©Sperry Rand Military Computers, 1957-1975

Author - George Gray

Introduction

Although many of the computers of the 1940s were developed as military projects, the use of vacuum tubes made them too big and unreliable for incorporation into actual weapons systems. The Eckert-Mauchly Computer Corporation built the BINAC in 1949 for Northrop Aircraft, but no one seriously expected it to be put into an airplane. The massive SAGE (semi-automatic ground environment) system built by IBM during the 1950s for the North American air defense system was for command and control, not for missile guidance. When vacuum tubes were replaced by transistors, it became possible to have computers of smaller size and greater reliability. The transistor was invented at Bell Laboratories in 1948, but it took several years of development to become suitable for use in computers. Bell Labs built the first transistor computer, the TRADIC (Transistor Digital Computer), for the Air Force in 1954. It used 700 point-contact transistors and 10,000 germanium diodes. (A diode is an electronic device which allows current to flow in only one direction.) Both of the two major computer development groups (St. Paul and Philadelphia) at Sperry Rand became involved in early transistor computer projects. Philadelphia became embroiled in the long and costly LARC supercomputer project for the Atomic Energy Commission. St. Paul, building on its early work for the Navy, became heavily involved in military projects.

Athena

St. Paul made its first venture into transistors with the Athena ground guidance computer for the Air Force's Titan intercontinental ballistic missile (ICBM). A ground guidance computer, as the name indicates, stayed on the ground and transmitted instructions to the missile. The Athena's designers had a choice of technologies. During the early 1950s there was a period of time when the magnetic amplifier, which was eventually used in the UNIVAC Solid State computer, was a serious rival to the transistor. One of the first proposed designs of the Philadelphia division's LARC computer used amplifiers, but they were soon rejected as being too slow for a machine which had to be very fast. At St. Paul, the lead computer designer for the Athena project, Seymour Cray, directed the construction of two prototypes. The Magnetic Switch Test Computer (MAGTEC) used magnetic cores, while the Transistor Test Computer (TRANSTEC) used transistors. They had identical instruction sets. Two versions of the MAGTEC were built; both had magnetic core circuits on plug-in cards less than three inches square which were mounted on racks. There were two models of the TRANSTEC, which had transistor circuits on its plug-in cards. The TRANSTEC II had 4,096 24-bit words of memory. After thorough testing, Cray was satisfied that transistors were superior and would be reliable enough to meet the stringent requirements in the Athena contract.

The Athena computer had 256 words of 24-bit core memory to be used as a data work area and an 8192-word drum for the storage of the program and data items which did not change (constants). The Athena was completed in 1957. It occupied 370 square feet and weighed 21,000 pounds. Once in service, it was found to have a mean time to failure of 48 days, twenty times better than the original specifications. Since the late 1950s were the time of the perceived "missile gap" between the U.S. and the Soviet Union, the U.S. Air Force deployed the liquid fuel Titan as an interim measure pending the completion of the solid fuel Minuteman ICBM. St. Paul delivered 23 Athena computers to Air Force sites by the mid-1960s. In the late 1960s, the Air Force gave one of the original Athena computers to the electrical engineering department of Carnegie Mellon University.

It was used for various class projects and later donated to the Smithsonian Institution. Another Athena was given to the electrical engineering department of the California Polytechnic State University at San Luis Obispo.

Bogart

St. Paul's original customers, the nation's cryptologists at the National Security Agency, wanted machines more powerful and versatile than the Atlas I (UNIVAC 1101) and II (UNIVAC 1103) to process text and look for patterns, a task which they called data editing. This led to a secret project for the Bogart computer, a code name which supposedly referred to a then famous newspaper editor, John B. Bogart. At other times the computer was referred to as the X308. Once the computer was completed the secrecy was not so great as to preclude a presentation on it at a 1957 Association for Computing Machinery conference in Los Angeles. The design team was led by Seymour Cray. The processor logic circuits did not use transistors, but a combination of diodes and magnetic cores, so it can be viewed as a further development of the MAGTEC. The instruction word was made up of:

operation code	6 bits
index register indicator	3 bits
memory address	15 bits

The memory address was in turn composed of a 12-bit address followed by three bits which gave the capability of addressing any of the three 8-bit characters in the word (partial-word addressing). There were three arithmetic registers and seven index registers. The Bogart had 4096 words of 24-bit core memory, the maximum which could be addressed in 12 bits. The memory system was designed by Cray and Sidney Rubens of St. Paul in conjunction with Jacob Randmer of Norwalk and was manufactured at Norwalk. The Bogart's central processing unit weighed 3000 pounds and occupied 22 square feet of floor space, a considerable reduction in size and weight from comparable vacuum tube machines. The prototype Bogart was completed in September 1956 and tested for ten months. The four production models of the Bogart were delivered between July 1957 and January 1958. Later the NSA wanted another one, so the prototype model was given some finishing touches and delivered in December 1959. It was used in ROB ROY, an early NSA test of the remote job entry (RJE) concept. After he left Sperry Rand in late 1957, Cray used much of the logic design from the Bogart in his first computer at Control Data Corporation, the 1604, which was completed in January 1960.

Navy Tactical Data System

The use of transistors made it possible to build computers small enough for the U.S. Navy to consider using them on board ships to control radar and weapons systems. One of Cray's last designs at Sperry Rand before he left for Control Data in the summer of 1957 was a prototype shipboard computer for the Navy Tactical Data System (NTDS). Its naval designation was the AN/USQ-17, but Sperry Rand documents usually referred to it as the M-460. In the first version, the processor/memory unit was the shape and size of a bathtub, about four feet high, with a hinged lid which could be opened to give access to the circuitry inside. The computer had a word size of 30 bits which was believed to be the biggest size which could be reliably handled by the transistors of the time. Thirty bits allowed for five 6-bit alphanumeric characters per word. The processor had one 30-bit arithmetic (A) register, with a contiguous Q register to provide a total of 60 bits for the result of multiplication or the dividend in division. There were seven index (B) registers and 32,768 words of core memory.

The instruction format marked the beginning of an instruction set which would be carried onward, with many changes along the way, into later UNIVAC computers including the 1100/2200 series which is still in use today. The parts of the instruction were referred to by letter codes, as follows:

f	6 bits	function code
j	3 bits	jump condition designator
k	3 bits	partial word designator
b	3 bits	which index register to use
y	15 bits	operand address in memory

The jump condition designator (j) could cause the next instruction to be skipped depending on the value or sign of the A or Q register contents.

In the second version of the M-460, the packaging was redesigned so that the unit stood upright, like an old-fashioned double-door refrigerator, six feet tall. Shortly after the departure of Cray, the Navy told Sperry Rand that it was impressed with the potential of the AN/USQ-17 and awarded the company a $50 million contract to build several service test systems for actual shipboard installation.

This was a great opportunity, but Cray and the other engineers who understood the design were gone. Furthermore, the AN/USQ-17 was not totally reliable, and its cabinet design did not provide good accessibility for hardware maintenance. Something had to be done to provide a workable computer for the Navy in a very short time frame. At this point, Robert McDonald (who had joined the company in 1953 from Northwest Airlines) was the most senior person left at St. Paul after the exodus of engineers to Control Data, and he was promoted to general manager of St. Paul operations. McDonald decided to do a total redesign of the NTDS hardware, carrying over the machine instruction set, so that programs developed for the original machine would still run on the new one. He assembled a new team of designers, starting out with people from the Athena project, and held a three-day organizational meeting for some 40 to 50 managers at the George Hormel mansion in Austin, Minnesota, south of St. Paul. This was followed by months of intense work by a group of 150 people under the direction of Arnie Hendrickson to produce the new computer, which received the Navy designation AN/USQ-20. It turned out to be an extremely reliable machine; for the first batch of 17 computers delivered to the Navy starting in early 1961, the mean time between failure was 2,500 hours (104 days). The Navy was very pleased, and it became the basis for an entire family of shipboard computers produced over three decades. The NTDS shipboard system involved linking multiple computers together to work cooperatively. By 1965, the Navy had achieved "reliable, continuous operation of equipment and programs" in two and three computer groupings. A version of the AN/USQ-20 for use by other military services was designated the UNIVAC 1206. By 1963, 94 machines had been produced for the Navy and NASA missile ranges. Another version of the AN/USQ-20, designated the G-40, took the place of the vacuum tube 1104 in the Air Force BOMARC missile program.

Airborne and Missile Computers

The Athena was the first in a line of missile guidance computers produced by St. Paul. Work began in 1958 on the Target Intercept computer for the Army's Nike-Zeus interceptor missile, which was intended to shoot down both airplanes and missiles. The Target Intercept retained the Athena's 24-bit word size, however an entirely new instruction set was developed where the length of an instruction increased from 17 bits to 24. Now that core memory was widely used, the Target Intercept did not have drum memory. There were 10,240 words of read-only memory for program and constants and 2,048 words of read/write memory for variable data storage. The Target Intercept had five magnetic tape drives, occupied 70 square feet, and weighed 5,200 pounds. The design was revised in 1961 to provide more memory (57,344 words of memory in five modules: program, operand, variable, constant, and buffer memory) and the name was changed to GPDC, General Purpose Digital Computer. Ten Target Intercept and GPDC computers were delivered to the Nike Zeus program.

St. Paul went on to develop computers descended from the Athena which were small enough to fit in airplanes. The UNIVAC 1000 and 1020 employed thin film magnetic memory, a technology which Sperry Rand had developed through government funded research. A thin film (4 millionths of an inch thick) of iron-nickel alloy was deposited on small glass plates. This provided very fast access times in the range of 0.67 microseconds, but was very expensive to produce. The UNIVAC 1107, intended for the civilian marketplace, used thin film memory only for its 128-word general register stack. Military computers, where money was less of a concern, used larger amounts of thin film memory. The processor and memory unit of the UNIVAC 1000, sometimes referred to as the ADD 1000 (ADD = airborne digital development), had 6,656 24-bit words of read-only memory for program storage and 256 words of read/write memory for variable data storage. It was very compact, occupying 1.1 cubic feet and weighing just 88 pounds. The UNIVAC 1020 was delivered to the U.S. Navy in 1963 for use in anti-submarine aircraft. It had 13,312 words of program memory and 1,024 of read/write memory.

Once the Minuteman missile was ready for use by the Air Force, the Titan was no longer needed for military purposes, but the improved Titan III was used as a vehicle for launching scientific payloads. The Titan III used the UNIVAC 1824 computer to control launch and booster separation. The 1824 maintained the separation of program from variable data memory and kept the 24-bit data word size of the Athena, but was a completely new design in every other respect. In a departure from most of St. Paul's previous designs, it used twos-complement arithmetic. The 1824 continued the use of thin film memory. The instructions were 16 bits long, comprising a 5-bit operation code, a 2-bit index register designator, a one-bit field to indicate whether the extension (base) register was to be used, and an 8-bit memory address. There were three index registers, 12,288 words of program and constant memory, and 512 words of variable data memory. The 1824 project encountered many difficulties and ran way over the original estimates for time and cost of development. The first computer was finally delivered in 1968.

The Nike Zeus missile did its first intercept over the Pacific Ocean in July 1962, but the system

could not discriminate between real warheads and decoys. To do that would require major enhancements in radar, communications, and computing. In 1963 the Army was authorized to develop the Nike-X anti-ballistic missile (ABM) system, which would incorporate improved radar and two types of interceptor missiles. St. Paul received a contract from Bell Telephone Laboratories to provide a computer for the guidance and control system of the Nike-X project.
The Central Logic and Control (CLC) module was composed of multiple processors, two memory units, and two input/output controllers (IOCs). The CLC used twos-complement arithmetic and a 32-bit word. The memory units were for program storage (up to 126,000 words) and data storage (up to 262,000 words). The CLC was completed in 1965 and machines were delivered to the White Sands Missile Range in New Mexico, Bell Telephone Laboratories, and Kwajalein Atoll in the Pacific Ocean test range. The first missile firings were in November 1965, and the ABM program, later renamed Sentinel and then Safeguard, continued until 1975. At that time it was terminated because of the enormous cost of its radar and communications components. It was estimated that deployment at just six sites would have cost $40 billion.

Multiprocessor Computers

The multiprocessor design of the CLC was adapted for use in St. Paul's UNIVAC 1108 for the commercial market and into the NTDS line of computers for the Navy. The AN/UYK-8 used the 30-bit word and the instruction set of the original NTDS computer, but could have two processors instead of just one. The memory was increased up to 262,144 words. In December 1967, St. Paul began development of the AN/UYK-7, a much bigger multiprocessor computer which could have three instruction processors, four input/output controllers, and 16 memory modules totaling 262,144 words. The word size, however, was 32 bits, not 30. The instruction set was a mixture of 16 and 32 bit instructions. The AN/UYK-7 was used in the Navy's Aegis shipboard fire control system. A typical shipboard installation utilized eight systems linked together. An airborne version of the AN/UYK-7 called the UNIVAC 1832 was installed in a Navy antisubmarine aircraft (S3A.built by Lockheed). It was also multiprocessor, but had only 65,000 words of memory.

Sperry and Burroughs merged in 1986 to form Unisys Corporation. While the company was still struggling to get used to the merger, it was hit hard by the recession of 1990. During 1991, many Wall Street analysts expected Unisys to become bankrupt. As part of its restructuring, Unisys put its defense systems units into a subsidiary named Paramax Systems Corporation and offered it for sale. There were no attractive offers at first, and Paramax continued to contribute about 20 percent of corporate revenue. However, after the end of the Cold War, the long-term prospects for the defense business were judged to be unfavorable, and Paramax was sold to Loral Corporation in May 1995 for $862 million. Subsequently, Lockheed Martin took over the ownership.