LECTURE -- JVA at DEC

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LECTURE -- Dr. John V. Atanasoff at Digital Computer Museum, Marlboro, Mass., 11 November 1980

Slide 1. The First Electronic Digital Computer by Dr. John V. Atanasoff

Gordon Bell: Now it is my pleasure to introduce Dr. John Atanasoff who is going to tell his story of the invention of the first electronic digital computer. Dr. Atanasoff was an applied mathematician and physicist working in the Physics department at Iowa State and I think at the time working on analog techniques for solving Laplace's equation and also doing some statistics using punched cards. In about 1936-37, at least according to the various writings I find and also in talking with him, that he really abandoned the whole idea of using analog techniques for computation and by 1938 had worked out the details of memory and logic using an electrostatic drum. Then in 1939 he went on to design this machine for solving 30 simultaneous linear equations. He then showed this work to Mauchly in June of '41. In essence he had invented the idea of the analog in what he called the impulse digital calculator. If I spend any more time introducing him I will begin to tell his story and he is going to tell it better than I can anyway, so this indeed is an honor to have with us Dr. Atanasoff.

JVA: Dr. Bell, ladies and gentlemen, I am very grateful to Professor and Mrs. Bell, to the museum and to Digital for the opportunity of presenting my early ideas on computing. I am very grateful that fate should have placed me at the beginning of this great adventure. I had great expectations, but none that matched present achievements and none that could possibly match what we all expect of the future. Computing will have no appreciable negative effect on our energy situation; on the contrary, it will have a large positive effect by sharpening our mental process to effect economy, and I think this is a major matter, too. Tomorrow I am going to visit Digital Equipment Corporation. Thinking of this visit is a poor mental preparation for a lecture on ancient ideas, but here goes.

Slide 2. Presentation Outline

I will not burden you with most of my homely efforts to begin life on this planet. However I will mention a few things in my early life which influenced my later interest in computers and I want to tell you about my first computer. The year was 1913. My father was an electrical engineer for a phosphate mine (in Florida about 25 miles east of Tampa) and he wanted a slide rule. It came after several weeks, by mail. We didn't have a car in 1913, and if you had taken a train and gone anywhere, you probably couldn't have found a slide rule. This was in the lower part of Florida. He really didn't need the slide rule very badly and the slide rule was left around the house and I had access to it and I read the instruction manual and got to where I could operate it a little bit in perhaps two weeks. However at the age of 9, I wanted to know why it worked, and here started a program, and I call this the "preposterous memory" that I have in regard to this enterprise, to try to find out about the slide rule. I started to work on the slide rule and put in two, three or more hours a day, and eventually I reached a place where I knew the definition of logarithms. My mother was pretty good in algebra and as long as I was staying in the algebraic field she could help me. Dad wasn't paying much attention. I commenced moving into calculus and I found a series (McLaurin's series) for logarithms and I calculated the logarithms of 5 to base 10 and this took perhaps most of my spare time for four months.

In 1913, I also studied radio and radio telephony. I wouldn't mention it here except the books were published in England. We hadn't reached that stage in the United States. There wasn't much to write about telephony except arcs. An arc was the only way we knew how at that time to generate continuous waves. But this book also contained my first information on Poulson's magnetic wire and this laid the foundation for all of our magnetic recording in the computing art.

Now I don't know what the situation was abroad, but my mother had a large arithmetic text book which she had studied in the 8th grade. It contained many other topics than those usually included in what you would call arithmetic and what I would call arithmetic. But it had a chapter on numbers with other bases than 10. I studied this with great care and I remember several of the pages to this very day. My mother said it was Robinson's Arithmetic. I am not quite sure.

In 1913-1915, I had contact with a Comptometer and a Monroe. The Monroe had a carriage that could be raised and I suppose we have some in the museum and you snap a couple of snaps and raise the carriage and you can look inside and see how it works, which I immediately did. This is my memory, sharp and clear, but I wanted to be sure that I wasn't going to tell you something wrong so I talked to Mr. Stan Schultz, your Mr. Stan Schultz, who came to my house to make a pick-up. He was formerly with Monroe and I asked him when they started making Monroe's; I wondered if they really had them in that day, and I remembered it very clearly, and he said that they did. He said they started manufacturing Monroe's in 1910.

I studied the International Encyclopedia on calculators. It was a very good discourse, but it didn't have much work on Babbage. Early in high school, I wondered what I was going to be and I decided on mathematical physics as my life work. I might say it has been good to me and I would do it again. When I got to the University of Florida, I took electrical engineering because it was the most theoretical course on the campus, but I had a machine shop, forge and foundry and power, but no electronics. You know at that time we were just building little radios that could hear KDKA.

Now in my first year of graduate work I found a proof in Hobson's Real Variables which employed base 2 numbers. I haven't looked at it since that term, but I'll bet you that if you look you will find it in Hobson's Real Variables. It is laid away in the library somewhere; you will find this base 2 number theory there. It is a simple matter but in the class of 10 people I was the only one that had ever heard of base 2 numbers. Even professional mathematicians didn't know it.

When I took the PhD thesis, I worked on the polarizability of helium. J. H. Van Vleck was my major professor. He was head of the Physics Department at Harvard for a number of years and then afterwards he finished up with some other kind of position. He got the Nobel prize in 1977 and I thought I would ask him to come to this lecture, but he died two weeks ago. I used the wave function of Hylleraas in defining helium and then applied a purturbation and calculated the polarizability of helium and compared it with the actual physical measurement of the polarizability of helium. I think originally I got 5% accuracy and later I got 2% accuracy. It took 8 weeks of hard work with a Monroe for me to do that thesis and I ~~got~~ became polarized towards computers in this instance.

After getting a PhD, I returned to Iowa State College as assistant Professor of Mathematics. I knew what I needed to do very quickly. I needed to study electronics and I started right in studying a book on vacuum tubes by H. J. Van der Bijl. Do any of you know that book? It was an old book, but it was good in its day and then I built a few receivers and got fairly good at it and that was what I depended on in building a computer later on.

I also studied IBM equipment and Professor A. E. Brandt helped me. He was in statistics and we were looking for some project that we could use an IBM tabulator for and I thought that we could make out in analyzing a complex spectrum with that. A critical examination of the IBM tabulator showed me that it wouldn't do it. I commenced to think and I decided that what I needed to do was to take an IBM tabulator and add some additional equipment to it and make it work. 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 book show that it says something nice about IBM. But some years later I saw some of the literature that IBM put out after the request of 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 University and pretty quick 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 that were interested in linear partial differential equations and I had a student that worked on the theory. I might tell you that in partial differential equations you can't make much progress by trying to solve them; you can't solve them in any ordinary sense. About all you can do is to approximate the answer. There are too many functions necessary to solve those equations, they are all over the map, there are things you have never heard of before and no one else has ever heard of before and you just can't get at the solution that way. You have to approximate it and you commence to approximate it.

Slide ~~3~~ 1. Approximate Solutions of Operational Equations (I)

I have a couple of slides here that indicate how we went about solving the differential equations. I am afraid I can't use the pointer on it, but in the first slide there I showed how you could start with an ordinary expansion with ordinary co-efficients and in two separate stages move it to equation 3 and in equation 3 we do not define the co-efficients in terms of integrals but in terms of the use of a functional. See that F in the third equation. It shows you that you can get the co-efficient by the use of a functional instead of by an integral form. You think it is just a simplification of the previous results, but it really isn't. It represents a generalization of that, and in the next equation down there, I show you how to select the ϕ's and the F's in order to make that expansion correspond to Taylor's expansion. That is really just a start on this.

Slide ~~4~~ 2. Approximate Solutions of Operational Equations (II)

Here are a couple of equations that we are going to try to solve to get an approximation of. Now we are going to use the system of functions ϕ_i and the system of functionals F_j. i and j both run from one to infinity in theory, but in doing an approximation you'll take a finite number of them. You can see the two equations given at the top there and we substitute in place of the unknown U an expansion in terms of the ϕ's and then we apply the F's and we come to the last equation down there, in either one, and they are slightly different kinds of equations, and I can tell you more about that.

Those last systems of equations, there, are a system of linear, algebraic equations, because everything else is known. To approximate the solution you have to solve that linear system, so we were getting very interested in solving them. Now in order to solve any particularly hard problem, you could sit down with a piece of paper and solve two or three equations and two or three unknowns. Eight or ten equations or eight or ten unknowns will make you pretty busy if you don't have a computer, but we needed 20 or 30 equations and 20 or 30 unknowns to solve that problem and that was a problem that was bugging us.

Now I might say that those equations given there are very like the equations that are known for approximations. They are called Rayleigh-Ritz, Boussnesque and perhaps by modification the Treffstz system of approach to the equations.

This is what actuated me really more than any other problems to get me interested in the computing art. As I felt the basic need for more powerful methods of computing, I commenced to take stock of what methods and apparatus existed. It soon became evident that one could divide all calculators and computers into two classes -- analog and digital. I believe that division was ours. The first word, "analog", was of my coining, but I missed naming the second, I didn't call them digital. (I almost put Digital out of business, didn't I?) I called them "computing machines proper".

I will use the word digital in everything that follows because it is a better term. In analog machines the numbers are represented directly by some physical quantity. The larger the number the larger the quantity. The quantity can be movement, velocity or voltage, or in fact any easily measured physical quantity. In a digital computer we must use some physical quantity to represent the number. We do use some quantity to represent the number, but the physical quantity is related to the number by what I call the Hindu-Arabic number system, although the base of the number system may not be 10, but can be any integer above 1. Now I list some analog computers here: The slide rule. Then I was thinking about building a slide rule using 35mm film for the slides and putting it over sprockets. I don't think anybody else ever built one. I didn't build one either. It turned out that with reasonable length of moving picture film I could work to one part in 100,000. This is a way you would make a slide rule do better. This is what you have to do if you take any analog process and try to make it more accurate.

Then at that time the publications were filled up with the Bush differential analyzer. Prof. Vannevar Bush was at MIT; you ought to know something about him. He and his staff built a very fine analog computer, but I didn't get interested in it, too much. I couldn't really believe that it was a project for the future.

I might tell you of one or two other analog computers. You take the anti-aircraft fire director for military purposes. It has in it an analog computer. I don't know whether anybody has ever built a digital computer into that. Then there was a device that was used in those days that was called a Fourier analyzer and it used motion as the quantity. Then later on Mauchly told me he was going to build a Fourier analyzer; I guess he built one which used electrical devices.

Then we built in my laboratory an analog computer for solving Laplace's equations of two unknowns and I don't have a picture of the machine, it was rather simple. I do have the paper that we published on that. (A Mechanical Device for the Solution of Equations involving the Laplacian Operator, by Glenn Murphy and J. V. Atanasoff, Iowa Engineering Experiment Station, Bulletin 166, 1949)

When it came to digital computing we had the miscellaneous simple computers, Comptometers, Monroe, and Marchant and then the only two bigger machines that we had were the IBM and the Remington Rand tabulators and those both existed in that day. That was about 1936.

This is the analysis that I gave. I soon found out that no machine or system available could solve the growing lists of problems of theoretical physics, technologies, statistics, or business. Analog methods were generally specific for some special problem. That is the trouble with the Bush analyzer as far as that goes. To adopt them would take time. You have to re-organize them to start them on a new job. They are also of low accuracy, perhaps giving 3 or so significant figures. So I turned my attention to digital methods. These could be of sufficient accuracy, but operational flexibility was limited. Even the largest IBM tabulator of the day in existance had an internal memory of 266 bits. To use such methods would require a very new art. I didn't want to do computers, I had graduate students doing other things and I didn't want to build them but somewhat sadly I moved in that direction.

There I was in 1936, turning my mind to invent a digital computer, not knowing how it would be built or how it would work. However I believed that it should be fast, accurate and flexible. I wrote out a few ideas. You will recognize an item or two from my early years. Of what stuff would my digits be constructed? You see we were going to use some quantity to represent digits and of what stuff would that be? Would it be mechanical, electrical, or some other and what would the structure be? And the only thing that I could think of was to separate memory and computing and maybe it wasn't a bad idea.

Now I thought, does base play a role? When building a digital computer what are we going to do about the base? What determines this? How should I do computing? What was the computer going to be like? And how should memory be constructed? I had all these words at that time. For base 2 numbers I thought of:

* a two step mechanical system,
* ferromagnetic material, going back to the wire, you know, and I thought that an awful good idea, and in the end I didn't use it.
* A two state vacuum tube circuit, and
* a capacity with two states of charge. That is what I did use.

Then if you wanted to build bases of size n you could use:

** a ring or circle of metal with n stops, and that was common in the base 10 computers throughout the older days.

** a combination of base 2 elements to yield a base n, and

** a vacuum tube ring circuit.

You should realize that these concepts represent the hodge podge of ideas. I tried again and again to sort them out. Nothing seemed to work. After months of work and study I went to the office again one evening but it looked as if nothing would happen. I was extremely distraught. Then I did something that I did in those days but I've had to stop lately, I got in my automobile and started to drive. I drove hard so I would have to give my attention to driving and I wouldn't have to worry about my problems. When every once in awhile I would commence to think about my efforts to build a computer and I didn't want to do that so I would drive harder so I could not think. I drove towards the east. I was driving a Ford V-8, with a South Wind heater. I suppose you don't know what a South Wind heater is; pretty warm, but the night was very cold. It was the middle of winter in 1937-1938. When I finally came to earth I was crossing the Mississippi River, 189 miles from my desk.

You couldn't get a drink in Iowa in those days, but I was crossing into Illinois. I looked ahead and there was a light and of course it was a tavern and I stopped and got out and went in and hung up my coat (I remember that coat) and sat down at the table and got a drink and then I noticed that my mind was very clear and sharp. I knew what I wanted to think about and I went right to work on it and worked for 3 hours and then got in my car and drove slowly back to Ames. I had made four decisions in that evening in the Illinois road house:

* Use electricity and electronics, that meant of course vacuum tubes in those days.
* Use base 2 in spite of custom for economy.
* Use condensers but regenerate to avoid lapses.
* Compute by direct action, not by enumeration.

You know it is an easy thing if you know about a number system that just has things that count, the kind of an internal counter that gives you enumeration, but I was going to do it by direct action.

This concept was new. I had yet to devise a circuit. I didn't know how I was going to do it, but I thought I could do it.

After the trip to Illinois I took time to go over the decisions and in the end I decided to build according to the decisions made in the short time in another state. I have a few points that I want to make with you. I had to use vacuum tubes. For a period I would think that vacuum tubes would not be stable enough for the purpose. Then I would remind myself that I was not building an analog, but a digital device. I would go over some parameter in a mechanical calculator and then I knew that such parameters do not have to be very precise to give not just ordinary results but perfect results. That is the characteristic of a digital machine. You all know that.

So vacuum tubes were in as a component of a computer. I might say that I immediately was faced with the costs of vacuum tubes, because they were large, they used quite a lot of power, and they were large in initial cost. I thought I wanted a vacuum tube with the size of a grain of wheat and I thought I knew how to do it. This was in my mind but I never did it. We used to use galena and silicon carbide to rectify the current in a radio and galena would be used without a DC bias, but when we used silicon carbide we would apply an external voltage. Here is the thing, did you know that some of those silicon carbide crystals would oscillate? Did anybody in the room ever hear of silicon carbide oscillating? Anybody, hold up your hand. I am afraid that not many people knew it at that time, but I knew that if it oscillated that it was amplifying and hence all I needed to do was to strip it off and straighten it out and I could get an amplifier that way.

Now in the road house I thought that I could build a vacuum tube circuit that would receive the two digits being added or subtracted in a given numerical digit and would receive the carryover into that place and would give out the addition or the subtraction which went into that place and also give out in another point the carryover. I had already studied something about Boolean algebra at that time, but I didn't design this circuit by Boolean algebra; I notice that other people design such circuits by Boolean algebra today, but I designed it by sheer awkward force, I just went to work and did it. In my notes I have one page that notes that this process deserves more algebraic finesse.

Here is another point; it should be noted that one digit is calculated in full including carryover before the next place is calculated. We call this serial calculation. I expect you call serial calculation something else, but that is what we called serial calculation. This decision represented a major advance in computing. Babbage did not have it, I think that each of you do not use anything else, as far as I know. You must tell me if I'm wrong.

Now I reached a place where I had to be more reasonable about my own computing efforts and I had to have some help. I went out to find someone to help me with the job. I saw Harold Anderson on the campus and I said, I need a man. He said, I have the very man for you. It was Clifford Berry and I couldn't have had a better man. He was absolutely tops in all respects.

Slide 5. (Photo) Clifford Berry

In the fall he and I went to work on the job and by Christmas we had a prototype in operation.

Slide 6. Digital Computer Prototype

This prototype was designed to work out all of the aspects which worried us about this kind of a computation. Now you see up at the left-hand side up there we have some discs and on those discs are the condensers which are going to be the memory. We needed a name for those discs so I used the Chinese "abacus". I called those discs "abaci". In that disc I had two sets of condensers. The one on this side we called the keyboard abacus. It consists of the row of condensers around there. I believe there are 25 in that particular machine. That would give us 25 base 2 places there. On the other side there is another row of condensers and it is called the computing abacus. The keyboard abacus and the computing abacus. The keyboard abacus came from the point that more or less takes the place of a keyboard in a computing machine. Now down at the left here we have 3 sets of chassis. At the bottom of the first chassis there is the circuit that regenerated the keyboard abacus. The second one is the add subtract mechanism which I devised. You will hear more about that later.

The add subtract mechanism also regenerates the computing abacus. The other chassis is the power supply. There are a couple of additional points in there that you ought to know something about. In order to get the voltages to work out right we have to boost the slip ring at the inner edge of the condensers. Then there is another rotating commutator with a condenser on it which is a carryover capacitor and that picks up -- when the machine is working at one level, it picks up the carryover from that and carries it over to the next place and that is what the machine consisted in.

We started to work on that in September and by October or November we had the whole thing complete and it was working fine. Never gave us a minute of trouble. That particular arrangement that we used for the add subtract mechanism worked fine. This machine, by the way, is what you have in the museum. What you have in the museum is more or less equivalent to this. The successful conclusion of the prototype was an occasion of some moment to us:

* We had in our hands the first electronic digital device.
* Proof of vacuum tubes and computing.
* Direct computing to base 2.
* Serial calculations.
* Simple and easy to build, and
* I believe that it was the advent of a new era.

We are not giving the circuits for this device because these circuits were substantially the same as those used in the ABC which comes next. We will cover the circuits there. There is one little point that is different. At this point we thought that we would have a little trouble picking up the charge from the regenerator or from the add subtract mechanism so we put pentodes in there to furnish the condensers. The nice thing about a condenser is this -- I should tell you this and I didn't say it in the right place, but a condenser is a good thing to have for memory if you are very short of vacuum tubes and can't afford very much because it would furnish enough power to operate the vacuum tubes, and the plates of the vacuum tubes would furnish enough power to recharge the condensers. I would have built a magnetic memory, but I couldn't afford the vacuum tubes.

Now the next thing is the Atanasoff-Berry Computer. This represents my main effort in computer construction. It was designed specifically to solve the problem that bugged us, the solution of linear algebraic equations. You see I knew we could build almost anything with the devices that we had at hand, but this was the thing that pressed me deeply and I went right to work on this. I named this computer the ABC (the Atanasoff-Berry Computer) in 1969, after Clifford Berry was dead, to give him some recognition for his great efforts in this enterprise. I will describe our work from slides.

Slide 7. Regeneration and Computer Input

Now that gives you a hint as to what the circuits were like. This was a circuit with just one ring, such as we had in the prototype. Now you see those upper three tubes there were used for regenerating that keyboard abacus and the lower circuit CA is a computing abacus and it is shown there connected to the add subtract mechanism. On the right is the carry-over and the square in the center is the add subtract mechanism and you notice the letters there; we have A which comes directly off the computing abacus, B comes over from the key-board abacus there, and C is carried in from the carryover. Now you notice the boost on there and the boosts were necessary as I said before to bring the voltages into correspondence, the input and output voltage of the tubes into correspondence.

Slide 8. Logic Circuit

Here is the add subtract mechanism. Now you have seen that type of circuit yourselves. That's just as I designed it in the year 1937 or 1938. You will see the same letters there, they are the input and output, and then there are a couple of letters down at the bottom called G and F. G and F are the points at which voltages are applied in order to make the device add or subtract.

Slide 9. (Photo) Add Subtract Mechanism

This is the form in which we built the add subtract mechanisms and you have two of those almost in exactly that form in your museum.

Slide 10. Truth Table

This is the output of the add subtract mechanism and this is a retyping of a chart we made in those days, 1939 or 1940. It shows when we are at each point, we are getting certain signals into a particular level there and they are showing you, for instance, the 000. When you get 0, why according to our specification you have a high voltage. How high is the voltage? Well, it is such voltages that you easily would get off of a vacuum tube and maybe you would have 120V on a plate and maybe the output off the plate itself would be 50V, a high voltage. Now let's go down to the last one down there. In that case we have a 1 in the keyboard abacus, a 1 in the calculating abacus, and we are carrying a 1 into that place, and when you do that addition there you have low voltages in both cases. Those low voltages correspond to about zero volts.

Slide 11. (Photo) Frame of Machine

We went right to work on it and built a frame to put it in. It is about as big as an office desk. You see a motor there but that is not the motor we used in the end. You see some places to put the add subtract mechanisms and we were building -- I will need to go through, when I have time, to go through the method of calculating that we were going to use and we were building this machine to solve 29 equations and 29 unknowns to work on the terminals with 30 places. So we were going to use simultaneously 30 add subtract mechanisms.

Slide 12. (Photo) Memory Cylinder

You will find one of these in your museum, too. Just exactly like that. Unbelievable. The condensers are inside there. The end plates have been taken off the one that you have in your museum, but there were commutators there into which you put the booster voltages.

Slide 13. (Photo) Memory Cylinder in Place

There are a couple of drums. This is the keyboard abacus (to the left) and that's the computing abacus over on the other side. That shows just about how the machine was made.

Oh, yes, now, here is the problem. I needed something going in and going out. I needed some slow memory. You didn't just order one from somebody in those days, you built it or you didn't have it, and I would have liked to have done this with magnetic tape, but of course we didn't have magnetic tape then. I could have used wire, but that would require amplification and I couldn't afford amplification.

Slide 14. (Photo) Base 2 Card Reader and Writer

So I built a new kind of card system, and I don't suppose you have ever heard of it before, but you place the card in that left-hand trough and at proper operation of the machine the pins would start it in through the rollers at the left and it would go through there and it would be punched according to the quantities that were in the computing abacus. It was punched electrically right through the paper and when it punched it would make a hold through right where the electrode was and for a moment the circuit would be on, but it wouldn't make the hole elongated at all because it would just hang onto that same position. Then you put the card over in the next place and there it was sensed with electrodes on the top and the bottom and these signals were sent into the computing abacus.

Slide 15. (Photo) Front View

Now there is a picture of the machine as it was towards the end. You'll see at the upper right a synchronous motor. Down below is one of the power supplies. Can you see that add subtract mechanism? You can count 15 of them, and there are 15 of them on the back side. Then you can see the thyrotrons at the left of the divider there. They were used to control the punching voltage. Behind them was some tubes that were used for regenerating the keyboard abacus.

Slide 16. (Photo) Best View of ABC

Here's another slide, it's the best slide that I have. It shows the base 2 card systems, in and out, and it shows a base 10 card system which used an IBM card. You would put the numbers into the machine by punching them with an ordinary punch on IBM's base 10 cards. The IBM cards had 80 columns and we divided that into 5 fields and that made 16 in each, and 16 base 10 places corresponded to about 50 base 2 places. As the machine operated the signals would come out there and go over just to the left of the keyboard abacus where there was a rotating mechanized table which converted the base 10 numbers into base 2 numbers. So when the numbers passed into the computing abacus they have already been changed to base 2 numbers and they could also be taken out of there and turned back into base 10 numbers by the same process.

During the time that the ABC was under construction, the various parts were tested. At the end the system was used to compute the solution of several systems of equations to compare with known solutions. The machine was also used to compute the eliminate of two large equations. In all this work, everything worked perfectly. I didn't hear of any trouble at all (of course I wasn't there all the time) except for one thing and that was that the base 2 card system gave errors. It wasn't a very good system, or maybe it just wasn't developed sufficiently. Oh yes, we had one piece of cardboard that gave perfect results, but we only had one piece to try it on so perhaps that wasn't too good.

The ordinary cardboards that were used, such as that used in IBM cards, would give about one part in 10^4 errors. Of 10^4 spaces that passed, you would get on average about one error. That's rough. That is not very much error but it was far too much for a computing machine.

On June 13, 1941, Dr. John Mauchly visited ABC installations at the invitation of Dr. John V. Atanasoff and he was shown the complete developments.

Slide 17. (List) Appraisal of Invention

I might tell you how things went about that computer.

The Iowa State College staff members were not unduly enthusiastic. One of my friends from across the hall said it wouldn't run a street car. I saw him a few years ago, and I asked him if he remembered saying that the machine wouldn't run a street car and he said yes, but they are making computing machines so complicated that maybe it would run a street car now.

Corporations were not impressed. When it got out that I was building an electrical machine I got negative answers from companies that were building computing machines, and IBM said they would never build such a machine.

Mauchly had been rather enthusiastic about my machine, but in 1943 Mauchly declared that he and Eckert had found a new way to build a computer. I asked him to tell me how, and he said he couldn't, it was classified. I really believed him pretty much.

But in 1954, an IBM patent attorney declared in my office that we should upset the ENIAC patents which were derived from my work. I got one more letter from IBM and then IBM went and made a deal with Sperry Rand. I had told them I couldn't work on it full-time, I would work with them, but not full-time because I was running a corporation. I had to make the corporation work and in the end I did, but not as well as some of the other corporations that I know of.

About 1967, Sperry Rand and ISD, a corporation of their's, sought a billion dollars in royalties. Of course they were laying the royalty levels pretty heavily on all the manu--facturers in the field. They came into controversy. I think Honeywell would have paid them several million for their license, but they didn't want to pay a considerably larger amount. Then a gentleman from Control Data had heard about me and he came up to see me. They both agreed to use my services. And I went to work investigating the ENIAC patent. I found out that Mauchly wasn't perfectly right in claiming that they had invented a new method of building computers. At first when he came to visit me, he told everybody about his visit. The best evidence that I have that I used the word "analog" was from Mauchly's writings on the subject. Later he didn't talk nearly so much and he didn't tell any of his patent attorneys anything about me and one of his patent attorneys named Eltgroth said Mauchly and Eckert did not mention me to him. "I have never heard of you". "If I had known of you I could have protected them". I asked another patent counsel how he would have protected them. He said the only thing that he could do would make Mauchly and Eckert foreswear everything that they had gotten from Atanasoff and then he said they wouldn't have had much of a computing machine. Those were his words, not mine, you notice. I was a little uncertain about the matter at that point.

I might tell you very quickly that we had a little time there and I got a letter from a man named Professor Blagovest Sendov in Bulgaria and he said Atanasoff is a Bulgarian name and I know you or your forebears came from Bulgaria and he was right; my father had come from Bulgaria. My father had left Bulgaria in 1889, and he went out to my father's village and found out that plenty of people knew about my father in spite of the fact that this was in 1970, 1889 to 1970, including one cousin that had seen my father at that time. He wanted me to come to Bulgaria. I did and I spent three weeks there and towards the end of my stay I got a call from the English speaking secretary of the Bulgarian Academy of Science and, as we were about ready to leave, she said "could you stay over a little longer, the Parliament has acted and we have permission to give you an order." Well, I didn't know very much about receiving an order, but the next day at the investiture of some kind at the Academy of Science they made a long speech in Bulgarian which I couldn't understand and they pinned a medal on me and I'll show you the medal.

Slide 18. (Photo) Medal, Order of Cyril and Methodius, 1st Class

There it is. This order is called the order of Cyril and Methodius, and Cyril and Methodius were the people who invented the Cyrillic alphabet and after they pinned the medal on me I had to say something and I told them that I was very interested in this because I am very interested in alphabets. The Cyrillic alphabet is a pretty good alphabet. It is better than the Roman alphabet as used in the English speaking world. It is much better than that. It is as good as the Roman alphabet used in Spain, we'll say, or Turkey where the alphabets have some meaning. In the English speaking world, alphabets only have about a 61% accuracy. They are complicated. I think that this is a matter that affects our children's ability to learn to read and write.

Now when I got back it was time for the trial of Honeywell and Sperry Rand. Sperry Rand sued Honeywell, but Honeywell sued them back and it was carried under the latter terms and it took 10½ months. I was there one month and I was on the witness stand for 2 weeks. Then nothing happened for a long time and then on the 19th day of October, 1973, the judge issued his decree and it was a long decree. It covered many different subjects. But I will read you just a little bit of what he said about the ABC and Atanasoff. This is called Atanasoff . . . . and "the subject matter of one or more claims of the Eniac was derived from Atanasoff, and the invention claimed in the Eniac was derived from Atanasoff. SR and IDS are bound by the representation in support of the counterclaim herein that the invention claimed in the Eniac patent is broadly 'the invention of the Automatic Electronic Digital Computer'. Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John V. Atanasoff."

There are 19 of such topics and I am not going to read them all to you but I will read one or two more that I have thought might be of some interest to you. "Prior to his visit to Ames, Iowa, Mauchly had been broadly interested in electrical analog calculating devices, but had not conceived an automatic electronic digital computer. As a result of this visit, the discussions of Mauchly with Atanasoff and Berry, the demonstrations, and the review of the manuscript, Mauchly derived from the ABC 'the invention of the automatic electronic digital computer' claimed in the Eniac patent. The court has heard the testimony at trial of both Atanasoff and Mauchly, and finds the testimony of Atanasoff with respect to the knowledge and information derived by Mauchly to be credible". Then at the end of the rather thick order the judge said "the clerk shall enter judgement forthwith on these findings and conclusions as follows: The Eniac patent, US serial number 3,120,606 of Illinois Scientific Development, Inc. (that was the Eniac patent) it is hereby declared to be invalid and unenforceable. The counterclaim of ISD against Honeywell is dismissed." Then he ordered that the officers of Sperry Rand and the other corporation would not under any circumstances attempt to effectuate those patents and then he signed his name, Earl R. Larson.

Now I want to just state my own appraisal of our work in conclusion.

We examined the computers of the day and classified them as analog and digital. We didn't use the word digital, we used the phrase "computing machines proper".

We decided that no computer could meet the need except a new more powerful and flexible computer of the digital type. I researched the structure of a new electronic computer, I determined that our structure would have memories in a separate operational bank in which the numbers from the memory would be combined. In the main this structure has been preserved in modern computing.

We decided to use numbers to the base 2 in our computer. The advantages of this base are very great. They include economy, speed, and simplicity of memory.

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

We developed the concept of serial calculations. In such a system the sum or differences in one digit of the number system including carryover, is completed before one passes to the next larger digit. As far as I know, no other machine at that time used this principle, and now everyone does it.

We first used a regenerative circuit to retain memory elements which tend to fade with time or use.

Now I want to summarize my own feelings in this way. Since the beginning, many men have worked on computing and many have furnished elements that were important. This applies to Mauchly, Eckert, some members of the staff such as Burks, Brainerd and others. Historically the list should contain Pascal, Napier, and Zuse. Credit must also go to the originators of our number system which began computing.

What each man accomplishes depends on his brains and energy, but also on the surrounds in which he works. In this, timing is important. Pascal could not have invented the 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 and on the shoulders of others. Many are quietly 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.

QUESTIONS AND ANSWERS

Q. The base 2 card readers that you spoke of, did that mechanically punch the holes? I had the impression that you actually burned the holes electrically. How did that work?

A. It burned the holes. I just told it to punch, but it burned the holes. Of course, the carbon in there is what gave it the signal afterwards when we attempted to read it. We laid brushes on the face of the card and the signal occurred through that.

Q. I would like to know if there was feedback in the regenerative circuit?

A. Yes. You know it was a peculiar kind of feedback. It would pick up the signal and then after a moment it sent it back in. You can call that feedback depending on your point of view.

Q. Was there any mechanism there to insure that the tubes saturated or to decide what the voltage was that came off the capacitor? That is what I'm trying to get at.

A. Sure there was saturation and clipping. You know that vacuum tubes always clip. We just about used the full capacity of vacuum tubes so the clipping was just what was inherent in the vacuum tubes.

Q. What was the physical mechanism from which you made your capacitors? What were they made of?

A. You don't take much to do this. Almost any old condensers that you have around the house will do it. The condensers that we used were .00015 μfd. They were little paper condensers and even these were too large in size so I got the guts they put in the paper condensers and used them. You see the drum down there, that contains the guts of what they put in the paper condensers of that day. It contains 1600 of them. Maybe 1700.

Q. How was it programmed or coded to solve different problems? Does it always solve equations with 32 unknowns?

A. No, it could be programmed for any size system up to 29 unknowns. Strangely enough, the man who knows most about that is a lawyer. He set out and figured out what it would do because he expected to get a lot of opposition on this, showing that it was a very limited device. Of course, it was a limited device because I used a soldering iron to make it a limited device. It would do a lot of different things. My original prototype could have been built into any kind of computer you wanted to build, but this machine was made to solve systems equations and it solved them very well.

Q. How was the multiplication for that done?

A. It was programmed in. Shifting was done in multiplication and division by shifting the numbers around the drum.

Q. What was the order of magnitude of speed of the machine? How long did it take to solve 29 equations in 29 unknowns?

A. The speed of the ABC was made rather slow so that I could use the standard 60 hertz ac current in punching the base 2 cards. It went through a cycle of adding or subtracting every second. Professor Arthur Burks has estimated that it would take about fourteen hours to solve the system of 29 equations in 29 unknowns. My memory was of the same magnitude. Probably such a full system of 29 equations in 29 unknowns had never been solved by man. This cycle was for a 50 bit number.