign airlines use systems supplied by Sperry for reservations, message-switching, maintaining data on crew and aircraft availability, aircraft maintenance, and air cargo movements.

The ARTS III computer-aided traffic control system, organized around Sperry systems, is generally considered to be one of the best air traffic control advancements. The computer automatically transmits information to the air traffic controller's radarscope on the identity, altitude, speed range and bearing of all aircraft entering or leaving the airport terminal area.

Beyond the numerous computer systems used in air transportation, Sperry customers represent a diversified range of interests. Computer systems have been supplied to engineering laboratories, petroleum concerns, geophysical exploration firms, manufacturing companies, banks, savings and loan associations, insurance companies, stock brokerage companies, distributors of financial information, newspapers, hospitals, universities, and state and local government agencies.

Computer systems supplied by Sperry are also used in such applications as apprehension of "wanted persons" by national, state and city police departments; market research in advertising; keeping track of rolling stock for the French National Railway; travel reservations for a tourist agency in West Germany, and checking credit cards for a nationwide service company headquartered in Atlanta, Georgia.

Computers from Sperry have continually included new technological advances in the state of the art. From such earlier models as the LARC, the UNIVAC II and the UNIVAC III, and the Solid State System, came advances incorporated into the SPERRY 1050 system.

From the systems developed for the U.S. Navy, came technology embodied into the 418, 490 and 1100 commercial series of computers. The SPERRY 1107, announced in 1962, was the first commercial computer to employ thin-film memory.

A big brother to the 1107 —the 1108— five times faster than the 1107 —was introduced in 1964. A year later, the 1108 multiprocessor system was unveiled with the new concept of up to three single processors sharing common peripheral equipment.

A new milestone in 1100 series history arrived with the introduction in 1970 of the 1110 system, which incorporated more advanced circuitry and carried the concept of multiprocessing even further.

The 1100/20 and 1100/40 systems, introduced in March, 1975, marked the first use of semiconductor integrated circuits in the main processors of large-scale Sperry computers. They also improved still further the speed and cost/performance qualities of Series 1100 computers.

SPERRY Series 1100 systems have been acquired by some of the largest business and industrial organizations in the world. These users include a substantial number of leading aerospace contractors, whose requirements for processing scientific calculations for research, engineering and production operations are particularly demanding.

In the worldwide academic environment, SPERRY 1100 computers are installed at famous institutes of learning such as the Universities of Paris (France), Rome (Italy), Frankfurt, (West Germany), and Lund (Sweden), to mention just a few.

In addition to real-time, Sperry has consistently pioneered many areas of computer technology. These have included communications-oriented data processing, where a central computer receives and transmits data to a number of remote terminals or smaller computers, and the concept of a computer being operated as a service for many persons on a time-sharing basis.

Considerable interest has been generated in business and industry in recent years in using computers as the nucleus of compre-

hensive management information systems. Such systems provide executives with up-to-the-minute data on all parts of company operations, which proves to be of inestimable value in policy and planning decisions.

Sperry's growth curve took on a new dimension on January 1, 1972, when the company acquired RCA's former computer customers and assumed responsibility for providing hardware and software support to these users in the United States, Canada and Mexico.

This customer base included 1,000 computer installations and 500 customers. In addition about 2,500 professional personnel, formerly with the RCA computer organization, joined Sperry.

Sperry entered the minicomputer market in 1977 by acquiring Varian Data Machines (VDM), a subsidiary of Varian Associates, Palo Alto, California.

In October, 1982, Sperry announced its entry into the office systems market with the introduction of the SPERRYLINKTM office system, its first totally integrated office system aimed at serving medium to large organizations.

The SPERRYLINK office system brings together word processing, data processing, personal computing, electronic mail and voice services in one integrated system for all levels of office personnel.

Another recent development has been the emphasis placed by Sperry on making available programs and systems to make it easier for the non-professional data processing person to operate computing equipment.

One such program is the MAPPER[™] system, an applications development system, which not only makes it considerably easier for the non-professional to use but also expedites the development of new programs in much faster time than by using conventional methods. The MAPPER system has rapidly gained favor among users and now accounts for a large proportion of orders for Sperry computer systems.

Currently, the key mainframe computers marketed by Sperry are the 1100/60, 1100/70, 1100/80 and 1100/90 large-scale systems, and the System 80 family of processors serving the small to medium segment of the marketplace.

Recently, there has been a strong drive to reinforce Sperry's technological leadership by becoming active in joint ventures with

other companies. The information processing industry has become so diverse that a single organization, restricted by normal limitations in developmental resources, can no longer be expected to compete successfully alone. Thus, cooperative agreements have been entered into with other companies to guarantee the kind of growth planned for Sperry's future.

One such venture was a cooperative agreement concluded in June, 1982 with Mitsubishi Electric Corporation of Japan, which is actually a "two way street" for technical development. The agreement is designed to strengthen the abilities of both companies to service their respective markets through jointly developing, manufacturing and marketing computer systems in the world marketplace, including Japan.

Early in 1983, Sperry joined Microelectronics Computer Technology Corp. (MCC), a consortium formed by 12 American companies with headquarters in Austin, Texas. MCC's objectives are to share the high costs of research and development, to stay abreast of the latest worldwide developments in computer technology, and to keep the United States in a leadership position in advanced research to combat the subsidies and outright government support given to R&D in other countries.

In April 1983, Sperry joined Magnetic Peripherals, Inc. (MPI), a subsidiary of Control Data Corporation, jointly owned with Honeywell, Inc. and CII of France. Under this agreement, Sperry has a 13 percent ownership share in MPI and contributed to this organization the facilities of its former Information Storage Systems (ISS) disk drive manufacturing operations in Santa Clara, CA. This arrangement gives Sperry faster access to a greater range of mass storage products required by expanding Computer Systems operations. Sperry also has the benefit of lower costs because of greater volume production and the sharing of both overhead and research and development expenditures.

Another agreement was concluded in June, 1983, with Trilogy Limited, Cupertino, CA., under which Sperry acquired an option to use advanced technology and, additionally, to obtain preferred stock in Trilogy, representing approximately a 15 percent equity position in that company.

Headquartered in Blue Bell, Pa., the Computer Systems unit of Sperry Corporation serves more than 15,000 customers in 50 countries and, in fiscal year 1983 (ended March 31, 1983), reported revenue of \$2.8 billion.

Computer Systems is the largest unit of Sperry Corporation. Other units are Electronic Systems, Flight Systems, Sperry New Holland and Sperry Vickers.

Burroughs

In 1885, at the age of 28, William S. Burroughs filed an application for his first patent, establishing priority for the adding and listing machine.

Burroughs didn't actually invent the adding machine in the sense that he created it from nothing. Calculating devices had existed for centuries, at least since the abacus. Burroughs combined existing technologies to build the first practical adding machine. It could be mass produced and it promised to eliminate untold hours of boring human toil.

In 1904, when it became clear that the young company had outgrown its St. Louis facilities, the company packed up and moved to Detroit.

The company was renamed the Burroughs Adding Machine Company in 1905, in tribute to the man whose vision had led to the company's founding less than 20 years earlier.

In 1944 Burroughs was awarded an Army-Navy "E" for outstanding achievement in the production of war material, principally the Norden bombsight. This program made accurate, high-altitude bombing possible and was considered by some military authorities as the single most significant device in shortening the war. Previously, mass production of the bombsight, a very advanced precision instrument, was believed impossible due to the one-half millionth of an inch tolerance required.

John S. Coleman, who was credited with working out the system for mass production of the Norden bombsight, became president of the company in 1946. Under Coleman's leadership, the decision was made to begin a full program of electronic research, and in 1949 permanent facilities for electronic research and development were established near Philadelphia. Three years later, an Electronic Instrument Division was established in that city to manufacture and market scientific instruments and electronic memory components and systems.

The new emphasis on electronic products had already resulted in a series of innovative banking and accounting machines called the Sensimatic, which was produced by Burroughs in the late 1940s.

In 1950 the company introduced the first Sensimatic accounting machine with programmed control panel, a product considered the greatest advance in accounting machines in 25 years. Burroughs' Sensimatic and later Sensitronic machines - called the Series F - became the standard of bookkeeping machines.

In 1951 experiments began at the company's research and development center, which were aimed at developing a series of com-

puters specifically for business problem solving. In 1954 Burroughs introduced the E 101, a desk-size electronic digital computer for scientific, engineering and business applications. Later Series E systems, such as the E 2000, and counterpart Series F systems, became widely accepted and were Burroughs' leading products for accounting applications in business, industry and banking well into the 1960s.

In parallel with Burroughs development of electronic products for accounting applications, the company expanded its capability for development of larger, multipurpose computer systems. The Burroughs memory system, built in 1952 for ENIAC, the world's first electronic computer, increased the computer's memory capacity sixfold and demonstrated the company's capability in electronic computation.

With the acquisition of several companies in the late 1940s and early 1950s, Burroughs began to diversify its operations.

Burroughs soon became recognized as a single source for a variety of products for business management. Refelecting the company's more diverse operations, Burroughs Adding Machine Company was renamed Burroughs Corporation in 1953. The company was now a major force in this rapidly evolving industry.

Burroughs acquired the Electro-Data Corporation of Pasadena, California in 1956. ElectroData, a leading producer of computing equipment, provided Burroughs with much needed engineering and manufacturing capacity. The same year Burroughs Great Valley Laboratories were opened in Paoli, Pennsylvania.

Burroughs development of a full range of computer systems progressed steadily. The company introduced the large-scale Data-tron 220 in 1957, the B 251 Visible Record Computer for banking applications in 1959, the B 200 series of small to medium-scale solid-state computers in 1961, and the B 5000 solid-state modular data processing system, also in 1961.

The B 5000 was regarded as the most advanced business and scientific computer offered by any manufacturer. It departed from traditional concepts of computer design and featured such pioneering concepts as automatic multiprogramming, exclusive use of compiler languages, Burroughs Master Control Program, and "virtual memory".

The B 5000 was followed by the more powerful B 5500 system in 1964, as Burroughs began its "family" approach to computer design. In addition to the B 5500, the "500" family included the large-scale B 6500 and medium-scale B 2500 and B 3500 systems introduced in 1966, and the small-scale B 500 systems released in 1968.

The "500" family served a broad cross-section of data processing requirements in fields such as banking, manufacturing and government. It solidified Burroughs position in the computer industry and provided the base for the company to further expand its computer manufacturing capabilities.

Burroughs' success at solving business problems took a further evolutionary step in the late 1960s with the introduction of the Series TC terminal computers and the Series L mini-computers. The Series TC internally programmed computers were designed for use with on-line data processing systems and could function as either terminals or independent computers. The Series L was designed primarily as a self-sufficient billing computer but featured a data communications option which enabled it to operate on-line as a terminal computer. Both Series TC and Series L mini-computers were well received by all types of customers and over 140,000 units were sold worldwide in 10 years.

As developments in microcircuitry were applied to Series TC and Series L systems in the 1960s and 1970s, the systems evolved from electro-mechanical machines to fully electronic computers.

The early programs to expand Burroughs electronic capabilities also resulted in the company being awarded numerous government and defense contracts. Burroughs computers were used by the United States Navy in its POLARIS program and by the U.S. Air Force in the SAGE, ALRI and BUIC Continental Air Defense networks. In 1961 Burroughs was named by the Air Force as hardware contractor for the NORAD combat operations computer complex and data display system. The computer was used to make split-second evaluations of threats to the North American continent using input from satellites and radar throughout the world.

During this time Burroughs was also an active participant in the U.S. space program. The world's first operational transistorized computer, produced by Burroughs in 1957, was used in guiding the launch of the Atlas Intercontinental Ballistic Missiles. A later version of this computer guided every launch in the Mercury and Gemini programs of manned space flights.

With the completion of the first space rendezvous, made in 1965 between Gemini VI and VII, Burroughs guidance computers had handled more than 300 successful missions without failure, error or delay. That year, the Burroughs computer that had guided the first Atlas missile was presented to the Smithsonian Institution by the U.S. Air Force, and another of the first ground guidance computers was installed in the Air Force Space Museum at Cape Canaveral, Florida. The last of 17 such Burroughs guidance computers was retired by the Air Force in 1978 after completion of over 400 successful missions.

Throughout Burroughs' extensive involvement in electronic research, defense projects, and the space program, the company

remained in the forefront of the commercial market by supplying a variety of products for banking and business.

The 1970s saw the further merging of Burroughs electronics and computer development efforts of the previous two decades. The decade also marked Burroughs' entry into other areas of information management, principally office automation. The company used its growing resources to develop several complete new families of computer systems — from minicomputers to large-scale computers — and to support them with a full range of related software products, computer peripherals, terminals and data communications systems, and data management equipment.

Burroughs Series TC and Series L electronic systems, which had been introduced in the late 1960s, were continually refined for various business applications. These refinements, along with continued electronic developments, led to the introduction of the B 80 series of small-scale computer systems in 1976. The B 80 brought the power and memory capacity of much larger computers to the small systems range. These features were further evident in the B 90 series announced in 1979.

Burroughs also continued to place strong emphasis on the development of larger computer systems during the 1970s. Following the successful "500" family of computers, the "700" family was introduced between 1971 and the end of 1975.

The "700" family considerably extended Burroughs coverage of the data processing market from the base established with the "500" family.

In late 1975, Burroughs began introducing the "800" family of systems with the announcement of a series of computers designed for medium-to-large-scale applications. This family was to be the successor for each member of the "700" series.

In 1979, Burroughs announced the first models of the "900" family of systems. The "900" models typically occupy half the space and require 50 percent less power to operate than the "800" family models.

During the 1970s, the company also continued its developments in other areas of data processing with products for data preparation and document handling; a full range of displays, keyboards, printing terminals, and related data communications computer systems; memory subsystems and high speed printers; software products for applications in banking and finance, manufacturing, health care, education, government, transportation, and many other areas.

The Burroughs expansion in data processing was paralleled by its entry into the office automation market. The company entered the facsimile communications market in 1975. In 1979 the company added an optical character recognition page reader system to this

growing range of office automation products, which have become an increasingly important segment of Burroughs "total solution" approach to information management.

In the early 80's Burroughs, together with Convergent Technologies, introduced the B 20, a family of powerful microcomputers that can operate either as stand-alone intelligent workstations or small business-computers, or hooked into a distributed processing network. Convergent developed and builds the B 20 to Burroughs specifications.

Products introduced in the first few years of this decade were as broad as they were deep. The "900" family of computer systems featured new entries at the low, medium and high end. The OFIS 1 office information system, introduced in 1981, comprised a series of components for editing, filing, and retrieving documents. It included a broad line of graphic communications (facsimile) equipment to provide still another dimension - document sending via telephone lines. Other products included communications processors and large-capacity disk drives built by Memorex.

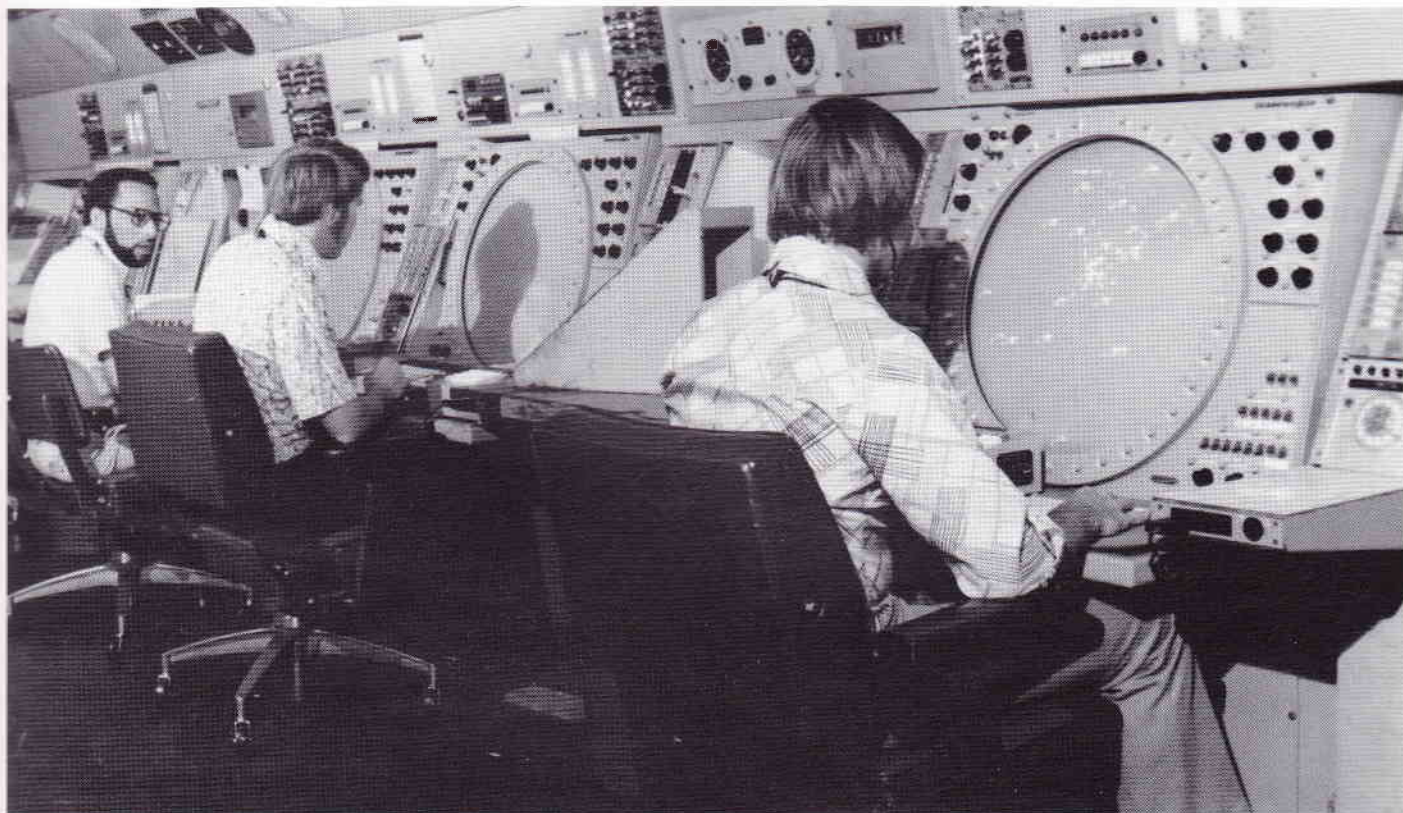
Finally, in software, Burroughs introduced a new product called LINC (an acronym for Logic and Information Network Compiler)

that actually writes other programs for a wide variety of business situations. Since you don't have to be a professional programmer to use it, LINC will put the power of the computer in the hands of a great many more people.

This project was started in early 1954 when transistors were still a technical novelty and were packaged with one transistor per small canister. The transistors used surface barrier transistors manufactured on a laboratory production line in Spring City, PA.

The ability to develop, design and produce a transistorized computer to operate under military environmental conditions was challenged by the Scientific Advisory Committee of the U.S. Air Force and by members of the technical staff of Ramo Wooldridge, the Government's Program Manager. Due to the superior technical competence of the Burroughs staff, the computer was designed and operated during every launch of the Atlas Missile.

Another unique characteristic of this development was the extraordinary high reliability of the system which utilized a wired core programming technology, unique for its period as well as a unique checking system for online real-time missile guidance.



The ARTS II system, manufactured in Paoli, PA for the FAA by the Custom Products Group of Burroughs Corporation, is used to control air traffic at 96 small and medium-sized airports in the U.S.

Auerbach

Isaac L. Auerbach (F '58)

AUERBACH Corporation for Science and Technology was founded in July 1957 by Isaac L. Auerbach. The company's subsidiary, AUERBACH Associates Inc., was the first computer consulting company in the United States, if not in the world. It was spearheaded by Auerbach and two of his associates, Arnold B. Shafritz and Paul Winsor III, all of whom left the Burroughs Defense Space and Special Projects Group in Paoli which they created by successfully applying advanced computer technology to real-time defense projects. That business continues to this day as a major employer in the Philadelphia area.

AUERBACH Associates became world renown for its creativity and unique computer system architecture and digital communica-

tion systems design. These people were one of the country's earliest and foremost leaders in the application of computer technology and programming to online, real-time systems. Examples of their innovations can be identified in System Projects such as air traffic control, airline reservations, air defense systems, store and forward data communications and industrial control.

Another of the parent company's subsidiaries, AUERBACH Publishers Inc., was the first company dedicated to publishing updated loose-leaf information about computer hardware, software and systems, and the management of computers and communications.

AEROSPACE / MILITARY

General Electric Space Systems Division

J.G. Terino
Manager, Product Information

If any year ushered the space age into the Philadelphia area, it was 1960 when ground was broken for the complex of buildings that today is the headquarters of one of the nation's major aerospace companies, General Electric's Space Systems Division. And, it can be truly said, in the years since the first shovel was turned some of the most significant achievements in our nation's space program have been developed, engineered, built, and brought to fruition through the efforts of the men and women at the Valley Forge complex and its associated field operations.

The importance of Space Systems Division's role in advancing the nation's presence in space and technology in the years to come was set while the buildings were being erected. The division received the National Space Club's Jackson Award for the most significant space achievement of 1960, the recovery of the first space vehicle — Discoverer XIII — from orbit.

General Electric's close association with the National Aeronautics and Space Administration's space exploration programs, which continues to this day, can be traced through the alphabet soup of NASA acronyms — OAO, BIOS, GEOS, GGTS.

In its work for NASA, earth atmosphere and resource monitoring have long been a specialty of the division. In the sixties there was the series of Nimbus weather satellites.

The seventies saw the advent of the highly successful Landsat series of satellites. The fourth Landsat is now in orbit and a fifth is planned for 1984. With Landsat, NASA introduced a new, experimental tool for collecting data with remote sensing instruments on a space platform. During its eleven years of operation, the NASA-GE Landsat program has been maturing into a system for examining and managing the earth's resources.

Today, there are about a dozen nations worldwide which have the capability to receive and process data directly from the satellite. In addition, more than 100 nations use Landsat data for resource development and management. Landsat images of the earth are internationally recognized for their value in oil and mineral exploration, agriculture, land use planning, forestry, water management, map making, and other endeavors. Landsat provides NASA and the international community using its data complete surface coverage of the earth, except for the poles, through overlapping swaths, every sixteen days.

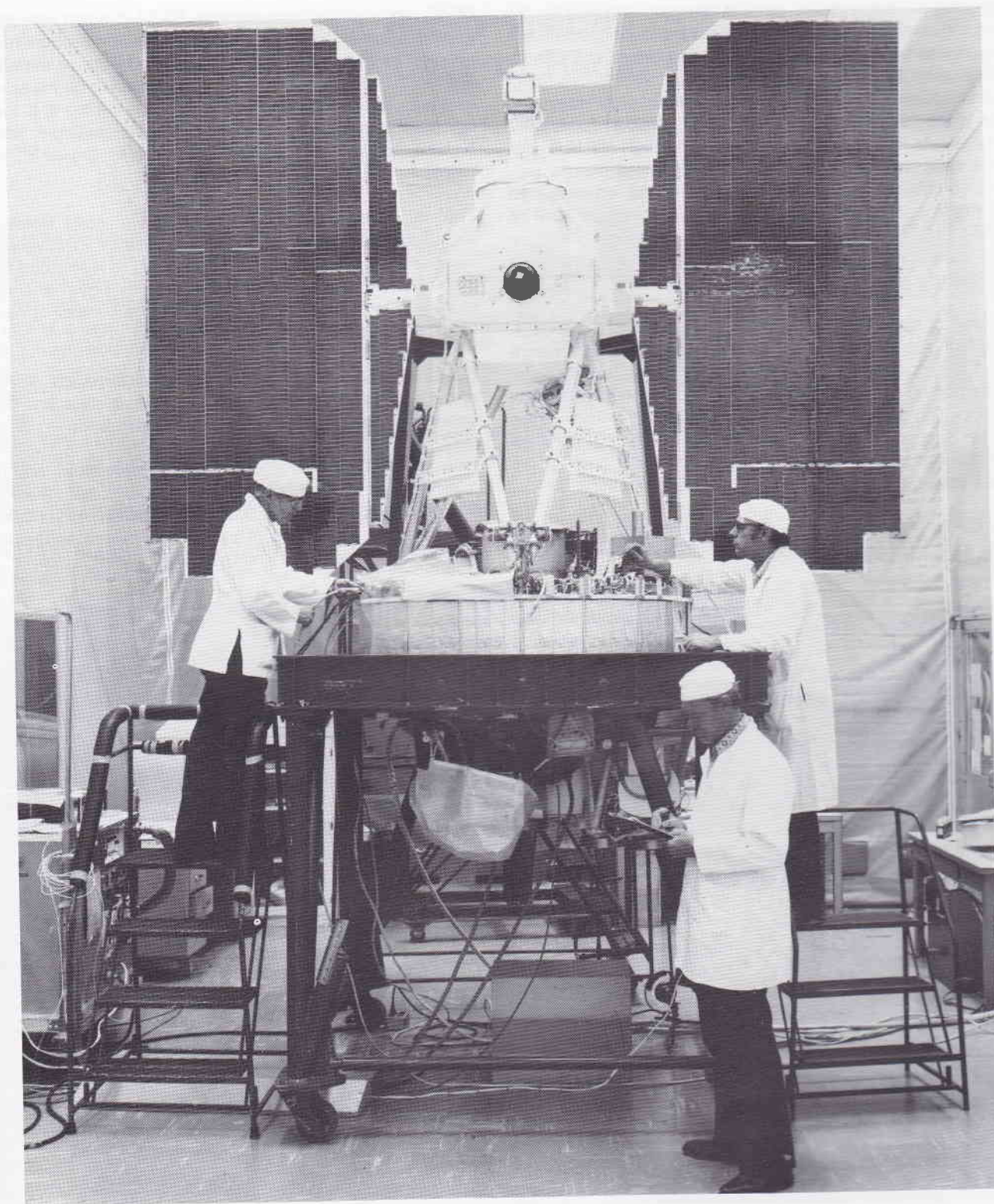
In America's manned spacecraft programs, GE has been intimately involved in numerous, technically demanding, vital aspects inherent to mission success. During Apollo, Space Systems

Division was responsible for pre-launch checkout stations for the spacecraft; launch-complex controls and check-out equipment; reliability assessment; and systems integration. It also handled the technical support of the static testing of the booster stage and engines for the Saturn rockets that carried the astronauts into space and to the moon. Today, Space Systems Division is similarly committed to the Space Shuttle program. It conducts the system checkout and subsystem acceptance testing of the Shuttle Orbiter and provides major ground support management of the life science spacelab experiments on all shuttle flights. The galley, waste collection system, vapor compressor refrigerator freezer, urine monitor, and oxygen partial pressure sensors of the shuttle cabin are also GE contributions.

GE provides the deceleration module for the Galileo Probe. The module includes entry thermal protection, parachute retardation, separation subsystems, lithium battery power supply, transit thermal control, and probe/orbiter adaptor.

In support of the United States efforts to maintain peace through a credible, deterrent defense structure, the division has over the years provided reentry systems for the Titan II and Minuteman II & III missiles. It has also provided the Army with over 200 mobile, rugged, transportable DAS3 data automation systems for field combat service support and Combat Information use, with 250 more improved models scheduled for delivery. In addition, GE has developed for the Navy a maneuvering reentry system as an option for the Trident missile. General Electric Space Systems Division's DSCS III — Defense Satellite Communications System — brings satellite communications to an unprecedented level of capability. Electronically steerable antennas on each spacecraft can simultaneously connect a wide range of users at different places. Four DSCS satellites in synchronous orbit can provide global, radiation-hardened communications with long life and anti-jam capability. The first satellite was launched in late 1982. Five production satellites are under contract out of a total of 12 called for in the production program. GE is developing enhancements for DSCS III that include solid-state amplifiers, EHF transmitters, and adaptive nulling processor capability. Users of the system include the Department of Defense's Worldwide Military Command and Control System, the U.S. Navy, the White House Communications Agency, NATO, and the United Kingdom.

DSCS III spacecraft are designed with several antenna systems that provide spot beams and steerable sub-beams to produce different selected coverage, as well as a 61-element beam for nulling and interference rejection.



Nimbus 7, the last in General Electric's weather satellite series, is checked out prior to shipment to the launch site.

In international programs, the division designed and built for Japan the first communication satellite dedicated to TV direct broadcasting. It was launched in 1978 and relayed two color TV channels throughout Japan, including high-quality transmissions direct to home receivers that had one-meter antennas. An improved version of the satellite — BS-2 — will be launched in 1984. BS-2 will incorporate microwave integrated circuits, high-efficiency solar cells, helix-type traveling wave tubes, improved thermal protection, an offset-fed circularly polarized antenna, an increased power margin, and a five-year design life. The spacecraft will be stabilized pointing toward the earth from synchronous altitude with an accuracy of 0.10 degrees. Four solar panels will provide the electrical power to all the spacecraft's systems.

In the area of data automation, the division developed the GESCAN 2 high-speed search and retrieval system as a hardware solution to textual information search and retrieval applications. The heart of the system is a unique large-scale integrated circuit array providing search speeds 100 times faster — two million bytes per second — than the search speed of typical software sequential search technology. GESCAN is now at work at the United States Government's General Accounting Office.

GE is currently responding to NASA's UARS — Upper Atmosphere Research Satellite Program — Request for Proposal.

UARS is part of a comprehensive NASA-directed research program to see how the chemistry of the upper atmosphere has been affected by the activities of mankind and if those activities are altering the protective shield of ozone. Drawing on the science of its seven Nimbus atmospheric research satellites and the technology of Landsat, the division anticipates continued work with NASA's Goddard Space Flight Center to meet the UARS requirements.

The same bold, imaginative commitment, solid technological foundation, planned development programs, innovative management concepts, and team efforts that led to numerous General Electric Space Systems Division technology achievements being enshrined in the Smithsonian Institution is continuing now as it looks to the future.

Similarly, as we look to establishing man's permanent presence in space, GE has performed multiple system studies and been involved in many programs applicable to that effort.

With an impressive array of scientific, engineering, and mathematical talent in the 7,800 people in its workforce, there is little doubt that General Electric Space Systems Division is committed to maintaining its position of leadership in space and technology in the Philadelphia area and the nation.



During Apollo, General Electric's Space System Division was responsible for pre-launch checkout stations for the spacecraft, launch-complex controls and checkout equipment; reliability assessment; and systems integration.

Radio Vision

The Early Days of Radar at RCA

L. Wolff

When radar development was first undertaken, mostly by various military establishments, in the middle 1930s, the carrier frequency used for the transmission was several hundred MHz at the high end. It wasn't until compactness and greater directivity indicated the use of a basically higher carrier frequency, and a powerful pulsed magnetron was developed in England, that work on microwave radar started in the early 1940s at M.I.T. Radiation Laboratory.

In RCA, one might say that we had the cart before the horse. In the early 1930s, radar, we called it Radio Vision, was initially developed to find an application for microwaves some seven years before microwaves became the backbone of radar.

About 1932, publications were appearing, originating in Germany and Japan, relating to developments of microwave magnetrons. Research was also reported at the University of Michigan. This seemed to be a fruitful area for RCA research, and with the approval of Dr. E. W. Engstrom, Manager of Research, we initiated a program to develop a 3,000-MHz system. Dr. E. G. Linder was recruited from Cornell to undertake magnetron development. The receiver we first used was an old style silicon-crystal type.

By 1934, work had progressed sufficiently to have an operating transmitter-receiver system and RCA demonstrated the equipment at several IRE meetings during that year. At that time, the possibility of reflecting sharp beams of microwaves from metal objects and ionized gases was shown.

The Signal Corps was excited by these demonstrations and invited us to bring the equipment to Navesink Light at Sandy Hook, N.J., to test the range of the apparatus as a communication set. We were very thankful for this invitation because the location for distance tests was much better than any we had in Camden, NJ. The transmitter site was at an altitude of 250 feet overlooking New York Bay and there was a clear range over New York harbor of more than 15 miles. The transmission tests were quite successful, giving a range as great as line-of-sight.

From our standpoint the most significant experiment was an attempt to obtain a reflection from a boat entering New York harbor. The channel was about one-half mile from the transmitting-receiving location and we were elated to receive reflected signals from a ship passing through the channel. Some water tanks on shore at about the same distance were also good targets.

Our equipment at this stage used audio modulation of the transmitter; three-foot parabolic dishes on both transmitter and receiver obtained directivity. Thus, only the azimuth of the reflecting object was determined. The success of the reflection experiments at the Signal Corps Laboratory changed the orientation of our research from the possible application for radio relaying to use as a navigation instrument. For most effective application in navigation, however, distance as well as azimuth information would be required, leading us to start a project for pulse modulation of the transmitter and pulse amplification in the receiver. We aimed for a pulse of less than one microsecond duration to obtain satisfactory distance resolution.

Apparatus with such pulse modulation was constructed in 1938 and the equipment was placed on the roof of Camden's Building 5 for tests. The receiving equipment was later modified to substitute a superregenerative magnetron for the crystal or detector. We were able to pick up and follow the ferry boats and other shipping in the Delaware River as well as the trains on the elevated line on the Philadelphia side of the river.

At first, we had only a distance trace on the scope with a vertical blip showing the distance of the reflecting object. It was not long, however, before we tied the position of the antenna to the horizontal trace, the time after pulsing of the transmitter to a vertical trace, and the pulse signal to the grid, giving what is now called B scan.

In considering this development, it is interesting to think about the debt we owed television in what we were doing. If it had not been for the television research it is doubtful that we would have had the tubes to amplify the short pulses and the cathode ray tubes on which to show the return signals. These pieces of equipment are so commonplace now that it is easy to forget that they were new developments at that time.

How our Radio-Vision equipment could have been developed to have a commercial application is anyone's guess. We had in mind using it as a navigation aid installed on ships and with additional refinement it might well have gone in that direction.

However, a seemingly more important commercial need took precedence and changed the direction of our research sharply. Shortly before the time when the successful tests described above were made, there had been a series of very bad airplane crashes into mountains. At a high-level meeting, held to discuss

The lack of progress that RCA had made toward securing leadership in aviation radio, it was suggested that adopting our Radio Vision equipment to airborne use as a collision preventive could give us a big boost with the airline industry. This was the kind of imaginative technological advance using radio techniques that appealed to General Sarnoff, and we were directed to see what we could do.

The project, initiated in the spring of 1937, was oriented to the development of airborne equipment which would warn pilots of the approach to mountains and other aircraft. Owing to the instability, research nature, and antenna bulk at that time, a practical airborne system seemed doubtful until microwave components had gone through a development phase. Hence, the highest frequency which could be used with existing commercially available components, 500 MHz, was chosen for the radio frequency of the airborne equipment. We did not have manpower available to continue research on both the existing 3,000-MHz project and the new airborne unit, so the former was temporarily set aside.

In the latter part of 1937, the new equipment was installed in RCA's Ford Trimotor airplane and numerous flight tests were made during the ensuing year. Targets were the Catskill Mountains and the Alleghenies of Pennsylvania. Two antenna systems were employed. To get a signal from potential obstacles in front of the airplane, we used an inverted "V" type antenna installed along the length of the Ford airplane. A dipole antenna under the plane obtained the altitude signal. With the airplane in level flight at the height of the mountain top, signals were received at a distance of about 5 miles. If the airplane were 1,500 to 2,000 feet above the mountain no signal was visible. The signal picked up from the ground reflection on the dipole altitude antenna was always visible. Other airplanes flying up to one-half mile directly in front of our radar-equipped plane could be detected. This was probably the first successful airborne radar equipment flown anywhere.

It had been our intention to give public demonstrations of our apparatus, as well as a modification of it for shipboard use to ward against collisions with other ships and obstacles such as icebergs. But once more, our plans had to suddenly change. By the late 1930s, war clouds were thickening in Europe and the military personnel who were shown the equipment and results immediately clamped a lid of secrecy on it and gave us contracts to develop apparatus for their use. Thereafter we became essentially a government contractor.

In summary, some seven years after it had been first undertaken, microwave research led indirectly to first development, and then manufacturing, contracts for various types of radar apparatus for the military. Directly related to the airborne equipment which was demonstrated was a search radar using a Yagi antenna mounted on the wing of PBR flying boats and a high-altitude altimeter to aid in accurate high-altitude bombing.

It was entirely fortuitous that we just happened to have something very much needed by the military at the right time and it is interesting to speculate as to what might have happened if war had not been on the horizon. Assuredly, military application had not been our objective when we started the microwave research, or even when Radio Vision was well along. One can certainly say that progress in development and manufacture would have been much slower without the impetus of R&D funds and the urgency of equipment for a war.

This, so far, has been the story of our early pulse radar. However, "circumstance of location" led us into another use of reflected radio waves using frequency modulation of the carrier (now known as FM radar).

At about the time we were making the flight tests in the Ford Trimotor, a young man contacted our patent department and said that he had some equipment to demonstrate. C.D. Tuska and I went to look. This was the "circumstance of location" referred to above. If the young man, Royden Sanders, had not happened to live close to Camden, it is very doubtful that RCA would have undertaken any FM radar research at that time.

While a sophomore at engineering college, and unaware of the Bell Laboratories FM radar work, Sanders independently developed the concept of FM radar and left college to work on his idea. We were familiar with the Bell Laboratories work and noted that he appreciated some of the factors which limited accuracy and had taken steps to make needed improvements in his development. We were sufficiently impressed to offer to buy whatever improvement patents he might obtain and to give him a chance to proceed with his development in RCA. This proved to be a wise decision. Sanders turned out to be a prolific and determined inventor as well as a sound engineer with a great dedication to FM radar.

In due course, a development model of an altimeter was built and demonstrated to the military services. This altimeter was not competitive with our high-altitude bombing pulse altimeter, since the pulse unit was most useful at then high altitudes, such as ten to twenty thousand feet, where the ambiguity caused by pulse length was not of primary importance. On the other hand, the FM unit was most useful at low altitudes even down to fifty feet or less. When the FM altimeter was put into production, some tens of thousands were produced and, most unusually, the same apparatus was standardized for the US Navy, Air Force, and the British. The production demands and timing were too great for RCA to handle alone, so two additional manufacturers were recruited to build the same unit.

The FM-radar altimeter proved to be most useful over water, where its exceptional low-altitude performance could be well put to use. As a next step, the output was tied in with the aircraft altitude control to set the altitude automatically. Since the output

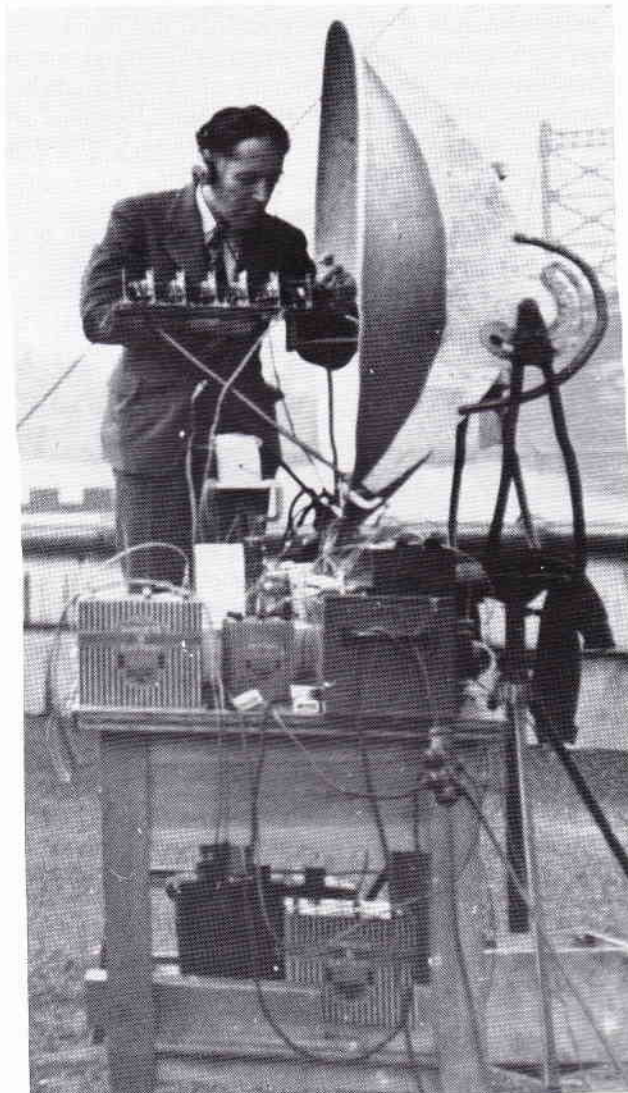
of the FM altimeter is most readily a current proportional to altitude, this step was not too involved, at least to the extent of getting adequate control signal from the altimeter.

Although it was obvious that the FM radar signal contained the information for determining the distance to the reflecting object, it was not generally appreciated that it also contained information on the speed of approach to the reflector. Sanders appreciated that where there was relative motion between the radar and the reflector, the sum of the up-sweep and down-sweep output frequencies gave a signal proportional to distance, whereas the difference was proportional to speed of approach to the reflector. Thus, the information required to drop a bomb in level flight over water, namely altitude, distance, and speed of approach to target, were all available from one instrument. One antenna pointed forward to get the target information and a second antenna pointed downward to obtain altitude measurement.

Equipment for dropping bombs automatically was constructed and numerous flight tests were made dropping water bombs against the lighthouses in Delaware Bay. Fortunately, none of the numerous fishermen in small boats in the river were ever hit.

A final step was to adapt the equipment to automatic bomb release in other than level flight. Before the more sophisticated development could be completed and put into production, the war was over.

This completes the story of the early days of radar (Radio Vision) in RCA, a project which was initiated to develop equipment and study applications of microwaves, and ended by supplying search radar, radio altimeters, and automatic bomb-dropping research and apparatus to a military at war.



Dr. Irving Wolff with early radar equipment in Camden, NJ.

The Early History of the Missile and Surface Radar Department

H. R. Wege, Retired Manager,
RCA Missile & Surface Radar Department
RCA Engineer, 1956

The Missile & Surface Radar Department is responsible for the engineering and production of radars and guided missile systems for shipboard, ground or vehicular installations. This department is unique in that its organization and facilities have been custom-built to fit the needs of its particular products. This did not happen overnight, but rather is the result of a planned program of evolution and expansion over the past ten years.

When the war in the Pacific suddenly ended in August of 1945, our production contracts, almost entirely for shipboard radars, were immediately terminated or drastically cut back. After reassignment of personnel to commercial activities, what was then known as the Marine & Ground Radar Engineering Group, located in Building 53, consisted of approximately 25 engineers. This group had little or no work and, since it had been concentrating on low-frequency production equipments developed either before or during the early phase of the war, our competitive position was not yet established in the high-frequency radar application fields.

RCA's post-war planning resulted in the establishment of an engineering activity called the Government Radiation Engineering Section located in Building 10-7, Camden, to which this radar group, along with other similar engineering groups, was transferred and integrated. Utilizing the best abilities of this reorganization, various types of developmental and study contracts were negotiated with all three of the Armed Services, aimed at reestablishing our competitive radar position and acquiring the necessary background of experience in the higher frequency ranges. Of particular significance was a study contract on radar techniques with the Bureau of Ordnance under the cognizance of the Applied Physics Laboratory of the Johns Hopkins University, in connection with the Navy's Bumblebee Guided Missile Program. This contract, negotiated in 1946, is still active today. Not only have numerous studies in the radar and guided missile field been made but various items of hardware, including a prototype of a very precise monopulse tracking radar, have been supplied to the Applied Physics Laboratory.

As a result of this broad development program, our "know how" and organization increased to a point where, by 1950, we were able to compete successfully for production business, even those systems on which we had not done the basic development. One of the important production contracts obtained at that time was for TPS-10D Height Finders for the Air Force. Several hundred of

these equipments were produced during the next five years and are presently giving excellent service in air defense nets throughout the world. As a matter of fact, this procurement was probably the second largest for a single type of ground based radar that the Air Force has made to date.

Having successfully and firmly reestablished our position as a capable radar supplier, we realized that we could now expand our position in this highly competitive field. Because of the heavy equipment involved and the need for ground floor space to accommodate trailers and field testing, a portion of Building 53 was rehabilitated. The radar group was separated from the Government Radiation Engineering Section and moved there in the summer of 1950.

Largely as a result of our work with the Applied Physics Laboratory in connection with the Bumblebee family of guided missile systems, we received a contract from the Army early in 1951 for a Land-Based Terrier Fire Control System for use with the Terrier Missile, a member of the Bumblebee family of missiles. This program, in addition to major radar development and production programs, resulted in further rapid expansion to the point where the facilities in Building 53 were no longer adequate for this fast-growing engineering organization.

This resulted in the acquisition of 420 acres of land on the outskirts of Moorestown, New Jersey, early in 1952, and the building of an engineering plant specifically designed for the engineering and assembly production of radar and guided missile systems for shipboard, vehicular or ground installations.

About this same time, we revised our engineering organization in preparation for the handling of major weapons systems by dividing it into four basic groupings—Systems Engineering, Project Management, Engineering Services and Equipment Development and Design—the latter being subdivided into Electronic Engineering and Mechanical Engineering. This organization can be more easily understood by the use of a simple analogy, that of the building industry, where Systems Engineering represents the Architect; Project Management, the General Contractor; and the Development and Design Groups represent the various craftsmen or specialists. While all four of the basic groups are essential, the Project Management Group must assume the initiative in the overall direction of any program based upon the weapons system concept.

By weapons system concept, we mean the capability of initiating the concept of a weapons system, starting with an idea or requirement and carrying the job to completion through many difficult steps, including feasibility studies, development and design, field evaluation, production, installation, training and maintenance—up to the point of transfer to the Military Services, as a complete operating system. This is sometimes referred to as a “turn-key” job.

The weapons system concept per se is not new. However, since conclusion of World War II, weapons systems have become larger and much more complex. The Military Services have therefore asked industry to assume more and more responsibility in the engineering, production and overall management of this effort. This is particularly true in the case of ground based missile weapon systems. Where previously a contractor might have been asked to build a radar to rather detailed specifications, today he is asked to devise and produce the overall system where the radar, a small system in itself, is only a part of the weapon system.

To do this effectively, he must first understand the threat and be as ingenious in visualizing all possible enemy systems as he is in devising a system to counter them. He must take into account all of the factors outlined above in the definition of a weapons system. Naturally, this type of effort requires many skills and talents, many of which are not often found in a single contractor organization no matter how large. This, then, is where weapons systems management plays such an important role. The weapons systems management organization need not have all of these special skills but it must have a broad technical grasp and understanding of them in order to subcontract for them and direct the efforts of these supporting organizations effectively.

The Talos Land-Based System is a typical example of what is meant by a weapons system. This system is a fixed installation, ground-to-air guided missile system, for defense of Military bases

and industrial centers against enemy air attack. It consists of many elements of electronic and electro-mechanical equipment, such as radars, computers, launchers and communication equipment, all integrated into one large weapons system. It can detect approaching enemy aircraft at long range. This information is automatically processed through its electronic brain and nerve center to permit the launching and controlling of missiles which will seek out and destroy the enemy aircraft. The system includes special buildings to meet tactical conditions and safety requirements. It represents what we believe to be the most advanced system concept for an automatic guided missile system being developed today.

In November of 1955 with the separation of the Engineering Products Division into two activities—Commercial Electronic Products and Defense Electronic Products—four operating departments were established under Defense Electronic Products. The Airborne Systems Department and the Surface Communications Department were established in Camden, while the West Coast Electronic Products Department was established in Los Angeles. Moorestown was established as the Missile & Surface Radar Department facility.

With the establishment of the Missile & Surface Radar Department, the major portion of the Shoran and Specialties Engineering Section, which had specialized in information handling and data processing techniques among other things, was transferred to Moorestown and integrated with the Missile & Radar Engineering Section. These two organizations complemented each other in skills needed in the handling of overall weapons systems. Likewise, a new marketing organization was formed out of personnel representing these two engineering sections by the transfer of these people to Moorestown. Transfers from other activities were also made to round out the new department organization and provide for such functions as production, personnel and financial.

Radar Systems for National Defense

"RCA News and Information",
December 1978

Thirty years ago on December 5, 1953, RCA dedicated a new engineering and systems manufacturing facility in Moorestown, N.J.

The original engineering staff developed radars and military fire control systems considered more accurate than any seen before. Contracts came from the Navy and then from all three services.

In the years that followed, MSR won contracts for some of the nation's largest defense projects, including the Air Force Ballistic Missile Early Warning System (BMEWS) and the Navy's AEGIS Combat System

The success of MSR in radar development work has roots that go back a number of years before the 1953 plant dedication. RCA began experimenting with "radio echo" — bouncing radio waves off solid objects — in 1932.

World War II was approaching in 1938 when the Navy installed an RCA radar on the USS Texas. Later the Navy ordered a quantity of aircraft detection radars.

Through the war, RCA built shipboard, airborne and land-based radars in Camden, NJ. When peace came, the company formed a "Marine and Ground Radar Engineering" group of 25 engineers assigned to continue radar development work.

In 1946 the Navy awarded M&SR a contract to conduct a study for the Bumblebee Guided Missile Program.

Year after year, the Navy added work to the Bumblebee contract. Army and Air Force contracts for other radar developments were awarded and RCA's knowhow increased to the point in 1950 when it was able to compete successfully for production programs. The time came to move the radar business out of Camden and into an engineering/production plant of its own, at a location where outdoor tests could be conducted.

RCA purchased a 430-acre site in the suburban community of Moorestown and began construction in the midst of an asparagus field in the spring of 1952.

The first major radar to be developed and produced in Moorestown was the AN/FPS-16 precision tracker, which was designed for the Navy and later put into service by the Army and Air Force as well. Between 1953 and 1957 MSR built 50 of these radars, many of which are still in service worldwide.

Sometimes referred to as "granddaddy", this rugged and reliable piece of equipment set the pace for a long line of radar systems. Some of the major programs that followed are:

The prime contract for the nearly \$1 billion Ballistic Missile Early Warning System (BMEWS), one of the most advanced electronic detection systems of its time. The BMEWS radars in Alaska, Greenland and England continue today to provide a reliable warning system against missile attack.

AEGIS, which will become the biggest project in MSR's history. This system is a sophisticated combination of radars, computers and weapons that will give the Navy a potent fleet air defense capability into the 1980s and beyond. Phased array AEGIS radars will monitor the entire sky continually and response to attack will be devastating and virtually instantaneous.

The AN/TPQ-27 computerized radar developed for the Marine Corps. This system provides all-weather, day and night control of multiple aircraft in support of ground forces.

The AN/FPQ-6 instrumentation radar and its transportable version, the AN/TPQ-18, which are descendants of the AN/FPS-16 and considered the most precise tracking radars in the world. These radars and another Moorestown system, designated CAPRI, tracked the Apollo orbital flights from ships and shore installations.

Erectable antennas used by lunar astronauts on the moon's surface to transmit signals back to earth. Similar pop-open antennas were carried on the Lunar Rover vehicles.

Communication antennas built at MSR and used in NASA's Viking Lander spacecraft sent to Mars in 1976.

A Target Resolution and Discrimination (TRADEX) radar designed and built by MSR for the U.S. Army Missile Command and completed in 1962. This installation is on the Kwajalein atoll in the Pacific Ocean. It has an 84-foot antenna that accurately tracks multiple reentry vehicles during intercontinental ballistic missile tests.

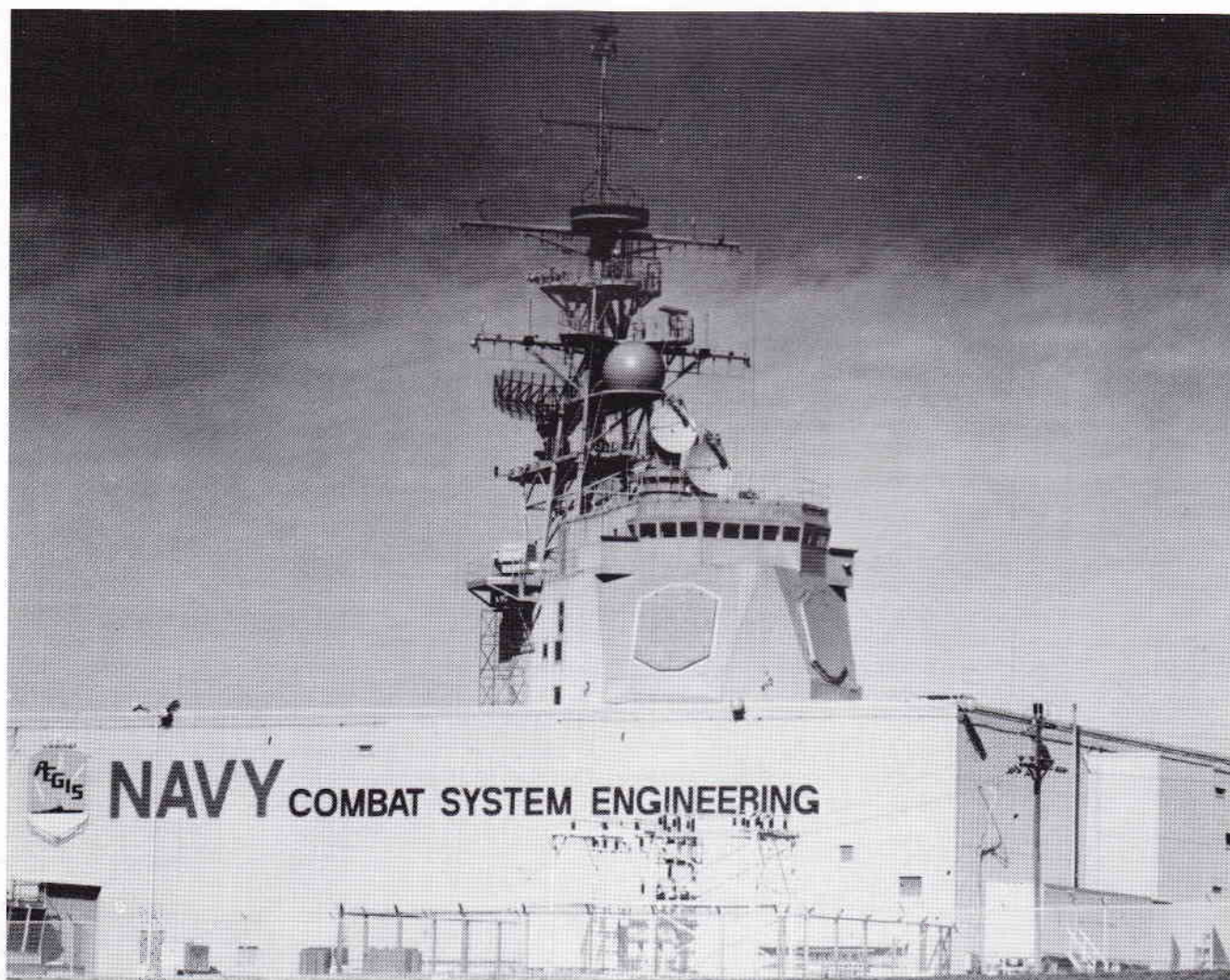
The Downrange Anti-Missile Measurement Program (DAMP). This shipboard system gathered data on missile performance during flight and reentry to aid in the development of systems for defense against ballistic missiles.

Hand-held radars designated AN/PPS-9 through -13, developed for the Army, Air Force and Marine Corps. These radars are designed for battlefield surveillance and identification of moving targets in all weather conditions.

The AN/MPS-36 integrated circuit radar, a mobile system designed for precise measurement of missiles and reentry vehicles. This system can track targets as far away as 32,000 nautical miles and measure range with an accuracy of one yard.

Digital Instrumentation Radars (DIR), developed for the Air Force and later adapted for use by the Army and Navy. DIR's handle a variety of tracking jobs, from range safety to scoring and evaluation.

The Generic Phased Array Radar, a new project for the Army Missile Research and Development Command. This system will be able to simulate various classes of radars, enabling American researchers to duplicate the signals of the latest equipment developed by potential adversary nations.



Combat System Engineering Development Site, Moorestown, NJ.

Avionic Systems and Flight Related Technology

Harry Krutter
Naval Air Development Center

From an earlier establishment in July 1944 as the Naval Air Modification Unit under the command of Captain Ralph S. Barnaby USN (of glider fame), the activity expanded to the Naval Air Development Center (NADC) in August, 1949. The Center has a long and successful record of contributions to the introduction of advanced aircraft into the fleet. It has been instrumental in the development of a progression of surveillance, fighter, attack, anti-submarine, reconnaissance and special mission systems for Navy land based and carrier based aircraft.

Many of the center's most publicized achievements have occurred in the advanced development of successful avionic systems. Less visible is the role of the center to develop technologies critical or uniquely required for advanced Navy aircraft. Digital flight controls, composite structures, high voltage DC electrical systems, hydraulic systems and special stores are examples. In addition to its technical contributions to Naval Air Systems, the principal role of the center is to facilitate government-industry transfer by providing technical advice and assistance to the Naval Air Systems Command and to its major industrial contractors for evaluation of the design and developmental progress.

Airborne Early Warning and Control Systems (AEW/C)
Based on the pioneer work of the M.I.T. Radiation Laboratory, NADC conceived, developed and demonstrated successive Airborne Early Warning and Control (AEW/C) systems in the laboratory, in airborne prototype form, and provided technical assistance to the production contractors. Of special note was the development of the APS-20B search radar, the APS-45 height finding radar, and the APA-56 radar indicator. These became the elements of the WV-2 Constellation (AEW/C) in the late forties and early fifties. This WV-2 system was scaled down and fitted into a modified S-2F aircraft to provide AEW/C for aircraft carriers. The aircraft carrier based system featured a 10 foot antenna radome atop the S-2F aircraft and became the E-1B.

The concept for a digital surveillance and control system (W2F-E2A) with automatic detection and height finding and intercept control via data link was developed by NADC and the Bureau of Aeronautics and featured the General Electric Company (GE) developed APS-96 radar and a large rotating radome atop the aircraft. A feasibility model of the automatic detection, tracking and display system, and the tactical interceptor control system was developed and demonstrated to the competing E-2A contractors.

P-3 Avionics

In the P-3A Avionics system, the crew was rapidly becoming overloaded and ineffective because of the overwhelming volume of information needed to perform Anti-Submarine Warfare (ASW) tactics. Early center research, development, and systems integration including extensive analytical studies and simulation identified areas of greatest potential pay-off in coping with this problem. Subsequently the Center provided major updates to the P-3C avionics, mission software, and system test software in a systematic stepwise enhancement of the capabilities of the P-3C. The basic concept featured a central digital computer to integrate and provide tactical support. Also unique in the development process was the strong military professional leadership and the industry participation by Univac for software, Lockheed Aircraft for installation assistance, Stromberg Carlson for displays, Loral Electronics for keysets, and many others. Various up-dates to the original modification have enhanced the capability of the P-3C system. Many of the features of the P-3C system have been incorporated into the S-3A and S-3B Navy Carrier aircraft.

The key civilian personnel involved in the advanced development to operational systems development includes J. McCullough, I. Zaslow, J. Heap, K. Hawkes, J. Wrigley and F. Bohn.

AN/APS-116 - High Range Resolution Radar

Basic investigations into high resolution radars for the purpose of detecting small targets (snorkels) in a sea clutter environment was initiated under in-house Foundational Research in 1959. The results of this effort led to a preliminary design specification for the X-500K radar in 1966. This was followed by the development of the AN/APS-116 with Texas Instruments as the contractor on all models including production in 1973. The AN/APS-116 is the radar portion of the A-NEW avionics system of the S-3B aircraft. The Naval Air Test Center participated in the flight testing of the Advanced Development Model. Mr. E. Koos was the leader of the basic research and development team. Significant members of the team included G. Straub, T. Sanks, O. Kessler, and E. Mebus.

Igloo White

The Igloo White Program was assigned to NADC by the Defense Communications Planning Group (DCPG) in 1965. The Igloo White System was composed of a sensor detection and encoding system plus an airborne and ground based processing/ display system. NADC defined, developed, tested and prototyped the various elements. This system was deployed by the Army, Navy,

es and Air Force in South East Asia. Most significant was quick reaction time of NADC and the on-time development.

ersonnel included the program manager at NADC was Cap-
t. Ewald supported by H. Beyer (Airborne System/Ground
Processing/Display System), F. Bolden (System Test and
ation coordinator), and J. Leavens and T. Herring (Sensor
tion and Encoding).

Buoys

1952, NADC has conducted research and development in
e of acoustics for the detection, classification and localiza-
underwater vehicles. It has maintained leadership and
ise in the design and development of acoustic sensors for
e ASW operations. The first significant airborne detection
ility was the introduction of the Jezebel and Julie buoys in
e 1950's and the early 60's. Included with these was the
e processors and other navigational aids and tactical dis-
Later developments included the development of direc-
sensors such as DIFAR and other array sonobuoys. Naval
mechanical isolation systems were developed for sonobu-
minimize the effects of wave and flow induced noise under
environmental conditions. Classification techniques were
developed leading to enhanced detectability of targets and
cation of the processor operator's workload.

ent among this long list of contributors are Dr. J. Coop
al ASW), H. West (Helicopter systems), H. Suter (Active
ssive sonobuoys), J. Howard (Julie), K. Jerome and W.

Gleiter (Jezebel), G. Gimber (minibuoy), E. Bair (Fleet Support),
E. Cotilla (General ASW), J. Dak (Hydromechanical Systems),
and J. Keane (VLAD).

AN/ASW-25 Airborne Terminal

During the early sixties the Navy was in the process of developing
an Automatic Carrier Landing System. This system accepts preci-
sion radar tracking data, converts and calculates ideal glide slope
information and transmits the data to the aircraft for glide slope
correction display and command data to the aircraft autopilot.
Essential to the system was the requirement for a reliable air-
borne terminal of minimum size and weight. NADC proposed a
program to the then Bureau of Naval Weapons for in-house de-
sign development, fabrication and testing of a micro-miniature
airborne terminal equipment. NADC elected to use the then
evolving digital microelectronic circuit technology (Texas Instru-
ments, Series 51, circa 1963) as the basic building block. Seven
months after the date of assignment the breadboard version was
flight tested. The prototype (cigar box configuration) was then
installed in an A-7 aircraft for a series of successful aircraft carrier
sea trials in April 1964. The AN/ASW-25 terminal was produced
by the Harris Corp. The AN/ASW-25 provided the first large scale
use of digital microelectronic circuit technology for military aircraft
avionic systems. More importantly the equipment fulfilled a Navy
operational need and to this date is functioning with a MTBF of
2500 hours.

Mr. Henry Beyer led the NADC team in this entire process.



AEL

At the end of November, American Electronic Laboratories, Inc. (AEL), will have completed its thirty-third year of operation. AEL, headquartered in Montgomeryville, PA, is a diversified research, development and manufacturing firm specializing in advanced electronic components and systems.

The corporation, employing more than 1,350 personnel, has facilities in Montgomeryville, PA, Monmouth County, NJ, Reading, PA and Falls Church, VA, which account for sales of \$70 million annually and a current backlog in excess of \$100 million.

The basic philosophy of the corporation, as stated by Dr. Leon Riebman (F), President, Chief Executive Officer and a co-founder of AEL, was, "Define the need, establish a firm basis, move ahead wholeheartedly." This later resolved into "Do it first, do it quickly, do it best." Today "Imagination in High Technology" is not just a phrase, but a daily challenge to advance the state-of-the-art, while continuing as a recognized leader in the field of military and commercial electronics.

This same philosophy has been applied throughout the corporation's history from its start in 1950 in 400 square feet of working space on the third floor of a store-front building at 641 Arch St., Philadelphia. The founders, Dr. Riebman and Conrad J. Fowler, Chairman of the Board, were members of the research staff at the University of Pennsylvania's Moore School of Engineering. By 1952, the business developed into a full-time enterprise that demanded the complete dedication and creative talents of its founders.

The original biomedical product line has given way to diversified and comprehensive product lines, including antennas, microwave components, amplifiers, controls and servomechanisms, hybrid micro-electronic devices, electronic warfare systems, pulse analyzers, radar test equipment, transmitters, receivers and solid-state devices.

In 1961, the company moved to its present Montgomeryville plant where the facilities have continued to grow. AEL's modern manufacturing center is located minutes away from the corporate headquarters. This facility is fully equipped to manufacture highly complex electronic and mechanical equipment ranging from mass-produced miniaturized electronic modules to complete receiving and transmitting systems and large mechanical structures.

The Monmouth County and Reading facilities provide airport locations and specialized services for high performance, fixed-wing and rotary-wing aircraft, including electronic systems installations,

airframe and ground vehicle modifications, electro-magnetic testing, avionic system testing and retrofit, special parts fabrication and electronic systems research and development.

The Falls Church facility closely monitors government business, particularly, specialized development activities in the microwave and communications field. This facility is also engaged in product testing and metrology services, which are performed at other strategically located sites throughout the United States.

To keep pace with the demand for its services and products, AEL continues to expand its facilities with men and women of unique talent. The corporate research and development efforts are directed toward both government and commercial businesses in order to provide increased job stability and sustained growth.

As President and Chief Executive Officer, Dr. Riebman remains extremely active by personally participating in its engineering and technical leadership. Dr. Riebman has enjoyed a long-standing relationship with the University of Pennsylvania as a student, faculty member and board member. He is currently an Associate Trustee and a member of its Board of Engineering Education as well as a board member of its Engineering Alumni Society.

His earlier involvements at the university include the development of ENIAC, the world's first digital computer, and his capacities of Research Associate and part-time instructor.

Experience at Naval Research Laboratory (NRL) and Philco Corporation also play a part in Dr. Riebman's background. At NRL, he was instrumental in development of fire control radar systems and components. His expertise in this area was supplemented at Philco with responsibilities for design and analysis of airborne subminiature receivers.

Dr. Riebman holds eight patents and has authored many articles for professional journals. He is a member of Tau Beta Pi and Eta Kappa Nu; his professional memberships include a Fellowship in the IEEE. Dr. Riebman's affiliation with the IEEE includes past service as a member of the Receiver Committee and its AFC Subcommittee. He presently serves with the Philadelphia Chapter of the IEEE's Member Awards Committee.

As Chairman of the Board, Mr. Fowler (SM), is actively engaged in supervision of manufacturing, product design, quality assurance, and marketing functions. Mr. Fowler served three years in the U. S. Navy, attaining the rank of Lieutenant. As a radar and communications maintenance officer and radar instructor, he was

involved with a large variety of airborne radar and communications equipments.

Upon his return to civilian life, Mr. Fowler joined the Moore School as a laboratory manager of the Research Division, where he specialized in radio interference and measurement techniques and RFI test equipment design. This work included exhaustive studies of radio-receiving equipment covering a wide frequency range. In addition, Mr. Fowler also served on military and industrial committees devoted to the standardization of interference meter construction and noise measurement techniques.

Mr. Fowler is a patentee in his own field and has authored several articles in journals. He is president of the Board of Directors of North Penn Hospital and is a Senior Member of the IEEE and its Professional Group on Electromagnetic Compatibility (PGEMC). He organized the Philadelphia chapter of PGEMC, served as its first chairman, and chaired the PGEMC's Fifth National Symposium. Mr. Fowler is also a member of Sigma Tau, Sigma Xi, the Association of Old Crows, and the National Security Industrial Association.

AEL recently received multi-million dollar contracts including: design and manufacture of aircraft antenna assemblies and amplifiers; fabrication of countermeasure systems; design and production of various tactical jammers; development and test of microwave amplifier subsystems; production and installation of helicopter receivers and a patented antenna/detector system; fabrication and installation of operational aircraft safety equipment, and production of special-purpose electronic equipment and systems.

The corporation's future, when viewed in terms of recent programs, is indeed bright.

Editor's note: The principal business of AEL Industries Inc., is Electronic Defense Products and Services. This business includes the design and manufacture of radars, receivers and various electronic equipment. AEL also provides field engineering services to the U.S. and foreign governments. AEL is also recognized for its state-of-the-art jamming and jamming-simulator systems including the Mobile Electronic Warfare Environment Simulator (MEWES), the AN/TLQ-15 Communicators Jammer, the AN/MLQ-27, 28, 29 and 30 Multi-Purpose Jamming Facilities and the Surveillance Radar Jammer (SRJ) Program.

The Early Development of HF Data Transmission Technology at General Atronics Corporation

Mark S. Zimmerman (SM '57)
General Atronics Corporation

Over the last several years there has been a resurgence of activity in the development of modems and radio systems which provide transmission of digital data over HF radio channels. The specific application of these HF data links is to military data links, high frequency. This current activity is a rebound from the relative dormancy characteristic of the decade between 1965 and 1975. General Atronics Corporation, which is now a subsidiary of the Magnavox Government and Industrial Electronics Company, continues to be a lead supplier of HF modems to the U.S. and foreign military and to play a major role in the development of new transmission techniques. These notes and references to relatively early developments in modern HF data transmission record some of the history of significant developments in communications engineering in the Delaware Valley.

Much of the groundwork for today's efforts began in the 1950s with the first applications of modern communications theory to the HF data transmission problem. General Atronics was founded in 1956 when the first of the HF spread spectrum systems was being implemented and Atronics has been involved in the development of HF data transmission techniques from that time to the present. General Atronics' principal founder was the late David Sunstein who, together with his co-founders, Bernard Steinberg, George Laurent, Glenn Preston, and Robert Roop, left Philco Corporation to start the new company. Their principal experience had been in radar signal processing systems.

Work at General Atronics began with the implementation of HF spread spectrum transmission techniques, and extended to a variable data rate system which traded off data rate for redundancy as required. This work has resulted in a family of HF modems which are in current military service usage.

The earliest successful wideband, pseudo random reference, transmission system for HF was the RAKE system developed as an applique to the F9C-A at Lincoln Laboratory. At the time General Atronics was started, this system was being manufactured by the National Company. One of General Atronics' earliest consulting contracts was with the National Company and it was through this contract that its work on HF communications and the RAKE system began.

RAKE fundamentally involved a correlation measurement of the channel impulse response and the use of the measured response to implement a self-adjusting matched filter receiver. The efficiency of the RAKE receiver was achieved at the expense of a cumbersome hardware implementation since fifty parallel channels of analog processing were required. General Atronics' engineering staff had developed a strong background in radar signal processing and had done pioneering work in the development of delay line filtering for radar signals. This technology was applied to the design of a time-multiplexed version of the RAKE filter which became known as Wholesale RAKE, and may well have been the first application of sampled data filtering to a data communications modem.

A limitation of the RAKE concept was the requirement to operate at a low data rate even though the external noise environment was favorable. A variant of RAKE which implemented the self-adjusting matched filter in the frequency domain was conceived by General Atronics and had the great advantage of providing higher data rates under favorable conditions while retaining its ability to operate in a redundant matched filter low data rate mode when needed. This system, first proposed in 1958, was named "KATHRYN" and eventually was named AN/GSC-10, the earliest variable data rate HF modem.

Although Wholesale RAKE and KATHRYN were designed around time-multiplexed sampled data filters, the long-term stability and reliability were not all that desirable since the state of the art in wideband memory and processing circuits was analog. Specifically, the sampled data filters used fused quartz, ultrasonic delay lines and, although techniques were developed which demonstrated analog memory capable of 3,000 signal recirculations through an analog delay memory, it was obvious that digital storage and processing would be the key to reliable sampled data communications data modems. Digital processing was used for a relatively small portion of the AN/GSC-10 since the most efficient hardware at the time provided only four flip-flops on a circuit card.

With introduction of the early resistor-transistor logic digital microcircuits, the digital implementation of sampled data filter modems became an attainable goal and an independent research and

development project was started which resulted in a digitally implemented HF modem using a standard multitone DPSK modulation format to allow testing with other modems. The rapid advances in digital integrated circuits soon allowed the design of an airborne data terminal for the U.S. Navy's Link-11 HF computer-to-computer command and control system. This modem was named AN/ACQ-6 and was the forerunner of modems currently in service for NTDS Link-11 and other services such as remote AUTODIN entry from tactical forces. These modems, in some cases, provide a variable data rate as did the earlier KATHRYN system.

The problem of achieving higher data rates over an HF voice channel gained importance for the transmission of secure digitized speech and early work was carried out at General Atronics to apply error control coding techniques to the reliable transmission of data at high rates. From this work two techniques evolved: one operated in the domain of parallel tone modems and the other a serial transmission technique. The parallel tone work resulted in the development of the coded demodulator system in which a block code was decoded using channel measurement information derived from the modem to extend the error correcting capability of the system. Experimental models of the MODEM were built and demonstrated a doubling of available data rate for a given bandwidth and error rate, compared to conventional diversity systems.

Almost concurrently, a most interesting serial transmission system was devised. At the time, it was generally accepted that a serial-to-parallel transformation was required to allow transmission of data whose bit duration was less than the time spread of the heavily multipath HF channel. The serial system, named ELSA, provided transmission at a rate sufficiently high so as to experience multibit time dispersion. The demodulation process treated the received signal as a convolutionally coded signal, although the "code" in this case was a naturally imposed one the ionospheric impulse response. Demodulation was accomplished by a sequential decoding process. Simulation and experiments made with software decoding of recorded transmissions demonstrated the ability to receive 4.8 kb/s.

Although not all of the early work mentioned directly resulted in fielded hardware, many of the techniques such as digital implementation of modems, combining of redundant signalling, and error control coding exist in the current HF modem family in production at General Atronics. These include the MD-1061 which is a variable rate modem for general data use, and the AN/USQ-76, a data terminal set used in ship- and shore-based Link-11 installations. A predecessor of the MD-1061 (the MX-513A) was used by the U.S. Marine Corps to demonstrate the capability of providing AUTODIN entry via HF from a remote tactical digital terminal. These early techniques are also serving as the foundation for future systems currently in development.

Secure Voice Digital Terminal

Michel M. Goutmann
General Atronics Corporation

Conferencing of analog voice signals is accomplished by bridging voice signals at a switching or interconnecting facility. In contemporary digital systems, conferencing has been attempted by converting digital voice signals to analog voice signals at the interconnect facility and then bridging the analog signals. In general, this technique is applicable only for linear voice digitization methods such as PCM. Nonlinear digitizing schemes, such as Delta Modulation, Linear Predictive Codes (LPC), Channel Vocoders, etc., cannot be bridged by reverting to analog signals, since tandem digitizers in such systems may result in unacceptable voice quality. Magnavox/GAC has developed a Digital Conferencer which permits these digitized voice signals to be conferenced in a digital manner without any digital-to-analog conversion. The resulting voice conference has no degradation of voice quality.

The AN/FTC-52 Programmable Digital Conference System (PDCS) allows, for the first time, low rate digitized speech to be conferenced without catastrophic degradation due to repeated conversion, a fact which has, to date, limited low rate digitization (used for cryptographic security) to point-to-point communications only.

The PDCS is a multi-microprocessor system. It performs short-

term analysis on the various inputs (up to ten in a non-tandem system) which are received, in digital form, from the network subscribers (for instance, over telephone, radio, satellite communications channels). This processing generates a sequence which may be encoded and transmitted to all conferees, also in digital form, such that they will hear and participate in what may be termed a conference call. All voice interruption and typical voice conference protocols are maintained in this digital approach.

The AN/FTC-52 is applicable to conferencing Linear Predictive Coders (at 2,400 bits per second), Channel Vocoders (at 2,400 bits per second), Continuous Variable Slope Delta (CVSD) speech encoders (at rates between 9600 and 32,000 bits per second), and Adaptive PCM (at 9600 bps).

The AN/FTC-52 combines several state-of-the-art technologies including multiple microprocessor implementation, optical isolators for electromagnetic security, fiber optics for a remote control channel, and automatic fault isolation. This conferencing system offers a versatile building block for further secure systems. Among the applications are Automated Conferences, Conference Directors, and Secure Voice and Graphics Teleconferencing.