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BEGINNING OF DIGITAL ELECTRONIC COMPUTING

Introduction

Professor Burks, Ladies and Gentlemen:

For my appearance here, I must thank the Computing Department of the University of Michigan who are having a series of lectures on this, their 25th year of teaching computing.

I am very gratified that accident or fate, what is the difference, have placed me at the beginning of this great adventure.

I felt that I was very well informed of the great need of a good computer for mathematics and all of science, for technology and business, but the accomplishments of our computers are much greater than I expected. For the future I believe that their reasonable extentions will show an even larger impact on all fields, including logic and what our minds think.

Which reminds me of a story! About twenty-two years ago, the hierarchy of Aerojet General was ensconced in a hotel somewhere between Los Angeles and San Francisco in a think-tank atmosphere, thinking up new concepts for our future. After dinner one evening, there was a period of some hilarity, but I noticed that it quieted when the executive vice-president arose and said that he had an important announcement. He pointed out that although Aerojet had a very important position in Space, it did not have a Space Division. "Now Aerojet General would have a Space Division and the head of that division would be Atanasoff," whereupon he sat down.

I was not at my best after that dinner and what had preceded it. I had only a few seconds to prepare my answer but the first part was easy. I arose and expressed my gratitude that the administration had thought of me for a position that was so close to their hearts. But what next! I begged the administration to believe that I had misled them, not willingly, of course. I was not their man. I had the peculiar notion that man's future and greatest adventure was not in Space but in the Mind. Then I could not think of what else to say and so I sat down. So now you see why I am so fond of computers; they are so close to our minds and not way out in space.

Sometimes I am a little pleased with man's response to his surround. Now when energy is becoming short, man is turning to computers instead of automobiles or aeroplanes, and computers use little energy for construction or use. But computers must do better than that; they must turn men's mind to an actual saving of energy, and they might just do that.

Early Interests in Computers (1913 - 1925)

I will not burden you with most of my homely efforts to begin life on this planet. However, I wish to mention a few things which influenced me later in thinking about our subject.

I was nine years old in the early spring of 1913. I could read very well, I had already read Spencer's Faery Queen and some essays of Ruskin but I do not know why; I considered them dull and still do. But I had tried novels and science and they were just fine. And I had one firm opinion, I thought that I could learn anything just by reading about it.

We lived in what was the wilds of Florida, 25 miles east of Tampa, where my father had just received a job as electrical engineer of a phosphate mine. The phosphate mine was very new and there was no school; what a place to turn towards science, but I did!

My father thought that he needed a new slide rule; it came by mail, a Dietzgen, with a nice instruction book. This was my meat and in two weeks I could do all the elementary things one does with a slide rule. It was my first computer and I was delighted with it. But I wanted to know how it worked. The book said something about logarithms and so I commenced to study about this subject, starting with a fair knowledge of arithmetic.

If you wish to remember me as normal, perhaps you should discount this part of what my memory tells me is true. I knew of algebra and my mother was very good at this. I nearly gave up on baseball, studied logarithms until I understood them, learned to use tables of logarithms and trigonometric functions.

By now I could use logarithms but I did not understand how they could be calculated. I still do not understand how a boy of 9 could give up his normal pursuits and study how to calculate logarithms, but I did. Of course I found a book* which was called ** a college algebra but which covered differential calculus, and with its help I calculated the $\log_{10} 5$. By this time the summer was nearly over. We moved to a new house and school started and my father bought a new Ford, a 1914 Model T, still in the year of 1913.

But this did not cover all I did that year. I studied about radio and radio telephony in books published in England, I remember the price in pence. I would not mention this except that the book in telephony told about Poulsen's magnetic wire and everyone of you should know of this, this is where magnetic discs came from.

There were still two other topics for 1913 that I want to record. My mother had an arithmetic which had a chapter "On Numbers with Other Bases than Ten". I studied that chapter in full and could easily work with other bases than ten. However, I do not remember that it spoke of base 2. This book is lost but Mother always said it was written by Horatio Robinson; but my examination of the large numbers of books written by him in the middle and late 1800's does not meet my memory of that book. ok

And then that year or the next I saw my first Monroe Calculator. This was my second computer and it was digital although I did not know the word. I want to record my appreciation of its designers who arranged that by sliding two clips, a little boy could look inside and understand everything about its structure, without injuring the calculator. When I could use this Monroe, which happened very quickly, my understanding of computer structure advanced greatly.

Within a year or two, my school got an International Encyclopedia and of course I studied about calculating machines, but they did not have much about Babbage. (I now find that I missed a separate topic on Babbage, the mathematician.) ok

Early in high school, I decided that I should be a Theoretical Physicist. It has been good for me and I would do it again. However, when I got to the University of Florida I chose Electrical Engineering since it was the most theoretical course given. I had Machine Shop, Forge and Foundry, but no Electronics, for this subject was just starting in our universities. At that time we were just building little radios that could hear KDKA in Pittsburg, which began broadcasting in America.

In my first year of graduate work I found a proof in Hobson's Real Variables which employed base-two numbers. The whole subject of numbers to other bases and of base-two numbers is not very erudite, notice mother's arithmetic, but most mathematicians of that day did not know of this and almost no one else did either. I think I was the only one there who had heard of the subject, and part of the class were professional mathematicians.

Major Motivations towards Computing (1926 - 1936)

During the early years of this period I majored in mathematics and minored in physics, teaching mathematics as a livelihood. I took the M.S. degree in mathematics in the summer of 1926 and then was an instructor in mathematics. In the spring of 1929, at the end of the first two quarters at ISC, I went to the University of Wisconsin and entered classes leading to the Ph.D. degree. The three classes I entered had all started in the fall and so I was late in their second semester. The U of W did not object but I had a lot of back work to do.

During the summer, I started work on my thesis which was the electrical polarization of helium. The problem related to solving Schroedinger's wave equation for helium. This atom has two electrons and there was an external field which complicated things. There is no exact solution, so I had to employ approximate solutions of the Raleigh-Ritz type. For the functions without an external field, I used those obtained by Hylleraas, which were really very accurate because of his unusual choice of coordinates. After much study and after many weeks of continuous use of a Monroe, I obtained a result which was less than 5% from the measured value. A better approximation and much more work gave a result that was accurate to 2%. This represented my first professional need for a computer.

After getting a PhD, I returned to Iowa State College as Assistant Professor of Mathematics. I knew what I needed, I needed to study electronics and I began by studying a book on vacuum tubes by J. H. Van der Bijl. Do any of you know that book? It was perhaps the first book in its subject. Then I built a few circuits and got fairly good at it. This and my background in electrical engineering was what I used in building a computer.

I also studied IBM equipment with the help of Professor A. E. Brandt of the statistics department. We were looking for some project in physics in which we could use an IBM tabulator. I thought that we could analyze a complex spectrum with it since it had the numerical capacity, but a critical examination of the IBM tabulator showed me that it could not do it.

I decided that what I needed to do was to use an IBM tabulator and add some additional equipment to it. We did that and we published the paper in the Journal of the Optical Society (Vol. 26, pgs. 83-88, Feb. 1936). I have it here* and the last pages of this** show that it says something nice about IBM. But some years later I saw some of the material that IBM issued after being directed by the court that they divulge every piece of paper that they had in their files that contained the name Atanasoff, and one of those papers said, "Keep Atanasoff out of the IBM tabulator!"

Well, I didn't have too much competition at Iowa State College and pretty soon I was made Assistant and then Associate Professor of Mathematics and Physics and then I had graduate courses and graduate students. I got some graduate students who were interested in linear partial differential equations and I had a student who worked on the theory. I must tell you that in partial differential equations, you can't make much progress by trying to solve them. The actual solutions involves many and unknown functions. About all you can do is to approximate the answer.

will now show three

I have here ~~two~~ slides that cover a little of our methods of approximation of the solutions of linear operational equations: ok

Slide 1. Expansion of functions, classical and extended.

Slide 2. Approximations for two cases.

Slide 2 includes the Raleigh-Ritz and Boussinesq or method of least squares as special cases. The method can be adopted to cases in which the functions of expansion do not fit the boundary.

Slide 3. Functions do not fit boundary conditions.

An especially interesting case for ease of application is when

$F_j[\quad] = [\quad]$ evaluated at $x = x_j$ Slide 4.

This system has been invented by others and is called Collocation.

Such an approximation always results in linear algebraic equations, and while such equations can be solved by classical methods, the practical use for the solution of partial differential equations usually results in very large systems. This problem gave me an increased impulse towards computing.

State of the Computing Art (1934 - 1936)

As I have just stated above, I was sharply interested in the solution of large systems of linear algebraic equations and I started to investigate the methods of such solutions.

In a very short time, I became aware that all of computing is divided into two forms which are substantially different and although I have not made a study of this division, I believe that I either started this division or sharpened its implication. One type of computing I called "analog" and I believe that was my word. The other type I called "computing machines proper" but others have called them "digital" and I will use that word since it is simpler and is in very common use today. As I look back, I am sorry that I did not invent a simple word for this concept. I will state what each concept means and enumerate some items of each type as I found them in 1935.

Analog computers. In this system we draw an analogy between the numbers we wish to compute and an artificial system called the analog computer. The elements of the analog computer advance in synchronism with the elements of the mathematics being studied. Since there is a limit to the physical knowledge of the elements of the computer, this limits the accuracy of the computer.

Slide 5. List of analog computers of 1935. Details.

Digital computers. In this case, too, we draw an analogy between the numbers we wish to compute and the elements of our digital computer; however, this analogy is not direct but through the Indo-Arabic number system. The operations that the mathematics require are carried out by known mechanical processes that yield those of the mathematics. Computers can be constructed to yield arbitrary accuracies. The element of accuracy of the computing structures reacts very differently in the two types of computers. In order to make an analog computer accurate, we must make the structure of the computer equally accurate. In a digital computer, if the structure is sufficiently accurate, it will give PERFECT results.

Slide 6. List of digital computers of 1935. Details.

It will be noted that each of the digital computers mentioned above used the decimal system of notation, that is, it used the base ten number system.

Since I was studying the possibility of solving large systems of linear algebraic equations, I selected three:

* Largest tabulator
* A large system of Monroes.
* The differential analyzer

In the end all three seemed inadequate. Discuss

The computing systems available in 1935 all seemed impossible for my purpose. I chose not to use the analog methods because of their basic faults, lack of accuracy and difficulty of applying them to a variety of problems. Digital systems would furnish accuracy, but (they) these systems suffered from lack of memory. Clearly we would have to go to digital systems, but we would have to devise a new art. ok

I was very unhappy, my purposes in computing could not be met by the existing systems. Many who have watched me through the years note my tendency to "do it for myself" but I was and am a practical man. I had plenty to do already and I was very interested in what I was doing. I did not want to study and invent, but sadly I turned in that direction.

Invention of a New Computer.

The listener who has followed me through the preliminary steps will realize that this all happened a long time ago and that the states of the arts and technology were very different from today. In the years just after I received my degree (1931 - 1934), I spent summers in Ann Arbor studying quantum mechanics with some of the best physicists in the world, mostly from Europe. I remember that Spinors had just been invented. During these years I had studied more French and German than English because there was more scientific information in those two languages.

Perhaps you will permit me to remind you that during these same years, we had a very severe depression and this depression persisted in part until WWII. Many people were out of work, perhaps more than in the present difficulty, and many salaries including those of university professors and mine had been reduced, particularly in the mid-west. Such was the state of the country in which I sought a new computer. There I was in the summer of 1936 turning my mind towards finding and perfecting some original concept. My immediate object was the solution of linear equations, but I was well aware of other uses for such a system.

I should perhaps say that I had only a very vague idea of what I was doing. Ideas did not come at all fast; my plight impeded my imagination. However, I proceeded to sort out the ideas that I had in my consciousness. Writing about the period is hard for me, ideas came, a bit of this and a bit of that, and I will have to sort out these concepts in order to convey them in a useful way.

I had a few rough ideas about what I wanted from my new computer:

* The machine would be of the digital type.
* This machine would have a much larger memory.
* We would separate memory and computing.
* Data-in and data-out would be automated.

But gradually my mind turned to other things that would have to be decided before I could even start on the formulation of this computer.

* I realized that all computers had used a mechanical motion of the parts as the medium of the computer. I realized that a new computer might use a different medium.
* How was I to provide for the large memory of my device?
* How was computing to be done?
* Would a change of base alter the coaction of the elements?

I will now treat each of these item in a preliminary way.

Medium for a computer. I believe that I have said that digital computers of the day had a mechanical media. This comprised rotation of a shaft in a Monroe but some other calculators used slicing members. At about this time, I considered using electricity and electronics as the medium of computing. I realize that the exact quantity of electricity such as current, voltage or quantity of charge is at the moment not specified, but I thought that I could work out some such system. If I planned to build according to these principles I realized that I would probably wish to use vacuum tubes.

But would an electronic or electrical system be as stable as a mechanical system? This supposition particularly applied to vacuum tubes, for these devices were regarded as erratic. I suppose that my previous work in analog machines caused me to make a mistake, for with such systems, accuracy was of paramount importance. As a result, I oscillated from mechanical to electrical and back. Much later, my vision cleared and I saw that electrical systems could be quite accurate, but what is more important, that great accuracy is not needed for digital systems.

Computing. This part of my computer was not even started. I did know how mechanical computers proceeded in this matter. If we chose to use electrical principles, I thought that I could imitate mechanical methods in electrical circuits and I called such processes "enumeration".

Memory. I spent a good amount of time studying this problem. I attach a slide which covers my thinking of that time.

Slide ~~9~~ 8. Methods of memory.

You will note that I have placed bases other than two first; this represented my thinking in those years.

Base of the number system. I suppose that my background in bases other that 10 caused me to think of this approach, but I am glad I did. I had previously studied what base should be used for mental calculation; this was theoretical, for I did not expect anyone to change from the decimal system.

Slide ~~8~~ 7. Best base for calculat~~ion~~ors.

Many months had elapsed since I had started to invent a new computer. As I look back over the parts which I have enumerated, it would seem to me that I was making progress, but in my self criticism of that day it seemed that nothing was happening. This was particularly the case since I had a full schedule and graduate students requiring my help. Another mental problem was the query: was I treating my classes and graduate students sufficiently well? I was working very hard and this eroded any feeling of self-satisfaction.

And so one cold evening of the winter of 1937-38 after an early supper I went back to my office at 52 Physics Building as I had done for many months, and looked over the material here described. Everything looked like a hodgepodge. A computing machine was not in sight. I felt no glimmer of it. I intended to spend the evening trying to resolve some of these questions and I was in such a mental state that no resolution was possible. I was just unhappy to an extreme degree, and at that time I did something that I had done on such occasions -- I don't do it anymore -- I went out to my automobile, got in and started driving over the good highways of Iowa at a high rate of speed.

I remember the pavement was clean and dry, and I was forced to give attention to my driving, and as a consequence of that, I was less nervous, and I drove that way for several hours. Then I sort of became aware of my surroundings. I had, of course, been aware of the road before, but then I became aware of where I was and I had reached the Mississippi River, starting from Ames and was crossing the Mississippi into Illinois at a place where there are three cities, one of which is Rock Island.

I drove into Illinois and turned off the good highway into a little road, and went into a roadhouse which had bright lights. It was extremely cold outside, and I took off my heavy overcoat and hung it up, sat down and ordered a drink, and then I noticed that I was no longer so nervous and my thoughts were sharp and clear and I went to work again on computing machines.

Now, I don't know why my mind worked then when it had not worked previously, but things seemed to be good and cool and quiet. There were not many people in the tavern, and the waitress didn't bother me particularly, and I worked for about 3 hours and then drove home much more slowly. I had made four decisions in the Illinois road house:

* Use electricity and electronics and hence vacuum tubes.
* Use base two for economy in logic and memory.
* Use condensers but regenerate to avoid lapses.
* Compute by direct logic, not by enumeration.

Slide 9, Decisions ~~from~~ made in Illinois. ok

The last decision was entirely new. During my time at the road house I thought that I could build a logic circuit that would take the two digits being added (or subtracted) and the carry and give the proper results in that place and give a carry-over to the next place. I call this logic instead of enumeration.

After this trip, I spent some time studying these results and in the end they all satisfied me. During this time, I studied the effects of a small error in a digital computer and found that such an error would not prevent the solution from being perfect. Now vacuum tubes were more acceptable.

However, by this time I had other objections to the vacuum tubes. They were expensive, required considerable power and used considerable space. In the end I would select the tubes to reduce these factors, but I wished for a tube the size of a grain of wheat. Strangely, I thought I knew how to get one. In the early days of radio, signals were rectified by using crystals, galena and silicon carbide. Galena was generally used without bias but silicon carbide performed better with a battery bias. In some circuits these crystals would oscillate and I knew that this meant an amplifier was present. I always wanted to analyze these results but I never did. I have heard that some one else had the same idea. These ideas were leading us towards transisters but in the end these devices were invented by other approaches. Today everyone agrees that transistors are much better for computers than vacuum tubes.

In retrospect I ~~should be~~ am very much pleased with the four results of my sojourn at the Illinois road house. Three of the items have passed into current computer practice and even the fourth is rather close to current usage. In a dynamic memory, the memory is held by capacitors, and refresh is exactly the regeneration which I devised. The real difference in structure today relates to the transistor and mos elements. Of course we must recognize much hard work by many people. ok

I spent months working on the decisions made in Illinois and in particular I worked out jogging and the details of the logic add-subtract circuit.

The Prototype.

Time had passed and we had reached the spring of 1939. I felt rather sure that I had the beginning of a new system of computing. I had carried the whole load in addition to my other responsibilities, but I now knew that I should have some help or stop work. Accordingly, I asked for financial assistance to carry the project forward. In due time the graduate dean gave me a grant and I had to find someone to help. My decision was that I should have a graduating electrical engineer who wanted to continue in physics. I saw Dr. Harold Anderson on the campus and I told him what my needs were and he said "I have your man" and in almost no time at all Clifford E. Berry had agreed to help with my computer. I must mark this agreement as one of the best things that happened to our project.

Slide 10. Clifford E. Berry.

In the fall, Clifford began graduate work. He would also work part time on my computer and would receive a salary for this. I was very pleased with his skill and general knowledge, and everything went smoothly. We were going to build a Prototype to see if my plans were workable. By November we were demonstrating our prototype.

Slide ~~11~~ 10. Prototype. 10

The Prototype was a simple little gadget which showed how the various elements I had designed would coact. It would only add and subtract base 2 numbers of up to 25 bits. Input amd output devices were absent. When it was finished, it began to work almost immediately. Both Clifford and I were delighted.

Slide ~~12~~ 11. Results of Prototype. 11

The Basic Circuits

Except for small differences which I will record, the basic circuits for the prototype were the same as those for our next project which will be described later.

Slide ~~13~~ 12. Input and jogging circuits. 12 ok

Slide ~~14~~ 13. Add-Subtract circuit. 13

Slide ~~15~~ 14. Truth table. 14

Solving Large Systems of Equations.

Since a major motivation in my interest in computers relates to the solution of large systems of linear algebraic equations I should make a statement about how these solutions can be carried out. The solution of such systems in terms of determinant is well known but such a solution really does not solve these equations, it only formalizes it. In what follows we shall not use determinants.

Consider two equations of the system. We can eliminate one variable by multiplying one equation by the quotient of the coefficients of this variable in the two equations and then subtracting the two equations. By a sucessive application of this principle, we can reduce the original system to a new one with one less variable and one less equation. In this way the system is solved, although any solution is lengthy. ck

But consider a computer that is so large that it has one computer abacus (ca) for each coefficient and for the constant term of one equation. The keyboard abacus of each will contain the coefficients and the constant term of the other equation. Now consider the interaction of these two systems of numbers by addition, subtraction and by shifting each of these coefficients together. After each step, the computer abacus ca will contain an equation that is consistant with the two original equations. But suppose we controll this process so as to eliminate one coefficient. The resulting equation will be an eliminant of the two originals. The process of additions (or subtractions) and shifting is really like the division of the two coefficients; the quotient will not show unless provision is made for it, but the eliminant is in ca. In order to make this process as simple as possible, we employ a process of division which I invented and which is called non-restoring division. We used this system of division in solving systems of equations, since it cuts the number of operations by 40%.

The Atanasoff Berry Computer (ABC)

The name of this device was selected by me years after it was constructed, to give Clifford Berry, who was dead, recognition for his work on our computers. The original name related to the purpose of the machine, since it was designed to solve large systems of linear algebraic equations. A name of such content was too long for use in court practice. There the letters (ABC) were usually used. The ABC was started in October before the prototype was finished. I had made preliminary specifications including the number of unknowns and equations which I chose as 29. I estimated the number of vacuum tubes and guessed at its dimensions, about the size of an office desk. These specification and size did not change. The basic circuits are those described above and pictured in Slides ~~13~~ 12, ~~14~~ 13 and ~~15~~ 14. 12 13 14

Slides ~~16~~ 15 - ~~24~~ 23. Construction and Structure of the ABC. ? 15-23

We have just shown you a slide showing the ABC in a finished form. In the process of constructing this device, every element was tested as it was installed and so it required only a short time until the machine was fully operational.

We tested the device by solving a simple set of linear equations. We also used it to obtain the eliminant of two large equations of over twenty unknowns. To avoid the work of verifying the results, we repeated the resolution with the computer. In one such repetition, the results did not check. A careful study showed that the base-two card-system was failing in about one punch in 10^4 or 10^5. All simple steps were taken to eliminate this error but this problem was never satisfactorily resolved.

Other Matters.

Long before the ABC was finished, we had many other matters which entered into the total picture of the device. We shall now try to bring this picture up to date.

Mauchly. In those days, it was my habit to attend meetings of the AAAS which always used to occur between Christmus and New Year's day. And so, at this period in 1940, I attended these meetings at Phildelphia. There I met Dr. John W. Mauchly, and after an exchange of letters, invited him to come to Ames and see my machine. After a further exchange of letters, he finally came on 1941 June 14 with his son to stay at my house and watch the construction of the ABC and observe such tests as we could conduct while the machine was under construction.

I considered our work on the ABC an invention and exercised some care in explaining it to our visitors, but in Mauchly's case I had decided that I needed some one to talk with, and he was told everything about this device. He was given a manuscript and allowed to read it, but was asked not to take it with him. He wanted to make some notes and I furnished paper for this from my supply of bond paper which I always kept at home.

In return, he told me about his own efforts in computing. The paper which he gave in Philadelphia was on an electrical analog Fourier analyzer and he told me of other computers of an analog type. I of course listened for some evidence of any work in the digital field, but there was none. He was very interested in my classification of computers into analog and "computers proper" altho I do not believe that he had heard of either. One morning he gave a resume of the paper that he had given in PHiladelphia to such of our students as were there during the summer.

At a later day, I heard that he said he had not been given access to our machine, that it was covered and no one told him how it worked. The machine was covered to keep it from the dust, but it was uncovered for him. There is plenty of evidence that he was told all about how it worked and he saw it in action. He was given access to my manuscript, and we can tell what that contained since copies of this manuscript have come to the court not only by my agency but also from others who held them from the 1940's. There was evidence that Mauchly was seen with his coat off working on the ABC.

He left Ames on Thursday or Friday. All of the letters he wrote thereafter were laudatory. Only much later, at the time of the trials, did we find him critical and inclined to delimit what he said of his visit and his letters.

Money. At the beginning of this enterprize we received several stipends from Iowas State College but early in 1940 it began to be evident that we would need an addtional source of financial help. Finding help for such a project in a mid-west institution was extremely difficult and took too much of my time when I had too much else to do. It was also evident that we needed a careful manuscript that told what our objects were and how we were getting along. So in the summer of 1940 I wrote such a manuscript and this paper was published much later, in 1973, by Brian Randell. For the moment, it was sent to a variety of organizations who might give money to a university. To make a long story short, I was refused several times and then was given about $8000 by the Research Foundation.

When this money was sent to ISC, President Friley said, lets keep our hands on this, and I found out that I could not use this money until I had a patent contract with ISC. I had not heard of ISC having any patent policy until then, and that they planned to give me about 10%. My small noise was called large by some but in the end I had a patent contract that gave me 50% after all costs were paid. I agreed to give Clifford 10% from my share but for a time the College refused to agree.

The officials at ISC said their patent counsel could not do this patent. I according got the name of Richard R. Trexler of Chicago from the patent office. Mr. Trexler could not do a patent from my manuscript and so we drew specifications, drawings and some claims. I am not sure who was to blame, but after many years of my expecting the patent to be filed, I became desperate. But no patent was ever filed.

War Comes to the ABC. War had come to our country. Clifford Berry had to register. I tried to get our project approved so that he could be deferred but ISC could not do this. He immediately got a job in California where he could be deferred, married my secretary and went away. All of my students had graduated and not many more were in sight except for Sam Legvold who was just starting. Perhaps I too felt the pressure of war and so I joined the Naval Ordnance Laboratory and took Sam Legvold and David Beecher with me.

Those Years

I must economize on space and I will try to limit myself to computers. Early in the spring Mauchly attached himself to my group at the Naval Ordnance Laboratory without any help from me.

One day he told me he and others had found a better way to make computers. "Tell me about it" I said. "I can't, it is classified" was his reply. I was inclined to believe him. I did not know how Mauchly got attached to the laboratory. Later I did take steps to rehire him.

I received the Navy's highest award for my services.

I became head of a new project on computers but it was additional duty for me. The project was effective for about a year. During this time, I attended the Bikini Atomic Trials for the Acoustic Division. Then the project was stopped by the Navy.

Etienne. After some complications I was operating The Ordnance Engineering Corporation, most of which I owned. In 1954 I was approached by Mr. Etienne of the patent departament of IBM. Would I join them and they would break the Mauchly Eckert Memory patent. It was derived from me. I partially agreed but I was very busy. I got one letter from them. I could not find my files.

Litigation. Meanwhile the Mauchly-Eckert Memory and Eniac patent had been acquired by Sperry Rand. They formed another corporation, the Illinois Scientific Development, Inc., and set out to bring in the royalties, I have heard that it was to be $\$10^9$. They sued Honeywell and Control Data. I am sure that these corporations would have given millions, but Sperry Rand wanted more and there was litigation. I agreed to help H and CD. When I began to read the patents I knew that Mauchly and Eckert had not invented a new system of computing but had derived ideas from me.

I will not give the details of the litigation which took several years. I was deposed and in the witness chair for perhaps 25 days but I did much research besides. On 1973 October 19, Judge Larson gave his decision in the Honeywell Case. It overwhelmingly gave me credit for originating computing.

The Judge's Decision. Give as much as you wish. slide 24

I expected that this case would be appealed to the supreme court but it was settled by a payment to Honeywell of sufficient money to pay for the litigation, and a separate agreement to support the litigation. end

What Has Happened Since the Trial

I supposed that after the judgement of this United States District Court of Minnesota, ~~that~~ everyone would agree that I invented the first digital electronic computer. However, certain persons continued to make the same statements that they made before and during the trial.

Copy of pages 24-25 of The Wall Street Journal of 1979 June 5. There was other evidence of the trend and it continues to this day.

Summary of My Accomplishments in Computing.

I shall now summarize the concepts that I brought to computing.

I studied the art of the computers of the day, and classified them as analog and digital. I decided that a new, more powerful and flexible computer of the digital type would be the best answer for the future.

I studied the mediums available for computers, mechanical and electrical. I considered the mechanical path to be more stable, but the electrical path would be more flexible. I chose the electrical medium with vacuum tubes.

I decided to use numbers to the base 2 for economy, speed and simplicity of memory. 'Binary' has entered common usage since my early days.

I developed the idea that electronics and a vacuum tube could be used in a digital computer.

I planned that my new computer should have a much larger memory than was customarily used in the current calculators. The word 'memory' comes from my usage. I found that the base 2 was advantageous for constructing memory.

I first employed a small capacitor for memory.

Since a capacitor might lose its charge between actions, I developed jogging, 'regenerative' memory, or refreshing circuits, to retain the memory that might be lost through time or use.

I first developed electronic logic circuits. These circuits did not imitate mechanical computers which have always used enumeration. Instead, I generated the answer by direct logic.

I planned that all calculations would be serial. As far as I know, no other machine at that time used this principle, and now they all use it.

I invented non-restoring division.

I first planned a digital differential analyzer. Professor Burks showed me how this led to the Eniac structure.

All of the preceding elements except the last were actually used in constructing a prototype and the ABC. In my inventions on computing, I had various ideas which have not been incorporated, but I had one which I feel should be named. This was the magnetic memory, which came to me clearly from Poulsen's magnetic wire. This concept impressed me many years before and I felt that it should be used in computing.

This illustrates my feelings in this way. Since the beginning, many people have worked on computing and many have furnished elements which were important. Credit must go to them all the way back to the originators of our number system which began computing.

What each man accomplishes depends on his brains and energy and the surrounds in which he works. Here, timing is very important. Pascal could not have invented an electronic digital computer although his brain power was overwhelming. In a larger sense, no man invents anything. He builds and extends a little with his friends. Many are involved in making this historical record clear and we all should support this effort. I have tried here to make my part in this understandable, and to convey some idea of the excitements of the period.

Thank you.