Univac Computers I Have Known

BY: GEORGE CHAMPINE, PH. D

I joined Univac directly out of college in the spring of 1956. I stayed for 22 years, leaving in December 1979. It was a wonderful experience and I have always been grateful for the many opportunities that they provided to me. The following is a summary of my early work at Univac in the Defense Systems Division. I transferred to the Commercial Division in 1970.

I started at Univac on March 19, 1956 with badge number 4472. I had gotten married three days earlier and my wife Barbara says I married her at the same time that I married Univac. My office was in a warehouse complex that Univac had rented in the St. Paul midway district on the southwest corner of University and Prior, a few blocks away from the Prior and Minnehaha Avenue glider factory. My job was to do numerical analysis and programming for Project 2052—the world's first airborne computer. I worked part time during spring quarter and then continued full time in the summer.

Project 2052—First Airborne Computer

The project was called 'Project 2052' for reasons that I don't remember. It could be because the project was started in 1952. The project was to build an airborne digital computer that would accept signals from the aircraft radar to get the location, speed, and direction of the target, and then point the tail gun on the airplane, which was a B-24. Because of weight and power restrictions, the computer used a special architecture that was a Digital Differential Analyzer, which computed the change in values rather than the entire value itself. The computer had a small drum storage device and a 64 word core memory of one bit per word. It had a serial arithmetic unit. As I recall the computer was about one cubic foot and was operational in the summer of 1956. The project manager was Rusty Hoover, and the lead programmer was Gordon Uber. The mathematicians that developed the equations that related radar inputs to gun pointing angles were Jim Young and Tom McSherry, both of whom went to CDC in 1957 when it was formed.

The design of the computer was done mostly by Seymour Cray, who was a quiet, soft-spoken engineer/mathematician who stayed mostly in his office and developed the specifications. Cray had left the project before I joined the project, but I met him several times. Later he became the most famous designer of large computers in the world. He had been born nine years before me. In 1957 he and eight others left with Bill Norris to found the Control Data Corporation (CDC). There he designed the CDC 6400, which was the fastest and most innovative computer in the world when it was first delivered in 1964. He continued to design the world's fastest computers at CDC and later at Cray Research which he founded in 1972. He died tragically in a car accident on 5 October, 1996.

Most of our design and software development work was done on the Univac 1103 computer Serial 7 [the second generation after the 1101] housed in the old glider factory on Minnehaha Avenue. This machine was unique in that it was the first 1103 with a core memory in place of an electrostatic memory. Later it was called the Univac Scientific when it got hardware floating point. It was an immense vacuum tube super computer that occupied a room of 1000 square feet. It was one of the largest computers in the world of its time. It had a main memory of 1024 36-bit words, and a drum memory of 16,000 36-bit words with paper tape input and output. The architecture was two address and ones complement. To print the output we had to run the paper tape through a Flexowriter, which had a paper tape reader and typewriter output. The memory drum was about 24 inches in diameter and about four feet long. The computer weighed 17 tons and required 45,000 watts of power. It could carry out 50,000 operations per second (such as an addition**).** In spite of its limited power by modern standards we did a great deal of very useful engineering work and software development on the machine. I was responsible for running many of the design programs on the 1103, and the feeling of power was awesome.

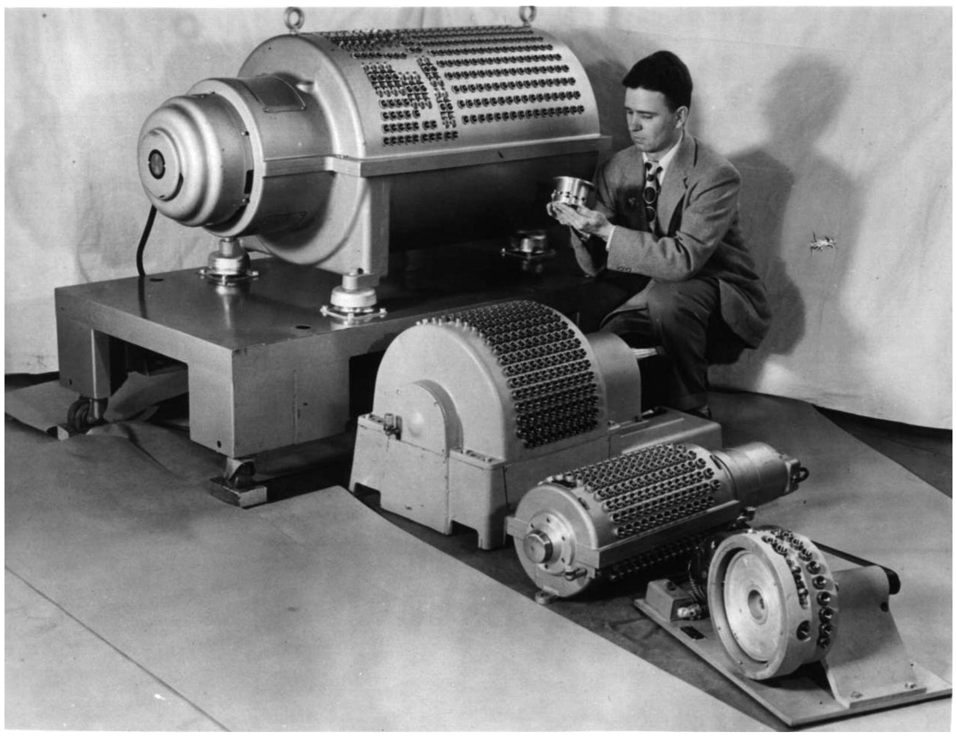
There was a simulator of the 2052 machine on the 1103. We wrote our programs in octal so there was no need for an assembler.

I spent the spring learning how to program the 1103, and in doing numerical analysis in the design of algorithms for pointing the guns based on radar input. At that time there were probably fewer than 2000 programmers in the world. During the noon hour, most of the engineers brought their lunches and played Hearts during the noon break. I quickly learned to play Hearts and joined in with them. The offices were not air conditioned, and the heat got almost unbearable in the summer. To cool off and avoid going to sleep, I would walk out on the back loading platform and look at the railroad tracks.

Editor's Note:

Magnetic Drum Memory was invented at Engineering Research Associates, one of the UNIVAC predecessors. Drum Memories were the world's first hard drives!

This photo from the Charles Babbage Institute at the University of Minnesota shows several of the early UNIVAC drum memories. Don Weidenbach is holding a mini-drum such as would have been used in the 2052 airborne computer. By his right shoulder is the 1103 computer drum memory.



Because Barbara and I had just gotten married, money was in short supply. To save the 10 cents streetcar fare, I rode my bike back and forth from the office to our apartment near campus - a distance of about four miles. We saved as much money as we could, and we were able to pay the loans back in a couple of months.

The mathematicians in the department had developed some equations that they thought would work. However, they involved very complex calculations that needed to be analyzed. Much of the work I did was to approximate transcendental functions [sine and cosines] using polynomial power function approximations. I used a mechanical desk calculator for many days doing the calculations. It was a very advanced motorized, Marchant calculator with a multiply-add function, but it still required several seconds to do a multiply and it was quite noisy. Then, during the summer I did most of the programming for the system and was well along in testing the program by the time collage started in the fall.

After much thought, I decided to return to the University in the fall and get my master's degree in physics. On my last day of work, Bob Patterson, head of personnel for Engineering Research Associates [by then the Defense Systems Division of the Univac division of Remington Rand] told me to be sure to come back the following year because they would have a job for me. Subsequent to my leaving the project, the computer and my software were installed in a B-24 and flown successfully that fall somewhere in Texas. I learned many years later that it was the world's first airborne computer. I wish that I had known it at the time.

I returned to college in the fall to continue working on a Master's degree in physics during 1956-1958. As part of getting the degree, I took the qualifying exam for a Ph.D. in physics. I passed the exam and was invited to continue on for a Ph.D. Through my work at Univac I knew that I wanted to go into computers and not physics, so I declined. I supported Barbara and myself by working as a research assistant at a salary of $300 per month. It was just barely enough to get by on. Our expenses were about $400 per month including $60 per month for rent, but we had saved enough during the summer to get by for the school year.

In the summer of 1957 I needed a summer job. When I had left Univac the previous year to return to school, they had promised me a summer job for the following year. When I went in to discuss it in early 1957, they told me that the company had fallen on hard times and they were not hiring. I later also learned that Bill Norris, head of the Univac division, had just left and taken many of the top people with him, leaving things in a general uproar. If I had not gone to school I probably would have followed the others to Control Data and my life would have been very different.

Since there was nothing for me at Univac, I interviewed at a number of companies and was offered a research assistant position at the Honeywell Research Center in Hopkins. Honeywell was one of the more important companies in town, with a large heating controls business and a large instrumentation business with the military.

One of the courses that I took at the University was programming from a professor named Marvin Stein. He had worked in computers in industry and had recently joined the faculty at the university. There was no computer science department at that time but Stein offered a course in programming. He had acquired a Univac 1103 serial number 4 from [I believe] Lockheed, the same type of machine that I had used when I worked at Univac in the summer of 1956. Only nine other colleges in the country had computers. We had to write the programs in binary, as there was no assembler. I am not sure that assemblers had been invented yet; I am sure that compilers had not been invented. The first program I wrote was a class assignment to do a matrix inversion. We were each given an assigned slot of time on the machine to get the program working. Input and output were on punched paper tape. There was considerable tension because time on the machine was very precious. The time for me to get on the machine came and I loaded my program. I pushed the buttons on the console to load the [binary] starting address into the program address counter, then pushed the start button. I watched the "stop" light to see when it would go out indicating that the machine was running my problem. The light never went out so I assumed that the machine had failed to run the program. I pushed the button several more times, but the stoplight never went out. I called up some of the registers on the console and found that the program had run each time but it was over so quickly that the stoplight never had a chance to go out. This was a graphic demonstration of the power of the computer. Later, Marvin Stein also taught my children, Mark and Lisa, how to program.

When I finished the coursework for my master's degree in physics in the spring of 1958, I looked around to see what jobs were available. I found that not much was to be had because the country was in a major recession. The opportunities were a teaching job in physics at Rolla Missouri, a job in computers at Convair Aircraft at Pomona California, or Univac.

Nike Zeus

Once again, [now the spring of 1958] Univac was hiring. I was interviewed by Bob Patterson and others to work on a new computer controlled air traffic control system for the Department of Defense, and was offered a job in this department at $5000 per year. Convair had offered me $6000 so I asked Univac if they could go a little higher. They came back with an offer of $5500. I decided that I wanted to stay in the area so I accepted. I started full time at Univac in the Defense Systems Division in late June 1958, and continued the work on my master's thesis part time.

I had originally been scheduled to work on a large Navy computer project for Univac called the Naval Tactical Data System (NTDS), which was one of the largest projects that the company had. However, before I started work, the company won the contract to build a state-of-the-art computer for the Nike Zeus anti-ballistic missile defense system for Bell Telephone Labs. Because they needed people badly on this new contract, I was transferred to this new department before I started work. My job was to help design the computers and software for the missile guidance and radar systems. Although I did not realize it initially, it was a wonderful assignment, allowing me to not only learn about computers, but to also work on state-of-the-art technology and travel all over America.

I found that the former president, Bill Norris, had left the previous year [1957] and had founded Control Data Corporation with Seymour Cray. If I had not gone back to school I probably would have gone with them because many of my friends had done that.

My office was in the Univac building on West Seventh Street in St. Paul. The building is on the bank of the Mississippi River near Ft. Snelling, overlooking the spectacular gorge of the Mississippi River. An early [or perhaps the first] manager of the project was Sid Green. He was followed by Leon Findley and later by Ernie Mutchler. Don Weidenbach and Ward Lund were in charge of hardware design. The overall manager of the software was Earl Joseph, and Leo Kennedy worked for him. My first boss was Leo Kennedy, and the first person that he introduced me to was Les Cochran, with whom I would work for the next 22 years and who, with his wife Monna, would be our life-long friends.

The Nike Zeus Project

The purpose of the Nike Zeus project was to provide defense against Intercontinental Ballistic missiles (ICBMs).There had been earlier versions of the Nike system such as Nike Ajax which were designed to provide defense against bombers and short range missiles. However, Nike Zeus represented a very large increase in capability in every dimension.

In operation, the system accepted radar inputs from an acquisition radar, which could search and acquire ICBM targets at long range. The targets from the acquisition radar thought to be threats were passed off to the target tracking radar, which had shorter range but much higher accuracy. The first computer developed on the project was called the 'Target Intercept Computer', or TIC. The data from the target tracking radar was sent to the TIC computer which could establish tracks on the objects of interest. If a decision were made to launch a defensive interceptor missile, that missile was tracked by the missile tracking radar and the data was also sent to the TIC. The TIC would then process the radar data and guide the missile to an interception and detonate the warhead at the point of closest approach.

Because the Nike program was secret, the project had extensive security. All of us on the project had government secret clearance. The entrance to the work area was locked with a buzzer for access requests and with a guard who checked everyone who entered. All files had to be locked up when we left the area; we were forbidden to talk to anyone about what we were doing, including our families.

Looking back, I cannot believe the audacity that we had. In the first few weeks of the project we were all called into a meeting with Gerry Probst, Vice President of Engineering. We were told that our task was to develop a state-of-the-art computer system, including a totally new computer, totally new software, and the world's first ground-controlled digital guidance system that would guide one missile to shoot down another flying at 17,000 miles per hour. Many or most of the programmers were new graduates that did not know what a computer was. Amazingly, five years later we had a successful test at Kwajalein atoll in the South Pacific.

As part of the project we had to develop the world's first all-digital missile guidance system under contract to Bell Telephone Labs, who had the prime contract for the entire anti-ballistic missile system from the Department of Defense. They had many other contractors to do the missile, radars, communications, etc. Univac had the job of developing the missile guidance computer and software.

Later it was realized that the offensive systems could overwhelm the defensive system with decoy ICBMs. Thus, a second radar - called the Discrimination Radar - was added to the system, whose task was to identify real targets from decoys.

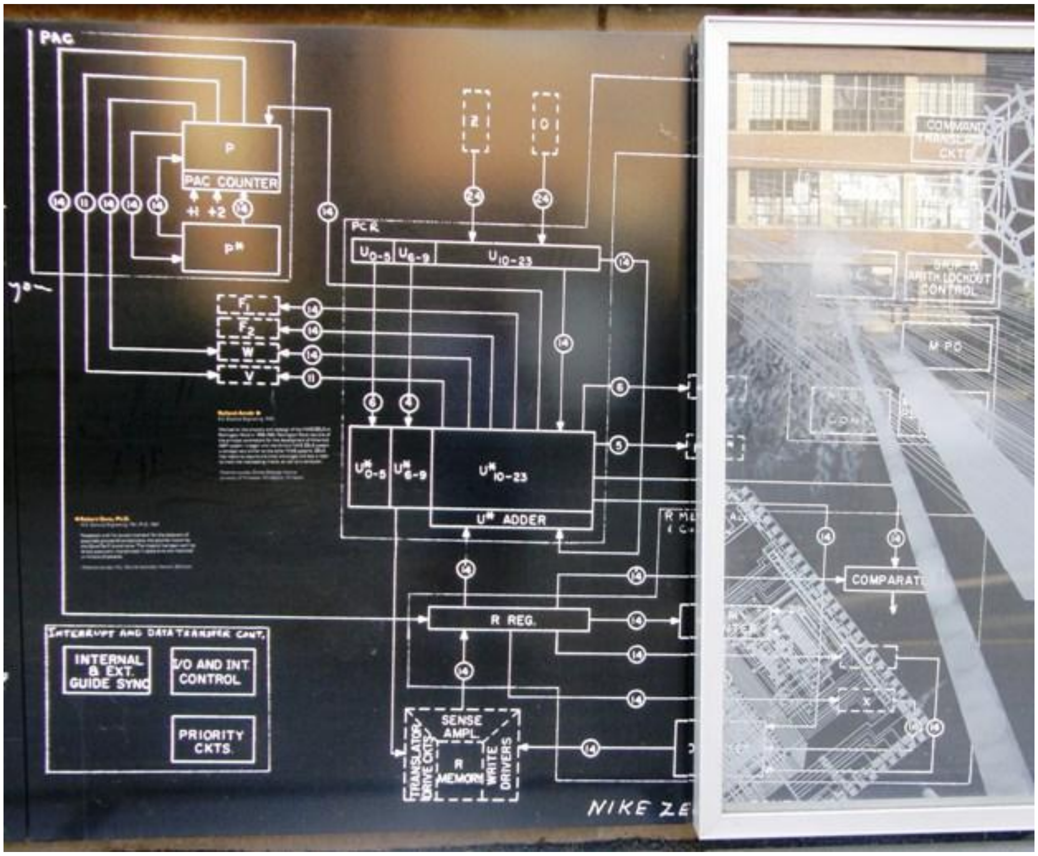
The Nike-Zeus Computer Hardware

The TIC was a transistor machine, 24-bit, single address computer with seven index registers, and two's compliment fractional arithmetic so that there was a unique representation of zero. Most instructions took five microseconds. It had a read-only program memory of [I believe] 16,000 words. The program memory used an element called the "twister". The program memory could not be changed under program control to make sure that it could not be changed in operation. The twister memory elements were mounted on a card about the size of a punched card. The only way to change the program memory was to insert the twister card into a special memory writer, and manually enter the data. This made program changes for debugging very slow and cumbersome.

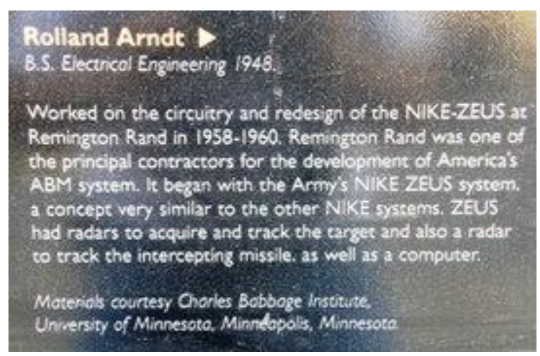
The TIC had a 1024 word memory for variables using convention core memory elements. The computer was the size of several large refrigerators and had the compute power of a modern hand calculator. There was no disk memory but there were tape drives for recording flight instrumentation data. Les Cochran also worked for Leo Kennedy. His first assignment from Leo was to write the arithmetic algorithms for the Nike Zeus computer and then to write proofs that they would work for all cases, especially around zero and for min and max values. Nothing was in the literature for two's complement arithmetic at that time. The software for the TIC involved a large number of multiply operations because of the use of polynomials to approximate transcendental functions. To achieve the needed speed in the TIC computer Les was involved in cutting the multiply time in half by multiplying two bits at a time. Jim Nelson and he received a patent on this. They should have expanded the patent to N bits at a time, but they didn't think anyone would ever implement that. The hardware in the arithmetic unit was as big as all the rest of the hardware in the computer at that time.

Editor's Note:

The University of Minnesota has a 3 ½ block-long Scholar's Walk extending from the Alumni Center to the Northrup Mall. The walk passes by the Computer Science and Engineering(CSE) building, Keller Hall. On the CSE north wall are several scientific illustrations, 'The Wall of Discovery'.



Nike-Zeus is memorialized on the Wall of Discovery with this 'TIC' logic design block diagram. This drawing came from the boxes donated to the Charles Babbage Institute by Rollie Arndt, one of the Nike-Zeus hardware design engineers.



I was unique in that I was one of the few that knew how to program. Along with the other new employees, I was given a self-study course in how to program that was supposed to take two weeks to complete. Because I knew how to program I completed the course in a few days and announced to my boss Leo Kennedy that I was ready to work. Because the missile guidance equations were not yet ready from Bell Labs, I was asked to do some scientific programming to simulate the new computer memory element that was being developed. In the course of doing that, I had to learn about numerical analysis in general and numerical integration in particular. For fun, I developed a software library to create graphical output on the only output printing device that we had, a 132 character/line high-speed printer.

The Development System

There was no compiler for the machine, and everything was written in octal with an assembler. The assembler was written by Bob Remund, who did a great job. The machine had not been designed to develop software on because of its read-only program memory, so we developed the software on a simulator using the Univac 1103 computer. The simulator, written by Bill Wallace, was of course very slow. In order to develop software, we wrote the programs in assembly code and then ran the assembler on the simulator.

The time to assemble the program was about 17 hours, and then running a flight simulation with the guidance program took about 20 hours. Needless to say we did not assemble the program very often, and instead used binary patches to fix the bugs. We had a lot of trouble maintaining up-to-date source code that tracked the binary patches. We did all of our debugging by looking at octal dumps of the program when it would crash. This was very slow, and only someone who knew the system very well could interpret the octal dumps to find the problem. Moreover, the guidance program was very complex with many feedback loops, so that everything affected everything else. Later, Sonja Tollefson joined the project as a mathematician to work on numerical analysis, mainly to approximate transcendental functions with polynomials with a minimum maximum error.

The Missile Guidance Software

The missile guidance equations were developed at Bell Telephone Labs by Nick Sharko and others. They started with the physics of situation, developed equations describing the physics, and then tested the equations in FORTRAN at Bell Labs. When the FORTRAN version of the equations worked properly [achieved interception], a specification based on them was written and sent to us in St. Paul as requirements for the TIC software. We divided the overall guidance software into two major parts. The first part was the Executive Control and Guidance Input Output (ECGIO). This software controlled the real time data inputs and outputs to and from the radar and missile, and the general sequencing of the guidance software. This software was not well-specified by Bell Labs as it did not involve the physics of the situation. The other parts of the software were the implementation of the guidance equations. Arleen Pontinen and Angeline Hansen were heavily involved in the specification and implementation of the ECGIO software. The team implementing the guidance equations was much larger, and included Les Cochran, Rita Lukas, and me. Bob Nystrom was also involved and later handled much of the data reduction software.

Going to White Sands

Starting in the spring of 1960, we had our missile guidance system ready for testing. The tests were to be carried out at White Sands Missile Range in New Mexico, 80 miles north of El Paso, TX. My first trip was on August 24, 1960, and I was very excited about it - not only to have a chance to fly, but to see El Paso and the missile range for the first time. At that time the Minneapolis airport was called “Wold Chamberlain Field” and the airport terminal was just a large warehouse-like building. There was no security or jet ways. I believe that the old buildings are still there on the west side of the current ‘Minneapolis St. Paul International Airport’.

When the flight was called, we walked out on the runway and climbed the stairs into the plane. On the positive side, they served shrimp cocktail and champagne on the flight. We usually flew to Dallas, and changed planes to get to El Paso. Traveling to El Paso was a great experience. I had never seen the desert or the high mountains, and I had never experience a foreign culture [Mexican]. El Paso was a desert army town surrounded by mountains and heavily influenced by the Mexican culture. In addition to the hardware people, there were perhaps ten of us who were responsible for installing the software and getting it to run correctly. We drove out to the missile range every day from El Paso, a distance of 70 miles each way. We would run tests on the guidance software, and install corrections as needed. They were debugging the very complex missile system at the same time. We participated in quite a number of missile firings. Many of the early ones failed during boost phase, before our guidance system had to be used. Later, the missile was fixed and our system was used extensively for missile guidance. I was to travel to El Paso many times over the next two years.

We had just barely gotten the guidance program to work using the simulator for our first trip to White Sands Missile Range. Program changes were very slow and difficult because they had to be made by hand with a special memory card writer, four six-bit bytes at a time. We took the program to White Sands the first time and tried it out. It did not work even though it worked with the simulator. Because there were no debugging tools it was almost impossible to find out what was happening. After working for a few days we found out that the computer hardware was giving the wrong answer on multiply instructions for certain kinds of numbers. After that was fixed in a couple of days, we started to get good results and started to integrate our system with the radars and missile range timing system. It was all very difficult because the program in the read only memory was never meant to be changed, and yet there was a constant need to change it. We found that there were all kinds of errors in the specification that we were working to, yet the pressure to get the system working was tremendous. Looking back I am amazed that we actually got it to work, but we did.

On the first several trips, the missile developer had a lot of trouble with the missile and we could not test our guidance system. During the firing they had us watch from a bunker at a considerable distance. The missile was very large, however, and it was a spectacular sight when it would take off and then explode a few seconds later. This continued for about a year, and I made periodic trips to El Paso during 1960 and 1961 usually staying for two weeks at a time.

After spending a day at the missile range debugging the guidance software, we would return to El Paso at night, all have dinner together, then see the sights. One night, I got out a map, screwed up my courage, and drove alone to the border with Juarez, Mexico. I parked the car and walked across the border into Mexico, not knowing what I might find. It was a wide-open town where everything was available. Liquor, leather goods, stone goods, food, and other Mexican products were all very cheap. Stores did not have fixed prices; instead, everything was bargained for. Of course the culture was completely foreign to me. It was great fun just watching the people and going in the shops. I brought back a lot of Mexican products to the people in Minnesota, especially leather purses and stones products. In those days they weighed the luggage and charged extra for overweight. On one trip I had a lot of stone products and know I would be substantially overweight in my luggage. Since they did not weigh me, I stuffed all of the stone into my pockets until I got on the airplane and could put it back into the suitcases. Later, several of would go to Juarez to eat supper because the restaurants there were very cheap. We got sick only a few times.

In later months I had to travel to White Sands alone and would generally stay two weeks. To entertain myself on weekends I would often go exploring. One place that interested me was Mt. Christo Rey. The one point where Texas, New Mexico, and [Old] Mexico come together is on a very small mountaintop called Mt. Christo Rey on the west edge of El Paso. Early one Sunday morning I climbed the mountain to see the cross on the top. I was the only non-Mexican person there among the people climbing the mountain. The cross was a Catholic shrine and was covered with ceramic plaques giving the names of people who had contributed money to building the cross.

Later I started staying on the missile base. The contractor professional people such as ourselves were treated as officers and given officer's privileges. We were allowed to eat at the Officer's Club and were allowed to stay at the Bachelor Officers Quarters (BOQ). To avoid the 70-mile drive each way I started staying at the BOQ during the week, and going into El Paso only on weekends to break the monotony. There were some very tall and beautiful mountains called the Organ Mountains behind the BOQ. They looked very close. One weekend I stayed on base and decided to climb one of the mountains. Instead of being able to walk to the mountain in a few minutes as I had thought, it took more than an hour. The mountain looked close because it was so big, but it was not that close. I finally got to the mountain and started climbing. The scenery was beautiful. After another hour or so I met two kids who lived on the base and who were also climbing the mountain. We climbed together for a while, but then got separated and I never saw them again. At one point I climbed over a big rock and was startled to see a large deer. I was glad it was not a mountain lion or a rattlesnake. I never got very close to the top. Climbing down was harder than climbing up. The next day I was very sore in every muscle, but it had been fun.

Unfortunately this was a difficult time for me to travel with a new house and new baby. I was often gone two weeks at a time, leaving Barbara to cope alone with a new house and two kids under two. Nevertheless the job required it, so I had to go. This put a terrible burden on Barbara, with Mark a new baby and Renee only 19 months old.

By the summer of 1961 things were working relatively well at White Sands. Emphasis had already moved to Point Mugu, a Naval Missile station at Oxnard, CA, and headquarters for the Pacific Missile Range. Oxnard is on the coast a few hours drive north of Los Angeles. The missile needed a lot more testing, and the overwater test range was needed. The testing continued in 1962 and was successful.

Other Nike Computers

Two other computers were developed on the Nike project: 1) the Discrimination Radar (DR) computer, and 2) the CLC. I had minimal involvement with them and cannot provide much history. The DR computer had the same architecture as the TIC, but was twice as fast and had larger memories. The CLC, developed on the Nike-X project, was a very advanced shared memory multiprocessor that used a thin film memory, and provided many ideas for the 1108 'commercial' computer design.

Epilog

As the guidance work scaled down, many of us relocated to work at the Bell Telephone Labs military facility in Whippany New Jersey to continue work on the anti-ballistic missile system. Dave Lewis was the manager of the Univac assigned at Bell Labs. It was a great experience to work with some of the superstars in the radar and missile technology areas. We usually returned to St. Paul after 2-3 years. But that is another story.

Thanks to George's brother John, who facilitated getting this IT Legacy paper to the VIP Club.

Editing and formatting by Lowell A. Benson: UNIVAC => UNISYS, 1960 => 1994 – BEE, U of MN 1966.