SPERRY UNIVAC

INTERCOMMUNICATION

TO: E. T. Michaud
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FROM (NAME & EXT): B. R. Borgerson, X2013

LOCATION & DATE: Blue Bell, PA - 03/23/79

DEPARTMENT & M.S.: Director, Research & Technical Planning

CC:

SUBJECT: CHAPTER 3 - ENGINEERING RESEARCH ASSOCIATES UNIVAC HISTORY BOOK

The technological history of Sperry Univac is being documented in a book which will be entitled, "Sperry Univac-The First Computer Company".

It has been suggested that you could provide an expert review of Chapter 3 which depicts the history of Engineering Research Associates.

As editor of this book, I would appreciate it very much if you would review this chapter and return your comments by April 23, 1979. Unless you request otherwise, it will be assumed that we have your permission to publish your name in the book as a reviewer.

Please send your comments and market manuscript in the enclosed addressed envelope to:

B. R. Borgerson
Blue Bell, Mail Station A2L

I thank you in advance for taking the time to assure the accuracy of this chapter.

Phil Holmes for B. Borgerson

B. R. Borgerson

BRB/krk

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3. Engineering Research Associates

No new organization or technology springs forth without roots in its past. The story of the origin of Engineering Research Associates (ERA) is a story of people and technology which both came from an earlier time. Although the course of development of technology was inevitable, the specific persons and organizations that became involved did so largely by chance. Above all, the story of ERA is a story of the interaction of technology with people in which personal initiative played a key role.

The origin of ERA is intimately connected with government activity in cryptography. A section of the U.S. Navy entitled "Communications Supplementary Activities — Washington", commonly referred to as CSAW and which was an immediate predecessor of the National Security Agency, had been engaged in cryptographic analysis since about 1935. Initial activities were based on punched card equipment which was the generic predecessor of the modern digital computer. During World War II, CSAW earned a well-deserved reputation for excellence in its cryptographic work while contracting with companies including Eastman Kodak, NCR, and Bell Telephone Laboratories for cryptographic equipment. Some of this equipment was special purpose, but some was for general purposes such as comparing or counting. These machines used digital techniques similar at a logical level to the modern digital computer. The companies and naval personnel involved in these projects gained invaluable experience in solving problems similar to the ones they would be encountering later in the design and application of general purpose computers.

After World War II, CSAW found that companies which formerly competed eagerly for contracts now would no longer accept them. Reasons for the lack of interest in military contracts were many. For example, the mandatory security clearances required time consuming investigations of personnel and the expense of meeting physical security regulations. In addition, special applications for the government, although low risk, had very limited profitability, while the pressure to meet the built-up civilian demand was enormous.

The CSAW organization was headed by Captain Joseph Wenger, a career Navy officer. Two individuals prominent in the organization were reserve officers Howard T. Engstrom and William C. Norris. Engstrom was formerly a math teacher from Yale, and Norris was a Navy commander from the University of Nebraska.

In the summer of 1945, with the war rapidly drawing to a close, Engstrom and Norris started to think about their return to civilian life. Each wanted to continue in the rapidly progressing area of cryptography and electronics rather than return to his prewar profession. One option that they considered was to continue to work for CSAW by joining the civil service organization. Another possiblity, suggested almost in jest by Engstrom, was to capitalize on their expertise by starting a business to design and fabricate cryptographic equipment for the Department of Defense.

Engstrom and Norris discussed this idea with other staff members of CSAW and found them to be receptive for the same reasons that made the idea attractive to Engstrom and Norris. They then approached Wenger with the concept, and somewhat to their surprise found him to be cautiously positive about the idea, as were several other senior Navy officers. These officers saw benefit in Engstrom's idea because they could not only have a qualified contractor to do CSAW work, but also could keep the CSAW equipment engineering group together, even if it were outside the government.

With this encouragement, Engstrom and Norris set out in the fall of 1945 to locate financing for the proposed company. Because the plan was to establish a high technology company to do classified government work whose nature could not be disclosed to potential investors, and because the projected profitability was low, little interest could be generated among sources of venture capital. But they presisted in their efforts.

Late in 1945 Engstrom and Norris were joined by another reserve officer, Captain Ralph L. Meader. Meader headed the United States Naval Computing Machine Laboratory (USNCML), a wartime operation located within the confines of the National Cash Register Company at Dayton, Ohio. USNCML had produced computing machines for CSAW and was scheduled to be disbanded at the end of the war. Before committing to endorse the Engstrom–Norris project, the Navy asked NCR to continue to support CSAW after USNCML was disbanded. NCR respectfully declined, preferring instead to allocate its resources to the cash register business.

By late in 1945, the CSAW equipment development group was becoming increasingly restless. It was obvious that the team of skilled, experienced people would soon be dispersed over the United States unless the new company was formed quickly. The entire venture was on the verge of failure before it started, when John E. Parker was introduced to Engstrom, Norris and Meader.

Parker was an investment banker, an Annapolis graduate, a Washington D.C. resident, and was well known in Navy circles. During the war, he had founded and headed Northwestern Aeronautical Corporation (NAC) which manufactured wooden gliders in St. Paul, Minnesota under contract to the Army Air Corps. The NAC gliders were military personnel carriers designed for airborne assault. NAC was the second largest producer of gliders in the war, having built over 1500. Some of these gliders were used in the invasion of France in 1944.

In 1945 the war was winding down, and companies every where were beginning to convert back to peace time products and production. NAC, which had been established to do war work, faced an especially difficult job in converting to peace time products because of the specialized nature of its products and technology.

The company occupied a government–owned facility at 1902 Minnehaha Avenue in St. Paul. It had established the usual support organization for accounting and interfacing with the resident Government accounting and inspection office. Production contracts were being cancelled rapidly. The market for NAC had disappeared, and they had no prewar expertise, experience, or civilian market to return to. As president, Parker devoted most of his energies to finding peace time directions for his company during this time.

Parker met Meader through a mutual friend at Dayton, and heard for the first time about the proposed new company from him. Parker expressed an interest in exploring the venture in more detail, and subsequently met with Engstrom and Norris who were constrained to describing their planned venture in only the most general terms. Late in 1945, a meeting was arranged at the Navy Department at which senior Navy officers were present. In addition to CSAW, the Naval Ordinance Laboratory near Washington was also interested in the new venture. They confirmed their support of the proposed company to Parker. Parker agreed to consider a joint venture.

In the days that followed, Parker met several times with the founding group. Negotiations went smoothly, and it soon became apparent that Parker had found a financial backer. On January 8, 1946, Parker incorporated a new company called Engineering Research Associates (ERA) under Minnesota law. The ownership of the corporation was split evenly with 50 percent of the stock going to the founding technical group of Engstrom, Norris and Meader, and 50 percent of the stock going to the investment group headed by Parker. The total initial investment was $20,000. Shares were sold at ten cents each, with 100,000 shares going to each group. In addition, Parker and the investment group agreed to provide a line of credit of $200,000.

Almost immediately, Engstrom and Norris started to recruit a technical staff and arrange for them to move to St. Paul to build the organization. Parker was appointed President, with Engstrom, Norris, and Meader as Vice Presidents. Technical programs were headed by CSAW veterans, John E. Howard as Director of Development, and Charles B. Tompkins as Director of Research. Tompkins was formerly a professor of math at Princeton.

The year of 1946 was a year of change, movement, and new beginnings across the United States. Engineers and scientists who had worked in war plants or served in the Armed Forces returned home and looked for work. Minnesotans with a technical profession had few job choices. Among the very few ads in the Minneapolis and St. Paul newspapers was a small one placed by ERA. Eligible applicants were told only that ERA was a new company doing advanced electronics work. Those who asked for more information were told that ERA was associated with NAC and was working on electronics systems for the aviation industry. All readily accepted the explanation that ERA was also doing what was simply described as "secret government work".

The ads helped recruit a small group of experienced technical people who wanted to return to work in Minnesota, plus a larger group of war time University of Minnesota graduates. These, added to the nucleus of some 40 seasoned CSAW staff who moved to St. Paul and a few engineers and scientists recruited from other Navy activities, formed the initial technical staff of ERA. The ex-CSAW personnel agreed to three conditions of employment with ERA.

- to buy a prescribed number of shares at $0.10 each
- to remain members of the U.S. Naval Reserve
- to remain with ERA a prescribed number of years (one or two)

A few months after the establishment of the ERA corporation, in June of 1946, the Navy Department issued two contracts without competitive bidding; a small one to ERA and a larger one to NAC. The reason for this was that ERA had no operating record and under the law was ineligible to receive a major contract award. On the other hand, NAC was eligible since it was an established defense contractor with a good track record. Of course, NAC and ERA had the same management and shared the same facility in St. Paul. One year later, in 1947, ERA became the prime contractor and NAC became history.

The founding of ERA and the receipt of its first contracts involved some obvious bending of Navy rules, but this should not be confused with questions of substance. The Navy was well aware of the risks involved, and took firm steps to maintain control and protect the taxpayer. Instead of disbanding USNCML, the Navy ordered it to move intact from NCR – Dayton to ERA – St. Paul. When the ex-CSAW group arrived to begin work in the middle of 1946, they found a complete contractor surveillance organization on site. The Navy Bureau of Ships (Buships) provided a blanket contract and arrangements for clearance and security. The contracts were cost plus. A number of tasks could be assigned as long as funds were available.

ERA engineers had to live with a resident Navy group whose mission was to monitor and enforce the very stringent specifications of the Buships contract under which they operated. They looked on this at the time as "a burdensome nuisance and a first class pain". The engineers had to contend with very conservative design, Navy style component mounting and wiring, and component de-rating. They were arguing constantly for wavers of inapplicable specifications. Later, when bringing commercial products to market, they came to appreciate that this early Navy conditioning of their engineers to a strict discipline of design quality was a major factor in keeping their products not only very reliable but also cost competitive with other products appearing in the market. ERA later developed a well deserved reputation for advanced technology and reliability based on the fact that they developed, under the Navy, standardized equipment of modular construction that could be disassembled and reassembled on site very quickly.

In 1946, as NAC, the infant ERA and the recently transferred USNCML, started to work together, rapid development was taking place in the new field of electronic computers. The importance of these breakthroughs was not lost on the Navy. The question was not what work to give ERA but rather how to contractually define its role. To this question the Navy found a relatively simple answer – task type contracts. These were annual contracts which called for the contractor to undertake a series of tasks to be defined later. A ceiling expenditure figure for the fiscal year was the major feature of each contract. NAC and ERA could, therefore, get started knowing the approximate level of financial support that would be forthcoming.

The ERA organization was straightforward but the organizational setup in St. Paul, with two private sector companies and a Naval station sharing one facility, could hardly have been more chaotic. The task type contracts served admirably to bring order out of this chaos. The tasks were defined and added one at a time as the situation developed. Serially numbered, starting with Task 1, they varied from training programs (a holding tank of uncleared people), to consulting programs, to building of special purpose electronic data processing devices, to research on data handling and storage techniques. Some represented ongoing programs; others had specific time schedules as short as a few months.

From the start, ERA showed strength in problem solving as contrasted with problem definition. This characteristic arose from the security aspects of the programs in which ERA was involved, Cryptologic work has always required that a high degree of compartmentalization be maintained. Because of this ERA was always assigned specific, concrete projects and each project was told only as much as it needed to know. This policy exacted a price from the customer - primarily in some loss of interplay between equipment user and equipment designer.

ERA also paid a price. From the early days onward, ERA was more specification oriented than user oriented, a characteristic that later hindered its entry into commercial activities and delayed its maturation into a total computer systems supplier. However, the emphasis on hardware and on specific solutions also built strengths. One benefit was the development within ERA of independent project teams capable of handling an entire equipment design from start to finish. Another was that under the ever watchful eye of USNCML, ERA soon developed into a disciplined, efficient supplier of reliable hardware.

At a time when electronic computers were being wired in place by their builders and nursed into operation in the laboratory, ERA machines were being built in modules, tested, dismantled and moved to remote locations where they were maintained and operated by persons unknown. At a time when electronic equipment exhibited mean time to failure of minutes, ERA was delivering finished equipment with mean time to failure of hours. ERA may have been hobbled by tight security, but the new company did have the advantage of working with a knowledgeable client who had resources. Under the auspices of the customer, ERA was made privy to much of the computer development work going on around the country and, indeed, the world. ERA designers were able to visit other laboratories and, as security permitted, to welcome visitors to ERA. They modified, adapted, improved and then made use of whatever was available.

The first ERA tasks involved not only development of special digital machines, but also called for research and development on both data handling and data storage technique. Out of one of these tasks came ERA's maiden paper at a national meeting. At the National Electronics Conference in November 1947, John Coombs described a magnetic storage technique developed for a specialized processor. From another task came important results in addressable, selectively alterable drum storage at what were then high densities and high scanning rates. These techniques paved the way for the drum storage used in ERA's first general purpose computer. By the end of the first year the tasks had begun to yield results, and ERA project teams were routinely being assigned development of large scale calculating devices incorporating hundreds and even thousands of vacuum tubes.

One interesting task directed ERA to conduct an investigation into "the status of development of computing machine components." The finished report provided a useful technical picture of applicable components and techniques, plus a generous quantity of tutorial material by ERA staffers. Dr. Mina Rees, head of the Office of Naval Research Mathematical Sciences Division, suggested that the report be made available in book form. High Speed Computing Devices (McGraw-Hill, 1950), the most comprehensive reference work of the period, was the result.

From a business point of view the two Navy contracts supported the company. Revenues for the fiscal year ending October 31, 1947, the first full year of operation, were $1.5 million on which a profit of $34,000 was earned. Employment which had been 145 at the start of the 1947 fiscal year had risen to 420 by the year end. However, with working capital of only $100,000 and a total debt of $330,000, ERA was seriously undercapitalized for its volume of business.

3.1. The Early Environment

In the early days, ERA had the very excellent team atmosphere of a small company. Decision – making was very informal and very simple. The interested people would meet in John Parker's office, and everyone had his say. The participants ranged from the lowest engineer to the company president. A concensus would be reached, the secretary would be called in and the decision documented. Decisions were made in hours rather than weeks or months typical of large organizations. Although not all decisions were the right ones, they were reached rapidly, agreed to by everyone, and implemented immediately.

There were other unique characteristics of a small company. Each employee was given a turkey for Thanksgiving and Christmas. Each individual was held accountable for his own work, which created a pride of workmanship and accomplishment. Also, the same team of people carried an entire project through from concept to installation. All work had obvious and tangible contribution to the success of the project.

Technology development was not too organized and thorough. If someone had a circuit that worked reliably, word spread quickly and others used it if they could. There were very few formal lines of communications. Most interaction was informal and in small groups. Cafeteria conversations were typically about what someone had discovered, because everyone was breaking new ground. Most designers were young, and the excitement and enthusiasm were contagious. There was so much innovation and invention that opened up all kinds of possibilities that people scarcely noticed the shortcomings of the physical plant.

The early physical plant facilities at 1902 Minnehaha Avenue left something to be desired. It started out as a foundry for American Radiator Company. During the depression it was used by the CCC as a warehouse and personnel staging area. The NAC used it to manufacture gliders, and then the Navy bought it for ERA to use as a tennant contractor. The facility had been a glider factory, had large open spaces, and a very high ceiling with skylights. The skylights operated all together by a pulley arrangement, but could not be operated quickly. When it rained, it took a while to get the skylights closed; meanwhile everything got wet. Some of the lower windows had no screens, so sparrows and swallows would get in and fly around the high ceiling. It was necessary periodically to chase birds out of the building. In the winter, the inside temperature dropped so low in the Minnesota weather that programmers wore overcoats and mittens at their desks. In the summer, the temperature rose to the point that whole departments worked without shirts on, and draftsmen had trouble with sweat dripping on their drawings.

The sub–basement had mice as well as office supplies and archives. The advantage of the sub–basement is that it was the only cool place in the building in the summer. The secretaries vied for the job of getting office supplies in the summer even though they had to stand on chairs to escape the mice. Rat poison was used liberally throughout the building. Soot from nearby trains was also a constant problem. Fly swatters were an essential item stocked in office supplies.

Company regulations were less developed then. Liquor was not forbidden on the premises. Some of the office Christmas parties were legendary. One of the Navy personnel imbibed too much, and on the way home in St. Paul tried to drive his car across a pedestrian foot bridge over a railroad track, with fatal results. On some occasions the five gallon bottles on the water coolers were emptied of water and filled with orange juice and vodka.

The wide open space of the glider factory was divided into offices by paperboard partitions, which were moved frequently as old projects terminated and new ones started. The general environment was gently dirty and characterized by uncomfortable temperature changes. But for a while this added to the pioneering atmosphere, and the little hardships were a plus. Early conference room furniture consisted of old folding chairs, no two the same, and two or three unmatched old tables. The furniture in an early office consisted of a barrel for a chair and a wooden bench for a table.

The minor inconviences were more than compensated by the comraderie that existed at all levels. Every morning at 10:00 a.m. the German chef brought out the fresh Danish rolls that he baked, hot out of the oven. He was an outstanding chef, and no one brought a "brown bag" lunch while he was in charge.

During one Christmas party, the company picked up an employee's organ, insured it, and brought it to the plant. It was placed on a dolly and pushed all over the building. The organ was played and a chorus of 75 to 100 people sang carols.

The presence of the Navy lent a special quality to the atmosphere at 1902 Minnehaha Avenue. From 1946 to 1950 it was a regular Navy Reserve Base complete with a full Captain, several Commanders, Lieutenants, Ensigns, Chiefs, and enlisted men, full time, stationed at ERA. Every time they changed the Captain there was the piping ceremony of the new Captain on board in the courtyard with much pomp. The employees had to be in attendance, and they would lower one captain's flag and raise the other's, along with certain ritual remarks from the incoming and outgoing captains. The Reservists had to drill in uniform one night each week after work, after which they would have the Reserve meeting at the plant.

One of the Captains was a very, very shipboard type and ran a very tight ship. Since the Navy owned the building, he looked on it much as he would his own ship. One time he surprised the employees with a white glove inspection, amid open skylights, train soot, and flying birds. Predictably the area failed the white glove test, especially on the tops of file cabinets. The Captain sent for the Project Engineer and ordered him to stop all work and get the place cleaned up. They were not allowed to use the janitors; the engineers had to do it themselves.

Because of the highly classified nature of the work, the security system was quite elaborate. All major projects were guarded by armed guards outside a locked door. He had to recognize all authorized personnel on sight, and controlled the door with a switch on his desk. All loading of equipment was guarded by two armed guards, who also were locked in the railroad car for the entire trip.

3.2. 1101

In August of 1947 the Navy's CSAW contracted with ERA for development of a general purpose computer system designated "Atlas", after the mental giant in the comic strip "Barnaby". Within ERA and under the system of task funding which was then employed by the government in working with ERA, work on Atlas was assigned task no. 13. This number is significant because later when ERA proceeded to develop a commercial version of the Atlas computer, the number 1101 was assigned, which is binary for decimal 13. The name 1101 was suggested by John L. Hill, and led to the 1100 series nomenclature in use today. The ERA 1101 was the first commercial computer produced by ERA and was also the first general purpose computer designed and built by ERA. A system view of the 1101 is shown in Figure 3-1. Two of the task 13 Atlas machines were built and delivered to the National Security Agency (NSA). From documentation available it is reported that the Atlas computers operated successfully over a period of six to eight years in classified government applications.

Figure 3-1. 1101 System View

Arnold A. Cohen was placed in charge of the logical design phase. The Atlas project called for the development of a 24-bit parallel, magnetic drum store, selective sequence calculator. John L. Hill was appointed to head the engineering aspects of the project.

The assignment of Task 13 to ERA was paralleled by the customer's decision to build a small relay model to prove the logic. This model, which used an ERA furnished magnetic drum, was itself useful for a number of years both before and after it surfaced as the unclassified ONR Relay Computer. The first Atlas was completed in the fall of 1950. It was moved to Washington in December 1950, installed in eight days, and operated immediately. The machine was operated 24 hours per day with 10 percent of each day allotted to preventive maintenance. In its first 4500 hours Atlas had unheard of performance; unscheduled maintenance amounted to only 4% of the total "heater on" time. A second system was delivered in March 1953.

Following successful completion of the NSA contract for the Atlas machines, ERA obtained permission from the customer to offer this machine in modified form for sale in commercial applications. The first machine built from the Atlas modified design and designated as the ERA 1101 was delivered and installed early in 1954 at a company-operated computer facility in Arlington, Virginia. Concurrent with the 1101 commercial machine construction ERA had, in process, development of a more advanced model Atlas machine for NSA designated as Atlas II. With the knowledge that this more advanced machine with it's 36-bit word length and two-address logic would be a more powerful machine for commercial applications, no additional models of the 1101 were built. Operation of the ERA computer service facility at Arlington was maintained for only a short period of time. The center was closed and in September 1954, the 1101 was donated to Georgia Tech University. At Georgia Tech the ERA 1101 was used for commercial and scientific data processing and for education and research in all fields of engineering and science. Modifications were later made to the 1101 including the addition of a 4096-word magnetic core subsystem of the type used on the 1103A computer.

The architecture of the ERA 1101 was taken from the Atlas I, although modifications of unspecified nature were made for the commercial application. The Atlas I design in turn had been adapted from the MIT Whirlwind computer, though the word length and other features were different. The 1101 employed a single address instruction, 24-bit word length, and operated in parallel, using the binary number system. Fixed point arithmetic instructions only were supplied, and one's complement subtractive logic was used. The 1101 had a repertoire of 38 instructions including arithmetic, logical, branching and shift. Apparently, the use of mnemonics had not yet been "discovered" as no such references are found in ERA 1101 literature.

The command word format was as follows.

Command Word

c	s	y
23 18	17 14	13 0

c = Command Code: 6-bits

s = Skip Code: 4-bits; control the increment by which the Program Address Counter (PAK) is advanced between storage references. The four s-bits are directed into any of the fourteen stages of the PAK by a manual selector switch associated with each s-bit. The s-controlled increment is in addition to the normal PAK incrementation, which is itself controlled by a manual selector switch. Normal PAK incrementation is manually selectable in increments of from 2^0 to 12^{13}.

y = Operand Address: 14-bits; for all commands except:

- SHIFT (y = shift count, k; 6-bits)
- CLEAR, CLEAR ADD, HOLD ADD, TRANSMIT, STOP, DO NOTHING (y = not used).

Typical execution times including data access and procurement of the next instruction were as follows: addition, 96 microseconds; multiplication, 352 microseconds; and divide 416 microseconds. Access time to information stored on the magnetic drum was 32 microseconds minimum (cell-to-cell references); 17 miliseconds maximum and 8.5 milliseconds average access time for any single drum reference. The 1101 internal clock operated at 400kc. The data input rate by a paper tape reader was 140 frames (35 computer words) per second. Output to a Flexowriter typewriter was 10 characters per second and output to a paper tape punch was 7 characters per second.

Hardware technology used in the 1101 was vacuum tube with diode logic. Tubes and other electronic components were mounted on pluggable chassis which were cooled by chilled air forced upward through the cabinet. Wiring between chassis positions was made either by a single conductor pole line wiring or by coaxial cables. The hardware count in the 1101 consisted of 2,700 vacuum tubes of 18 types and 2,385 germanium diodes.

ERA did not provide software for the 1101 system, other than programs used to debug the hardware. Machine language coding only in octal was employed and of course no compilers, assemblers or any higher level languages were available or were developed for this system. Philosophy at the time of the 1101 development was that of ERA providing the hardware and the potential customers providing the software. Programming as such did not exist at ERA except for maintenance and diagnostic tests, and some exploratory work in minimum latency coding techniques.

Storage initially planned for the Atlas machine was the Selectron electrostatic storage tube. However, development of the Selectron was not sufficiently advanced at the time to permit its' use, and a magnetic drum memory was substituted. Only one set of Selectron tubes was operational at the time, and that set was installed in Rand Corporation's JOHNNIAC computer. The type 1100A1 drum was used and its capacity was 16,384 24-bit words. The drum rotor was 8.5 inches in diameter and rotated at 3525 rpm, giving a maxium access or rotation time of 17 milliseconds and an average access time of one half that figure, or 8.5 milliseconds. Programmable and manual incrementation of the instruction address, plus a (manually) variable drum address interlace, permitted drum storage mapping for optimum performance.

The 1101 consisted of four cabinets each 84" wide by 76" high by 18" deep, housing electronic equipment. There were also three smaller cabinets housing the power supply, magnetic drum and a maintenance control station. An external motor generator set and an air-to-water heat transfer unit were also supplied. The complete system occupied an area 45' long by 9' wide. Total power into the system was 13 kilowatts, all of which was removed by the heat transfer to water. Water at a rate of 12 gallons per minute was required with a minimum pressure of 25 lbs. per square inch and a maximum temperature of 50°. Total weight of the machine was approximately 16000 pounds. The 1101 is believed to be the first application of false floor construction. The false floor was used as an air plenum to supply cooling air to the equipment.

The ERA 1101 was unique in bringing together in a single system the best state-of-the-art features available at the time in a rapidly expanding computer technology, including:

- Built-in margin checking.
- Modular construction using standardized pluggable assemblies.
- Self-contained cooling with raised-floor air plenum.
- High performance, high reliability, non-volatile, magnetic storage (rotating drum).
- Variable command address incrementation, and storage address interlace, permitting minimum latency programming.
- Self checking test programs.
- Central maintenance panel to aid diagnostic test.

- Reduced tube heater voltage control to limit thermal shock on start-up, and to detect weak tubes before operational failure.

3.3. Business Environment

From a business point of view, ERA's performance after the first year was erratic. The second year, fiscal 1948, had been strong. Revenues had more than doubled and earnings climbed 90 percent. But, under the frugal defense funding of the Truman administration before the Korean War, revenues and profits declined 20 percent in the third year. It its fourth fiscal year, just when the company was doing so well technically, revenues declined a further 25 percent and earnings barely exceeded those of the first year. Employment, which had risen to 652 in 1948, had dropped back to 528 by 1950.

Well before the 1101 announcement, ERA was becoming known in the infant computer industry. In 1949, ERA contracted to do a paper design for IBM on a punched card, magnetic drum computer system intended for business use. ERA's design was to be judged competitively with those of two internal IBM groups. Few if any of ERA's technical contributions seem to have found their way into what eventually became the IBM 650. However, two extensive patents came out of the effort, and these were assigned to IBM as sponsor of the project. In addition, a cross-licensing agreement between ERA and IBM gave IBM access to ERA's then pending patents in magnetic drum storage.

3.4. 1102

Also in the early 1950's, ERA under-took a wide range of concurrent developments for various customers; precursors of today's large-scale data systems implemented in general purpose computers with hierarchies of storage. One of these systems, sold to the John Plain Company of Chicago, was the first electronic inventory system for a merchandising application. This system led to the Univac File computer. Another was a system delivered to the Civil Aeronautics Administration in 1953, which accommodated 100 Teletype terminals in an experimental network for storing, searching, and processing aircraft flight plans. A third example was the Logistics Computer delivered to ONR in 1953.

In the same period, ERA built magnetic drum 1102 computers for on-line data reduction and open-loop control of experiments at USAF's huge Arnold Engineering Development Center in Tennessee. Another special order yielded the 1104, a programmable machine with both CRT and drum storage, delivered to Eglin AFB in 1954 for closed-loop control in the BOMARC Missile program.

Following WWII, American forces captured in Germany and returned to the U.S., plans and some of the equipment built for advanced aerodynamic test facilities. The plans and equipment were used to construct the Arnold Engineering Development Center near Tullahoma, Tennessee.

In October 1952, ERA was awarded a contract for the design, development, construction, and installation of three 1102 data reduction computer systems for the Arnold Engineering Development Center. The initial contract covering all work on three identical systems was one million dollars. These systems consisted of a processor, drum storage, cooling, console, raw data scanner and recorder, four plotters, five output tabulators, D.C. generators, motor-alternators, and electronically regulated power supplies. Subsequent contracts for building and delivery of three additional raw data scanner/recorder systems brought total funding to approximately 1.4 million dollars. A system pictorial view is shown in Figure 3-2.

Figure 3–2. 1102 System Pictorial View

The three major test facilities, each to be equipped with one of the data reduction computer systems were:

- Engine Test Facility (capable of testing any existing or projected jet engine under simulated operating speed and altitude conditions).

- Propulsion Wind Tunnel (capable of testing a jet engine, pod and wing section in its sixteen feet by sixteen feet throat at transonic and supersonic speeds, and at simulated operational altitude conditions).

- Gas Dynamics Facility (capable of testing aircraft models at supersonic and hypersonic speeds).

Architecture of the 1102 was adapted from that of the Task 29, Task 32, and 1103 commercial computer (then in development), with word size scaled down to 24 bits. Its architecture was one's complement, synchronous logic, parallel operation, 24 bit word length, single address instructions. The instruction set was similar to that of the 36 bit 1103 machine, with the addition of instructions tailored to the data reduction application.

Format of the instruction word was as follows:

Instruction Word

OP CODE	s	c	y
23 – 18	17 – 15	14 – 13	12 – 0

OP CODE = Operation Code: 6–bits;

s = Skip Code: 3-bits; Controls the increment by which the Program Address Counter (PAK) is advanced between storage references.

The three s-bits are directed into any of the thirteen stages of the PAK by a manual selector switch associated with each s-bit. The s-controlled increment is in addition to the normal PAK incrementation, which is itself controlled by a manual selector switch. Normal PAK incrementation is manually selectable in increments from 2^0 to 2^{12}.

c = Supplementary Control Code: 2-bits;

i_{14} = 1; Optional Stop (all but FINAL STOP, INTERMEDIATE STOP, TABULATE, MULT., MULT. ADD.)

i_{14} = 1 (TABULATE); punch 7th level on tape

i_{14} = 1 (MULT., MULT. ADD) change sign of product

i_{14} = 1; Operand read from or stored in Q register (all except ADD, SUBT. AND SEQ. DEV.)

i_{13} = 1 (ADD AND SUBT); replace (y) with (Q) and left sift (A) (final) by k places.

i_{13} = 1 (SEQ. DEV.); take next instruction from Q

Because of the single application of the 1102 system (data reduction), no instruction mix performance criterion was required or calculated. The one specific performance requirement was the scanning of 250 input data sources in 12.5 seconds; a rate of 20 per second.

Vacuum tube technology was used in the 1102, with basic logic circuits taken directly from the 1103 design.

Control logic was clocked at 500KC, with 1/4 microsecond clock pulses AC coupled via pulse transformers. Interchassis connections were made by single conductor "poleline" wiring isolated on stand offs, or via bundled twisted pairs.

"Suitcase" chassis with 74 pin screwjack connectors were similar to those of the 1103, but pre-perforated component boards were used rather than the custom-drilled boards of the 1103. Back panel channels were mounted vertically, each containing two columns of four chassis positions.

Vacuum tube filaments were powered by transformers mounted at the base of each chassis channel. Filament voltage was supplied at 5.7 volts as well as the normal 6.3v. The low filament voltage was used on start-up to reduce thermal shock to the tubes, and also applied (selectively) as a test to detect marginal vacuum tube operation.

Programming of the 1102 was by means of machine language coding only, as no assembler, compiler or any higher level language was available or developed for this system.

Operating software for the three facilities was developed by Arnold personnel; each customized for the application. Customer software was used, with simulated input data, both to verify the software and the 1102 hardware operation after installation. Customer supplied switch panels were used for the simulated data which was input via the raw data scanner.

The programmer had 8192 words of drum storage (total) to work with, for both program and data storage. Loading of programs and data was done via paper tape, except that in on-line mode, data words (15 bits) were input directly from the raw data scanner. A drum address interlace plug board permitted variation of drum address interval to best suit the specific program in process.

The main (and only) storage in the 1102 system was provided by the type 1120A1 magnetic storage drum. This drum was an extension (with greater capacity) of the type 1119A1 drum previously developed for use in the Card-to-Tape Converter system.

The type 1120A1 drum storage capacity was 8192 24-bit words. The drum rotor was 4 3/8" in diameter and 15 1/2" long, and the external shroud mounted 240 miniature heads. A small 120 cycle alternator was used to power the drum, via a direct-drive motor, at 7200 RPM.

Maxium access time per drum address (drum rotation period) was 8.3 MS, and average access time was 4.2 MS.

An address interlace plugboard permitted the selection of numerically sequential addresses to be varied in increments of one or more physical storage positions around the periphery of the drum. The interval between program instruction references was controlled by variable incrementation of the program address counter. The time interval between physical address locations could thus be optomized to a given programming application.

A fixed compliment of input-output equipment was initially supplied with each system. Univac later supplied three additional Raw Data Scanner and Recorder systems. Arnold personnel also made direct procurement of analog-to-digital converters, and it is known that alternative plotting equipment was being considered.

Program instructions, and input data (previously recorded by the Raw Data System paper tape punch) were loaded into the 1102 via a Ferranti Mark II high-speed paper tape reader.

The Ferranti reader read the tape perforations photoelectrically, and was capable of operating continuously at a rate of 200 characters per second, or in a start/stop mode, as required by the type of input operation.

Data read from tape was assembled under control of a wired-in load routine, for program loading, or under program control, for data input from paper tape.

Five output tabulators (10-characters per second, modified Flexowriters) each directly addressable under program control, were provided on each system. The commercial Flexowriter typewriter, with auxiliary paper tape punch, was modified for the application by addition of cams and synchronizing contacts, and the addition of an external, binary-to-Flexowriter code translator. The tabulators were capable of operating remotely from the 1102 processor at a distance of up to approximately 1000 feet. Typically, the tabulators would be located at or near facility control centers, as well as at the computer room.

Four Librascope Inc. plotters, each directly addressable under program control, were provided on each system. The plotters could produce either point or continuous plots, with a full scale traverse time of one second. Accuracy was 0.1%. Plotting was done on a concave surface. The plotter stylus motion was horizontal (x-axis) and rotational (y-axis). An 18 bit binary word from a computer output register supplied both axes of the plot, and a converter, external to the plotter, performed digital to analog conversion for plotter operation.

As with the tabulators, plotters could be located at the computer site, or remotely at a distance of up to approximately 1000 feet.

Power to the 1102 computer system was obtained from a 460 volt, 60 cycle, 3 phase AC source. The input power was supplied to a motor generator set which consumed 24 kilowatts, and, to two air conditioning units which consumed 12 kilowatts. Both of these loads were at 85% power factor. The motor generator set included a 50 hp, 3 phase induction motor driving an alternator and two DC generators. Voltage sensors were supplied on +5, -15, -25, and -80 volt supplies, and an out-of-tolerance condition on any of these voltages would result in a system power shut down. All voltages were monitored and controlled by a central control panel and power to the 1102 was applied and removed by an automatic sequence controller. Cooling of the 1102 equipment was accomplished through use of two mechanical refrigeration units using water cooled condensers. Cooling air from the air conditioners was conducted through a plenum in the base of each cabinet. Protective equipment in the 1102 consisted of voltage interlocks on all cabinet doors. If the doors were opened without the interlocks being bypassed, an automatic shutdown of power was initiated. Environmental sensors were supplied in each cabinet. At the temperature of 85°F exhaust air, a warning light was lighted on the cabinet and at the central control position. If the temperature increased further to 120°F, an automatic power-down sequence was initiated. Additionally, an air vane sensor switch in each air conditioning unit warned of the loss of cooling air.

Development of the 1102 computer system started in October 1952. The initial work was done in an office area in building 6 of the Minnehaha Avenue plant. Within a short time, the project was transferred to an area in the west end of the Minnehaha Avenue Plant, which had been undergoing renovation just prior to this time. An office area and a prototype area immediately adjacent to each other were assigned to the project. The initial work consisted of design of the 1102 system elements using the 1103 basic circuits, logic and hardware as a starting point. None of the original design engineers had prior digital design experience though all of the people on the project at the start had prior industrial experience, and the project engineer had prior experience within ERA. There were, however, many new logic and circuit requirements, and in these areas, the work started from scratch. Any component not already a part of the 1103 hardware, had to be selected from available commercial sources, specifications established, samples acquired and after approval, procurement of the prototye qualities initiated.

As the various elements of the 1102 system design were completed, fabrication was initiated on a piecemeal basis. Some of the fabrication took place in an adjacent manufacturing area in the same building. Other elements were built at a temporary manufacturing location at 2295 University Avenue just west of Raymond Avenue in St. Paul. During the design phase, the prototype area was also utilized as a lab in which circuit development was accomplished on all portions of the system where the design was new to the 1102. Among the areas involved in the latter category were an analog-to-digital converter which had originally been included in the contract with the Air Force. After several attempts at producing a usable converter, starting the design from scratch, these efforts were abandoned and the contract amended to drop that requirement. Additional areas requiring new design and laboratory test were the Teletype high-speed paper tape punch, the Flexowriter output tabulators, the Librascope plotters and the Ferranti high-speed paper tape reader. One additional area where some basic investigation was carried on during the development of the 1102 concerned that of the output plotter. Basic experimental work was conducted aimed at development of a flat X-Y plotter to satisfy the plotting application. The work consisted of using sensitized paper with an orthogonal grid of conductors on each side. An electric field was applied to the matrix lines in an attempt to create a usable plot. This work was not a part of the contract requirements but was an attempt to determine whether a feasible plotting system could use this approach. The work was not carried very far and was abandoned after the Librascope plotter was selected for this application.

The final assembly of the first 1102 system (there was no separate prototype) was carried out in the project area using personnel from the manufacturing organization as well as from the project. On completion of the first system, operational tests were conducted on each of the elements of the system and finally, on the system as a whole. On completion of testing, the first system was torn down, shipped to Tullahoma, Tennessee, and installed at the Engine Test Facility. The period of installation was from July 20 through July 31, 1954. This first installation was not complete because the control room for the Engine Test Facility was still under construction. However, all equipment had been delivered at the time the basic system was installed. The Scanner/Recorder, remote tabulators and plotters were finally installed at the Engine Test Facility in the period of September 12 through September 25, 1954.

The second and third systems were assembled, tested, and delivered in a similar manner. The second system installation, at the Gas Dynamics facility, took place during the 12th through the 22nd of December of 1954. The third system, for the Propulsion Wind Tunnel facility, was installed during the 7th through the 19th of February 1955.

Installation of the three systems as described, completed the initial contract work for the Air Force. However, the customer had determined that they would require additional raw data scanners and recording systems. Consequently under a separate contract, three additional systems of this nature were developed, intended for off-line recording of raw data. These systems were similar to the basic 1102 scanner/recorder systems but included a self-contained power supply. The three additional raw data scanner and recorder systems were built and delivered in the period from April 1955 through July 1956.

Though the 1102 system used architectural concepts and adapted circuits previously developed for the 1103 computer systems, it did mark the first application of several new hardware development areas and also new applications of the comptuter. This certainly must be considered as an early, if not the first, application of computers for on-line data reduction. Another first, at least for ERA, was the operation and control of the Teletype high-speed paper tape punch. In fact so new was this device, that the engineering prototype of the Teletype punch was obtained through U.S. Air Force contacts for use in the first 1102 system. Other first time, or early applications employed by the 1102 were the increased capacity small high-speed storage drum, the remote tabulators and plotters and certain simplification and cost reducing aspects which were designed into the basic hardware. By making use of previously established technology, architectural and logical design concepts, the 1102 development was accomplished in a relatively short period of time with few, if any, fabrication, test or installation problems. The useful life of the 1102 systems at Arnold is unknown. However, it is known that all systems performed their function in a highly satisfactory manner and it is likely that only the advent of newer and lower cost technology and higher performance requirements eventually caused the obsolescence and replacement of these systems at Arnold Engineering Development Center.

3.5. The Sale

In 1950, at the start of the Korean War, the first consolidation of the still tiny computer industry took place. Eckert Mauchly Computer Corp., developers of Univac, had gotten into financial difficulty and were absorbed by Remington Rand Inc. Remington Rand had already acquired some computer development capability when, in 1949, they successfully recruited a group of senior ERA people to join their Development Laboratories in Norwalk, Connecticut.

ERA's financial problems were by no means as serious as those of Eckert Mauchly although ERA remained severely undercapitalized. ERA management had three practical alternatives; they could borrow more, sell more stock, or sell out. To someone with Parker's background the answer was evident and the decision to sell was only a question of time and price. From 1948 onward he maintained and nurtured contracts with potential purchasers. IBM, Raytheon, NCR, Honeywell, and Burroughs were among those gently courted. In the end, it was none of these courtships that matured. Remington Rand simply approached Parker through a mutual acquaintance in the investment banking business in the fall of 1951, and serious discussions began immediately. On December 6, 1951, Parker announced to a surprised and somewhat dismayed group of ERA shareholder engineers that he had accepted an offer for the purchase of the company. Actual closing of the transaction was delayed until the spring of 1952 due to an inquiry by the Department of Justice and the Federal Trade Commission.

Parker recalls that the negotiation with James H. Rand, Jr., head of Remington Rand, was complicated by the lack of security clearance for any of the Remington Rand executives. This made it impossible to disclose to them the majority of ERA's computer projects beyond the 1101. The price paid was 73,000 common shares of Remington Rand worth about $1,5000,000 on the New York Stock Exchange. The final valuation of the business was arrived at by multiplying $5,000 by the 300 engineers employed; probably the only time since the Civil War that people have been "sold by the head" outside of the professional sports world. A multiple of 80 was realized by the original ERA investors in a little more than 5 years.

3.6. 1103/1105

Early in 1950, several months before Atlas was to be delivered, ERA was authorized to begin work on its successor, code named "Atlas II". Dr. A.A. Cohen was again in charge of logic design for this effort, designated Task 29, and under his supervision Atlas II was developed as a 36-bit machine with two-address logic, electrostatic storage, magnetic drum memory, magnetic tape, and an improved repertoire including the Repeat command. Atlas II is believed to be the first computer with a two-address instruction repertoire.

About one year prior to the delivery of Atlas II to the government, in the fall of 1952, ERA requested permission from the government to announce a commercial version of Atlas II. Approval was secured, and in November, 1952, a presentation was made to top management of Remington Rand about the existence within the company of a machine whose commercial designation was to be the ERA 1103. Because of the security classification of Atlas and the lack of clearance by top management, they had not been allowed to know of its development. Therefore they were astounded to learn of its existence to say nothing of the advanced state of development. Two Atlas II (1103) machines were authorized for commercial manufacture and parts for two more were authorized for purchase.

The 1103 was an immediate success. The initial four were sold in the first few months and eventually 20 were sold. The first one was delivered to the Bureau of Ships in October, 1953. Other early customers included Consolidated Vultee Aircraft (later Convair), Elgin Air Force Base, White Sands Proving Ground, Ramo–Wooldridge Corporation, and Westinghouse.

The 1103 produced other innovations in addition to the ones described above. It appears to be the first machine with interrupts. It also provided an external function code for the control of peripherals, and had hardwired floating point on the 1103A.

Six of the original 1103 machines were built with eight microsecond 1024 word electrostatic storage. Starting in 1955, four later versions of the 1103 were built with a 1024 word core storage in place of the electrostatic.

The 1103A was subsequently developed which had a larger core storage; up to 12K words in 4K modules. Predictions were wide–spread that no one could ever use 12K of main storage effectively. It also had wired floating point and a number of other improvements. Whereas the 1103 was limited to four Raytheon or Potter tape drives, the 1103A could accept up to 10 Uniservo tape drives, each with a transfer rate of 2130 words/second. This machine was also called the Univac Scientific, and its users formed the Univac Scientific Exchange Users Association, subsequently changed to USE. The first 1103A was delivered in September 1956, and early customers included Lockheed Aircraft, Boeing, Holloman Air Force Base (two), Ramo–Wooldridge, Johns Hopkins University, and Wright Air Development Center.

The original 1103 was a 36-bit parallel, binary, general purpose computer with a stored program. The "next instruction" address was incremented in a register rather than being held in an instruction as in earlier machines. Although these features seem routine now, they were quite innovative at the time. A pictorial view of the 1103 is shown in Figure 3-3.

Figure 3-3. 1103 System Configuration

The processor was constructed of 3907 vacuum tubes, with a clock time of two microseconds. It was water cooled and the system occupied 4000 sq.ft. The main storage was 1024 words of Williamson electrostatic CRT storage plus a 17 millisecond average access word-addressable drum with 16k words of storage.

Two operand address logic was used, with a 6-bit operation code and two 15-bit addresses. One's complement integer arithemetic was used. The arithmetic section contained two 36-bit registers and a 72-bit accumulator.

Basic peripheral equipment included a photoelectric seven level paper tape reader, a paper tape punch, and an on-line typewriter. Optional equipment included a 600 LPM Bull line printer, card reader and card punch. Up to four units of magnetic tape were also available with a fixed block size of 120 words with parity. All program development and most applications used paper tape input and output. Two I/O registers were provided - one 8-bits wide and one 36-bits wide.

The fastest instructions had an execution time of 16 microseconds, but most took 25-40 microseconds. The core storage unit provided for the later models of the 1103 had a maximum size of 1024 words, matching the size of the electrostatic storage, and had a cycle time of eight microseconds. The large core storage on the 1103A had the same speed.

The 1103A was program compatible with the 1103 except for the addresses of the two processor registers. The Program Interrupt was a new and innovative function which allowed execution of an application program until I/O needed attention. The interrupt transferred control to another program to service the I/O, and then could return control to the application program. This avoided making the processor wait while I/O was in process. This was important because each word transferred in I/O had to be loaded into the I/O register by the processor under program control.

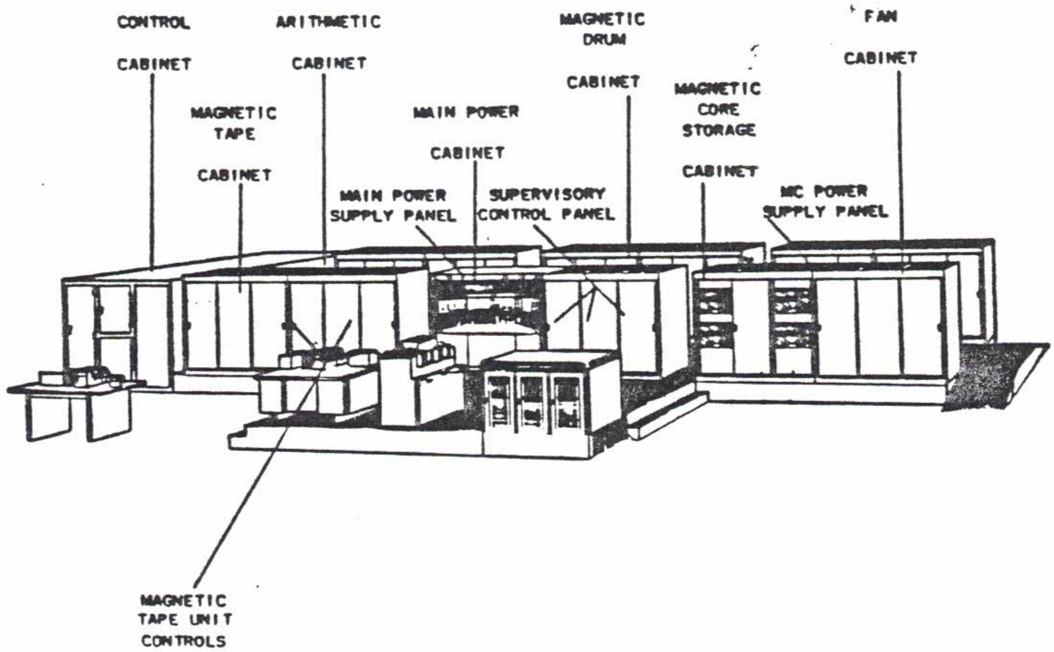


Figure 3-3
1103 System Configuration

The 1103A floating point format was the familiar 27-bit fractional normalized mantissa, 8-bit biased characteristic, and 1-bit sign. Floating point instructions included the four arithmetic functions, inner product and polynomial multiply.

The 1103/1103A were targeted at the scientific processing application. During the time of its introduction, it was recognized that a large number of business applications existed which were beyond the limited I/O capability of the 1103A. Consequently, the design of the 1105 was undertaken to significantly extend the I/O capability of the 1103A and to make use of the new peripherals (especially magnetic tape) that were being developed to meet the needs of business applications as well as scientific. The first delivery of an 1105 was in February, 1959.

The 1105 used the 1103 basic processor intact, with however the addition of a new console. A second 16K word drum was added to the system. The number of I/O registers was expanded from two to five. Two buffers were added for tape operation; each had a size of 120 words (one block) and double-buffering was the normal mode of operation. This allowed the processor to transfer an entire block of 120 words with the buffer using the repeat command and receive an interrupt only once per block instead of once per word. A tape controller was added to perform frame counts and parity checks so this would not have to be done by the processor under program control. Up to 24 of the Uniservo II tape drives could be attached, which provided bi-directional read/write, variable block length, at a transfer rate of 25,000 characters per second with a density of 208 frames per inch.

Early programming for the 1103 was done in absolute octal, punched onto seven level paper tape with a Flexowriter, and loaded with an absolute loader program. A great deal of the early software was developed with these very primitive tools. The first big improvement was the Regional Coder (RECO) assembler, a one-pass assembler which accepted mnemonics for the operation code and relative addresses for operands. RECO became available in 1954.

The next major improvement was the RAWOOP assembler, a two pass assembler that provided item numbers, allowed the use of labels, and performed storage allocation for symbolic addresses. This assembler was developed at Ramo-Wooldridge under contract to Remington Rand, and formed the basis for a later version supported by the USE organization which came into use in 1957. This assembler could include subroutines either from a library or which were externally compiled.

In approximately 1960 an algebraic compiler called UNICODE was developed. It had many similarities to FORTRAN, but never enjoyed wide-spread use and was subsequently dropped.

In addition to these efforts, each customer developed a local set of service programs to support operations. One set of service libraries which enjoyed wide-spread use was that of Wright-Patterson Air Force Base. Typical of the kinds of functions provided were the following:

- restore memory (from drum),
- memory insert and display,
- dump memory to flexowriter,
- paper tape memory dump,
- check sum,
- paper tape read,

- breakpoint display and stop,
- ferranti paper tape reader,
- binary loader,
- memory search,
- tape copy.

3.7. Univac File Computer

The Univac File Computer is a classical example of a machine architecture ahead of its time. As such, it was probably the first commercially successfully system to provide on-line time-shared interactive processing, a functionally-distributed control architecture, and associative addressing of data on a mass storage system. It also was perhaps the first commercial system to provide direct access to mass storage. However, because of its advanced nature, it also had somewhat more than its share of problems.

The File Computer started with the "John Plain Machine". The John Plain Mail Order Company of Chicago had identified a need for an on-line, interactive computer system for inventory control. The ERA engineering and marketing people were looking for applications for large drum technology, in which they were world leaders, and this seemed a natural application. A custom machine was designed, fabricated, and delivered to John Plain in about 1954.

It appeared that there might be a broad market for an extension of this machine, so Remington Rand management was approached with a proposal to develop a product based on the John Plain machine. A market survey was taken which indicated considerable interest in such a system, but also considerable skepticism because it was so far ahead of the competition. Based on the positive results of the market survey, approval was given for a product implementation.

Implementation of the (vacuum tube) product started in January 1955, along with a marketing effort. Many times, when a new customer was found for the system, that customer had an additional requirement beyond what the product provided. These additional requirements were often approved for incorporation into the product in order to get the order, so the system grew in complexity. At the same time, the technology was advancing rapidly with the advent of core storage and transistors.

The initial File Computer was delivered to Douglas Aircraft in Long Beach for inventory control on the DC-8 in September 1955 with plugboard programming only. The increasing complexity of the system plus the availability of core storage led to an early upgrade decision. The first version of the system was then designated Model 0, of which about 30 were built, and the upgraded version with internal programming in a core storage was called Model 1. The Model 1 was probably first shipped in 1957. Most of the Model 0 machines were late upgraded to Model 1 machines in the field. A system sketch is shown in Figure 3-4. Subsequently, a Model 2 system was defined that had a core storage unit in place of or in addition to the the drum. It appears that all of the Model 2 machines were field upgrades of existing machines to extend their application life, and there may not have been any new Model 2 systems built.

Figure 3–4.

3.7.1. Technical Characteristics

The Univac File Computer, Model 0, was a general purpose decimal character–serial three address digital computer. The basic unit of data was the alphanumeric character using the excess three binary code. The word length was 12 characters including one character for sign in numeric quantities. Characters were seven bits in length; six data bits and one parity bit. The machine incorporated extensive internal checking for error detection, including arithmetic and all transfers both internal and external to the processor. Another unique feature of the machine was the wide variety of peripherals supported.

The system, shown in Figure 3–5, included the following elements:

- processor,
- drum storage,
- unit record peripherals.

The processor was plug–board programmed by using patchcord wiring on a removable connection panel to define the sequence of instructions and operands. A total of 48 steps could be programmed, with a typical instruction requiring about 4–8 millisec. The Model 1 system could also be internally programmed via a core storage unit. The core storage unit was 20 words in length and had a cycle time of 900 microsec. The three addresses used included two operand addresses and one destination address, all on drum. When a stored program was used, three characters were used for the operation code and for each of the three addresses.

The storage system used magnetic drums; up to 10 on the Model 0 and up to 33 on the Model 1, with each drum holding 180,000 characters. The use of multiple drums on the same system was a first, and was made possible by the availability of diodes that could perform head switching at low voltage levels. Model 0 had fixed length records and a 34 millisec average access, while Model 1 had variable length records and 17 millisec average access time.

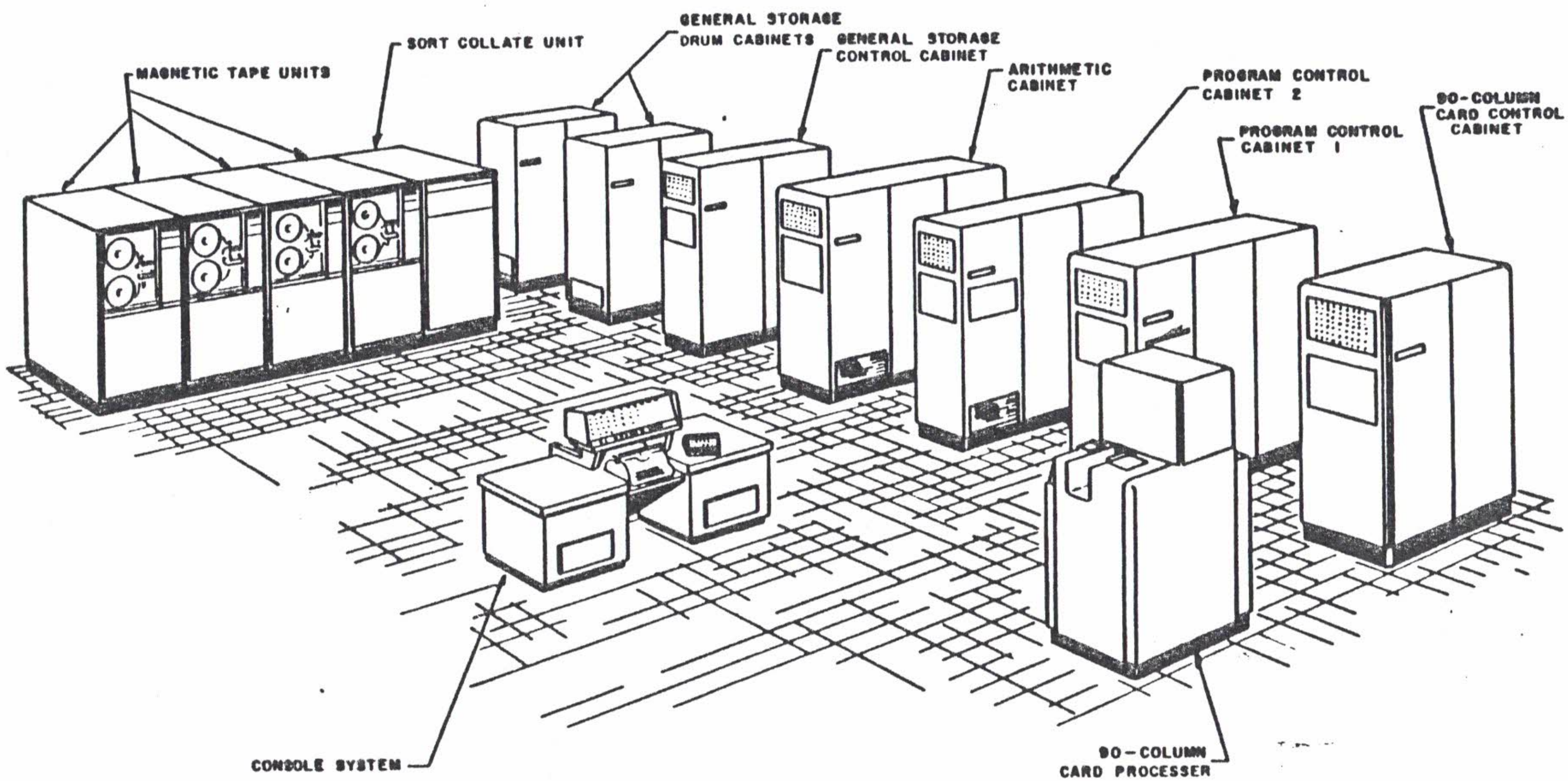


Figure 3-4
Typical Model 1 File Computer System

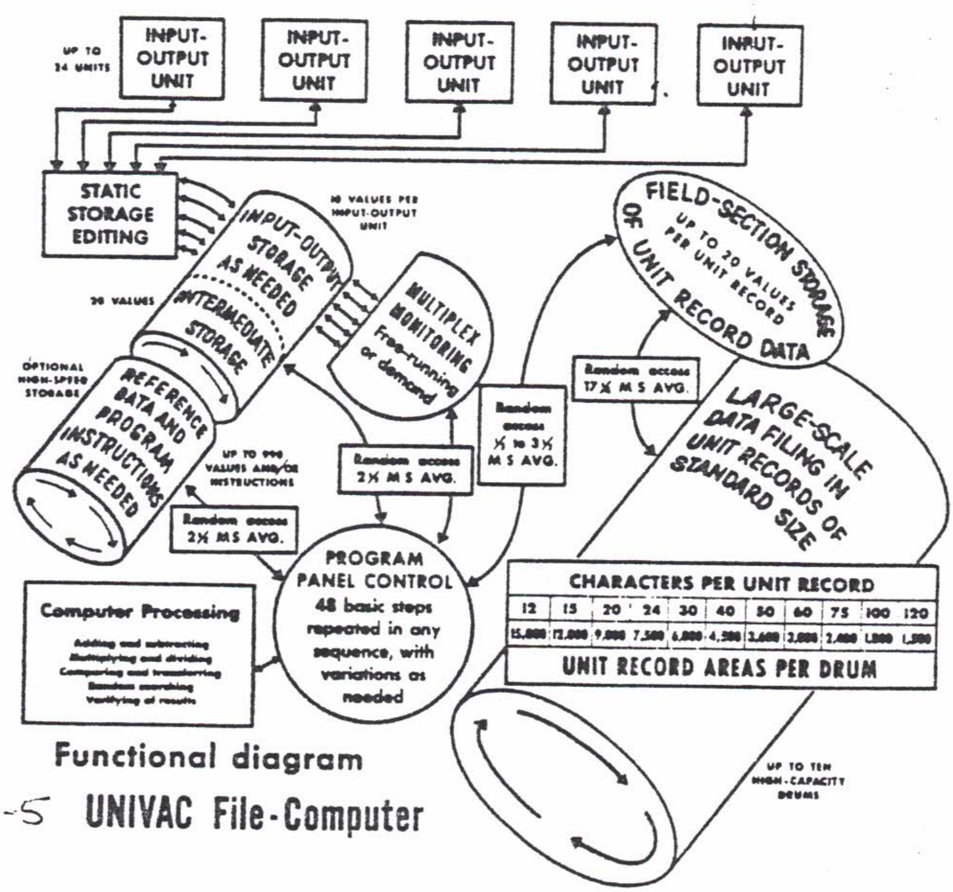
Figure 3-5. System Functional Diagram

When a unit record I/O device was cabled to the system, two drum tracks were dedicated to it with 120 characters each to provide double buffering. The I/O devices could communicate independently with the drum without processor involvement because of the intelligent control units employed. This was in contrast to contemporary machines which required the processor to execute I/O centrally; thus the File Computer may have been the first functionally distributed system. The Model 0 system could accomodate eight unit record I/O device and the Model 1 could accomodate 10. Unit record devices supported included card readers, card punches, magnetic tape, paper tape, and inquiry typewriters (early interactive consoles). The magnetic tape had a density of 139 frames per inch and a transfer rate of 10,000 characters per second.

Each unit record device control unit provided code translation and interfaced to the system in the standard excess-3 code. All unit record devices could operate simultaneously and autonomously without involving the processor to exchange information with the drum buffers. The unit record devices could be supported in any configuration.

The arithmetic section had four registers termed A, B, C, and D. The two operands were held in A and B, and the results were formed in C and D.

A function of special interest was the "channel search" capability. This allowed the searching of a file until equality was found with a desired key. This allowed the location of records by value instead of by address. New records to be inserted could be put anywhere in the file because of the referencing by value instead of position.



Functional diagram

Figure 3-5 **UNIVAC File-Computer**

In keeping with the distributed control business orientation of the File Computer, a sort–collate unit was provided. The sort–collate unit allowed the system to sort files on magnetic tape based on parameters supplied by the processor but without involving the processor.

These last two functions, location of data by value and local autonomous sort/merge capability, are now becoming of interest again in modern computer systems. This fact that they were provided in the File Computer in the middle 1950's indicates that they are not new ideas.

In physical size, the File Computer was no light weight. The computer system weighed approximately 19,430 pounds with a floor space need of 1800 square feet and required about 112 kilowatts of power. The air conditioner, with a capacity of 60 tons, took an additional 70 kilowatts. The rental of a basic system was about $15,300 per month with a purchase price of $500,000. The mean time between failure was usually a few days, with typical availability in the 94–98 percent range.

One last capability provided by the File Computer was airline passenger reservation capability. This allowed reservation clerks, through the use of special interactive terminals, to schedule flight space. The system was functionally identical with that used today as indicated in Figure 3–6, and could handle 10,000 transactions per hour.

In summary, the Univac File Computer contained many innovations, most of which were probably firsts in the industry considering its introduction in 1955. These included:

- interactive processing,
- functionally distributed control architecture,
- sort/merge autonomous subsystem,
- associative accessing of files,
- direct access mass storage file system,
- on–line passenger reservation system.

Approximately 188 File Computers were built of all three models through 1959. However, because of the rapid advance of technology, attention moved rapidly to solid state systems and the File Computer appears not to have received the recognition that it deserved.

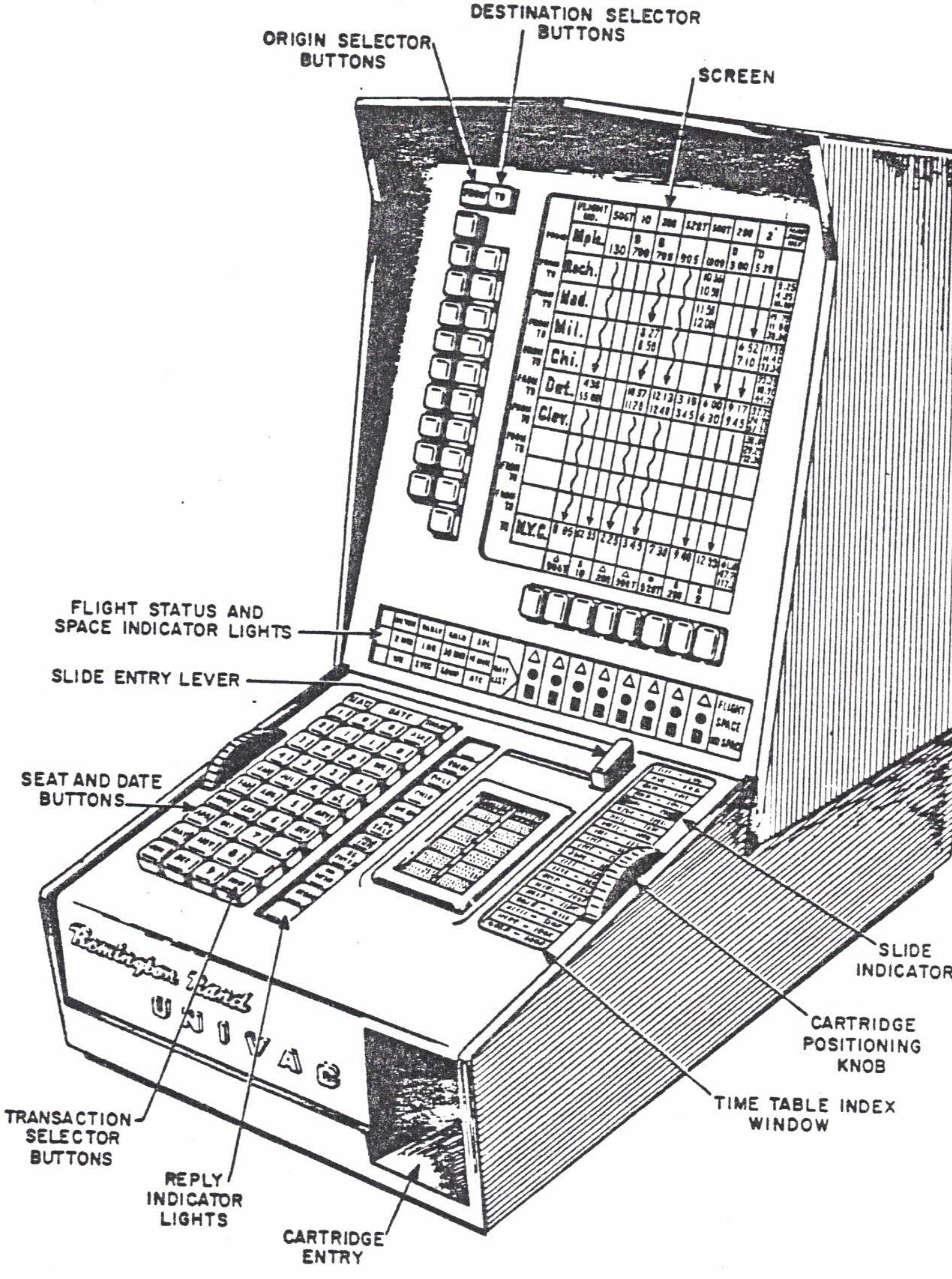
3.8. USE Formation

In December of 1955 the desire was expressed by several 1103A purchasers to form a cooperative organization of 1103A users. Accordingly, a meeting was held at the Ramo–Wooldridge Corporation on December 19 and 20 to form such an organization. Attending were representatives of Boeing Airplane Company, Holloman Air Force Base, Lockheed Missile Systems Division, Ramo–Woolridge Corporation and Remington Rand Univac Division.

The name USE – Univac Scientific Exchange – was selected for the organization. A number of objectives for the group were listed.

- exchange of programming techniques and ideas,
- exchange of programs and subroutines,

Figure 3–6. Airline Reservation System



File Computers

Figure 3-6 Univac Agent Set

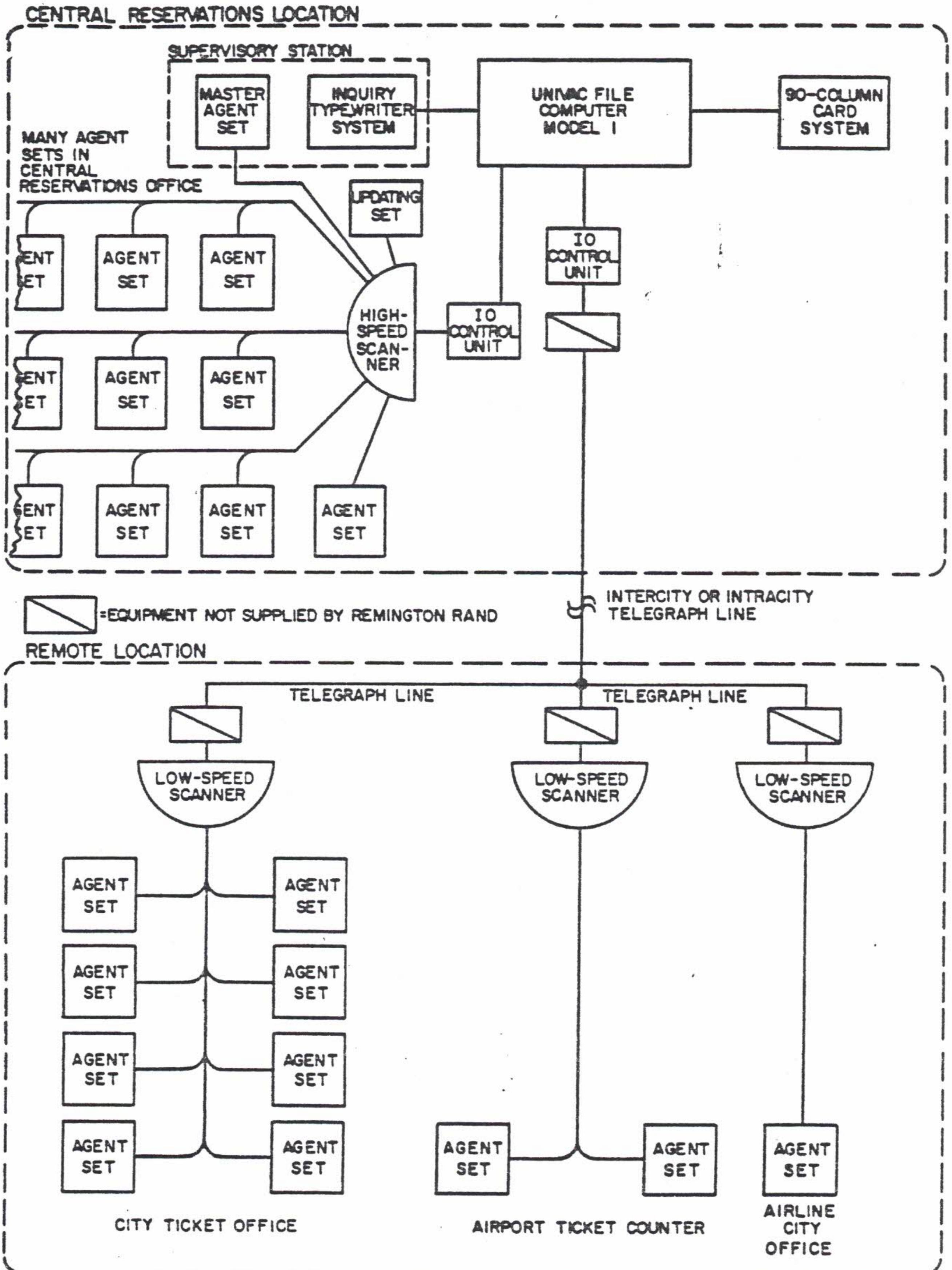


Figure 3-6 Typical Univac File Computer Airline Reservation System

- exchange of information on computing organizations, operating procedures, etc,
- adoption of a common programming language for exchanged programs,
- adoption of a standard format for program write-ups,
- adoption of standard subroutine conventions,
- setting up of a cooperative manpower effort,
- cooperation at the program planning stage,
- achievement of a uniform general purpose system for the operation of all 1103A's.

It was pointed out that Remington Rand was continuing the Central Exchange for 1103 and 1103A information. However, material in the Central Exchange was unsolicited and unedited. The philosophy had been to require no special language or format for Central Exchange material; this made it easy to contribute material and to distribute it quickly.

Membership in USE was open to any organization which was renting, had purchased or had a firm order for one or more Model 1103 computers. USE publications were made available to 1103 and 1103A users only. These publications were distributed to all 1103 and 1103A installations.

A structure of working committees was established. On January 9 and 10, 1956 the committees met as guests of the Boeing Airplane Company in Seattle, Washington.

Specifications for a common language for the exchange of library programs were discussed. It was emphasized that a particular installation would in no sense be bound to use this common language internally. The common language was designed to be sufficiently general to include most other languages. A minimum assembly program for translating common-language routines to octal programs was described. Specifications were also proposed for subroutine format and standard program write-ups.

Plans were made for immediate cooperation in achieving interchange of routines for the 1103A. Investigations of existing routines were initiated to determine the value of adapting such routines to the 1103A. In particular, common function routines from the Central Exchange and general matrix routines were to be surveyed. Assignments were made for the framing of specifications for minimum and ultimate data input and output routines.

Discussions of a common compiling routine were begun. The goals of such a compiler were listed as:

- translation: symbolic to octal,
- subroutine referencing,
- preparation for input and output formats,
- algebraic coding,
- storage assignment,
- automatic identification,

- scaling,

- automatic post-mortem and diagnosis.

Arrangements were made for meetings in St. Paul on February 16 and 17 as guests of Remington Rand Univac Division.

3.9. The Next Step

By the late 1950's, the 1103/1105 was becoming non-competitive. Transistorized computers were beginning to appear on the market, and a number of improvements in computer architecture had been developed. Numerous internal proposals were generated to modernize the 1103/1105 hardware (to transistors) and to upgrade the architecture by adding index registers and new instructions. The motivation for attempting to upgrade the 1103/1105 was to retain the large customer base of about 50 users that had been built. In the end, however, the decision was made to not remain compatible with the 1103/1105 architecture. The decision was made in favor of a new architecture, developed as a study and subsequent proposal to the Navy for a new scientific computer system. This new architecture was state-of-the-art in all respects and was heavily based on FORTRAN requirements. Although the Navy did not implement this system, it was developed for the commercial market and called the 1107, to continue the 1100 series name and image which had been so successful.

Certain aspects of the 1103/1105 system were carried over into the new machine, including the word length, number representation, six bit character representation, interrupts, and the repeat command.

3.10. The Merger

Remington Rand with its Norwalk, Eckert Mauchly and ERA operations now had in its employ a significant fraction of the total experienced computer engineering manpower in the U.S. But Remington Rand in 1952 was not a unified company; each of its three electronic units reported to different corporate departments, and no coordinating structure existed between these units.

In St. Paul, sound technological progress continued to be made. For example, transistors were not yet reliable, so in July 1954 ERA commenced work on a machine using only diodes and magnetic core logic. This project was given the code-name "Bogart" after the city editor of the New York Sun, John B. Bogart. Several of these workhorse ultra-reliable non-vacuum tube machines were delivered and they remained in service for years.

In Philadelphia, Eckert Mauchly was continuing its pioneering work on commercial systems. Univac was now a household word, having been used to predict the outcome of the Presidential election of 1952. In the beginning of 1953 John Parker moved to New York to head a newly established Electronic Computer Sales Department. Under his leadership, Remington Rand placed computers ahead of IBM at such places as General Electric, U.S. Steel, Westinghouse and Metropolitan Life. But it was a rental and service business; the more Parker succeeded, the more capital Remington Rand required.

By 1954, despite its head start, Remington Rand had started to lose ground against IBM. IBM announced its 702 and 705 against the Univac I and its 704 against the 1103. Remington Rand countered belatedly with Univac II and the 1103A. But by 1955, it was clear that Remington Rand had neither the management or the fiscal resources to maintain a position of market leadership. James Rand recognized the implications of Remington Rand's position and, as had John Parker before him, sought a stronger partner. On June 30, 1955, Sperry Gyroscope Co. and Remington Rand, Inc. merged to form the Sperry Rand Corporation.

Almost immediately Sperry assigned one of its senior executives to study its newly acquired electronic computer activities. By the fall of 1955 he had recommended the Eckert Mauchly, the Norwalk Laboratories, Engineering Research Associates, the Remington Rand tabulating machine business and the Electronic Computer Sales Department, be unified into a single electronic computer division. A few weeks later on October 1, 1955, William C. Norris, head of ERA in St. Paul, was appointed as the first general manager of a new consolidated Univac Division.

The unification brought together in one business entity the ingredients of engineering, manufacturing, marketing and finance and started Univac toward its present day success as a giant business with annual revenues of $2.0 billion and over 50,000 employees worldwide. This success came only after a difficult, sometimes traumatic, period of integration. During the integration period, in a process now recognized as quite normal for dynamic industries, a number of splinter groups left to form their own companies and some of these, in turn, spawned splinter companies. The first level of spin-off companies are shown in Figure 3-7, taken from [DRAHEIM66]. All companies are in the Twin Cities unless otherwise noted.

Figure 3-7. Spin-Off Companies of ERA

At this point, a short review of some of the important milestones should clarify the overall course of events. These are

Idea of ERA Conceived	Summer 1945
Incorporation of ERA	January 8,1946
First Navy Contract	June, 1946
Delivery of 1101 (Atlas)	December, 1950
Remington Rand purchase of ERA	December 6, 1951
Delivery of 1103 (Atlas II)	October, 1953