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Interviewee: Way Dang Woo

Interviewer: Richard R. Mertz

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MERTZ:

Dr. Woo, would you please describe your early training and education prior to coming to Harvard.

WOO:

Why, I went through a high school which was quite strong in the sciences and had a close connection to the university that I went to. That's Chao University. And the Ac University is, was something like the MIT of this country, had a very extensive technical departments and the electrical engineering department was especially the strongest and the curriculum at that time was more or less pretty close to the curriculum of MIT back in those days, a lot of classes and a lot of homework, and so on. Some of the faculty members had also gone to Harvard, and, in fact, the Dean of the Department was a Harvard graduate. I guess that's the reason why I happened to come to Harvard.

MERTZ:

I see. Earlier in school before you went to college you had done—

WOO:

More or less in a track which was pointed toward science.

MERTZ:

That was the area that you were interested in studying.

WOO:

I was very weak in the humanities.

MERTZ:

And also liked, were interested more in—

WOO:

Yes, that's right.

MERTZ:

More or less in what areas of your curriculum would you say that you found your strongest points in communication the engineering subject.

WOO:

In communication engineering, of course, even at that time there were only one or two courses as distinguished between electrical power engineering and electrical communications engineering. I guess back in those days one or two course on radio tubes or vacuum tube technology and how the radio waves was about all we had.

MERTZ:

Was there any particular overlap with the physics department in the field of electricity?

WOO:

It happened not very much in the college at that time. The first two years of physics were combined in other words the physics students and the chemistry students and the math students took the same physics course. Electrical engineering there are some, in fact after the first two years I was there were very few courses which were common to both the physics students and the electrical engineering. But I was particularly interested, really in the physics part, so though even I was not taking a course I was following it on the side quite a bit.

MERTZ:

There was a possibility of auditing the courses?

WOO:

I didn't do too much auditing but I was looking over the notes of the

MERTZ:

Oh, I see.

WOO:

the physics students.

MERTZ:

So that you from a fairly early time had a strong interest in physics as a field actually, as well as electrical engineering.

WOO:

That's right. I wished the university happened to have a stronger physics, department.

MERTZ:

When you decided to come to Harvard, did some of your professors write recommendations for you to Harvard?

WOO:

They did. So I had not much problem in entering Harvard.

MERTZ:

Was there any particular professor at Harvard that they recommended you to?

WOO:

At that time the professor in charge of admissions for the Communication Engineering Department here was Harry Mimno. He has since retired; he is still in, from this area. Harry Mimno. M-I-M-N-O. He has since retired; he was active in the field of ionosphere work and I think he was, since his retirement he has been quite active in IEEE activities. And he is still running, as I understand it, some experiments on a truck with ionosphere equipment.

MERTZ:

Did he do some design work on cosmic ray counters and this sort of thing?

WOO:

He might have. I did not follow his work too closely. There was another professor who was a senior professor, well, two very senior professors, whose name was very well known, George Washington Pierce, and Leon Chaffee, both very well known. I guess it's because of these names that Harvard at that time was reputed to be at the top in the communications field. And I took courses under Chaffee and Mimno and there was a new professor at that time, Ronald Pinn. During my first year I also did some auditing in the physics department, in the electro magnetic field and so on. Well, I got my MS degree in 1939, and then was continuing, and then in 1940 I had a chance to do practical work, you might call it, at RCA.

MERTZ:

If I might just go back, you were at Harvard about one year then.

WOO:

Actually for two years, then I left for one year to go to RCA.

MERTZ:

Did you write a thesis for your MS?

WOO:

No thesis, no.

MERTZ:

I see, it was an examination on course work that you

WOO:

covered. Yes.

MERTZ:

had taken. Was it, at that time, was it still in the field of communications engineering or was it a further specialization?

WOO:

General communication engineering. At Harvard communication engineering is most of the faculty members, I guess almost all, are also on the faculty of the physics department. It's sort of a combination engineering and physics department jointly operated and their laboratory is called Cruft, C-R-U-F-T, which is pretty well known. It was also the first year that Aiken had taught applied mathematics and that's where I first met Howard Aiken.

MERTZ:

In 1939?

WOO:

In 1938-39.

MERTZ:

'38. I see. And you were student in his course?

WOO:

I think so. I don't remember whether I audited or whether I was actually a student. I don't remember.

MERTZ:

Was this your first involvement with computational problems as such, or had you...

WOO:

I guess it was, I would say yes.

MERTZ:

Or had you been involved even earlier, before?

WOO:

No, more or less theoretical kind of, more theoretical. Howard Aiken was more interested in the numerical at that time already. I don't remember whether I took courses under him the first year. I think during the second year I was a teaching assistant and I think I was helping out in one of the courses he was teaching.

MERTZ:

This was the academic year '39-40?

WOO:

Yes, that's right.

MERTZ:

Then you got to know him

WOO:

More.

MERTZ:

More closely as a teaching assistant. Did this tend to focus your own interest?

WOO:

Not at the time, no. Back in those days a Chinese did not think of a career in this country. In fact, even if I had wanted to stay I couldn't have, because of immigration laws and so on, and we all planned to go back to practice engineering.

MERTZ:

I see. So you were thinking in terms of going back to be an engineer in Shanghai?

WOO:

In China. Yes, that's right.

MERTZ:

When did this start to change?

WOO:

The war came and changed things.

MERTZ:

Of course, there was already a war in China.

WOO:

That's right. Yes, yes. Well, in fact, maybe that's an interesting anecdote. The war in Shanghai started in 1937, and I graduated in 1938. And when the war first started, in Shanghai there is an international settlement so it was controlled by the British and Americans, and so on. When the war started--the University is not in the international settlement and my home was not in it--my home was lost the first day of the fighting back in 1937 and the university we moved into the international settlement or French concession area. And, oh no, just before we moved we were beginning classes. The fighting was going on, but the university was almost at the edge of the line, so that we didn't move. The Japanese was bombing the railroad station nearby and we were listening to bombs and Wheatstone bridge with an earphone.

MERTZ:

With the bombs going off. Oh my.

WOO:

With the bombs, or at least with the--what do you call it? with the airplane dive bombers.

MERTZ:

Dive bombers, oh yes. The pre-prototype of the Zero, I guess.

WOO:

I guess, I don't know even what it was. And I spent the first year, because the war in Shanghai was up in about two or three months, and we stayed on in the international settlement or French concession area. So we were not bothered by the Japanese.

MERTZ:

The rest of the city was occupied.

WOO:

The rest of the city was occupied.

WOO:

Did this cause some separation from your family at this time?

WOO:

My family happened to be all together.

MERTZ:

Oh, they were. I see. So, even though the home was lost, your family—

WOO:

Moved out into the French concession just before, a few days, just before.

MERTZ:

So they stayed intact. But that meant that this last year, the normal facilities of the college were not there.

WOO:

That's right, yes. In fact the last year of my college we had the classes and the laboratories, on a very make-shift basis, in another university. It's a branch of a missionary, a Catholic university operated by the French. We borrowed their campus

MERTZ:

Oh, I see. And that was in the international

WOO:

In the French concession, yes.

MERTZ:

That also made possible getting some books and things?

WOO:

It was all very limited.

MERTZ:

Yes. And the faculty also?

WOO:

We lost some, but they remained mostly on.

MERTZ:

That gave you an added incentive to wanting to continue your studies in the United States.

WOO:

As soon as I graduated I left.

MERTZ:

Did that cause any problems, getting out of the—

WOO:

Of course it was a little more difficult to get a passport, and so on, but it wasn't too bad. The Chinese Government had already moved in.

MERTZ:

I see. I was thinking maybe the Japanese Government—

WOO:

The Japanese Government did not take over the administration of the international settlement or French concession.

MERTZ:

Oh, I see. So that made it possible for you as a Chinese citizen to go, to leave.

WOO:

Actually we came out using a certificate which said we were residents of Shanghai, issued by the authority of the international settlement or French concession.

MERTZ:

I see. And this was then a more or less student visa to the United States

WOO:

It was a student visa.

MERTZ:

to complete your studies with a view toward going back to China. Of course, at that point that posed a problem of going back.

WOO:

Going back, marching westward.

MERTZ:

I'm not sure where you would go back. Maybe to Nanking or somewhere.

WOO:

Well some did go, some of the people who were on the same boat with me went back to the far interior.

MERTZ:

When you left Shanghai it wasn't with a view toward going back there, was it?

WOO:

Well, no. Of course at that time we didn't really know how long the war would last.

MERTZ:

That takes us up to--You received your masters degree in 1939 and then you stayed on as a teaching assistant?

WOO:

Teaching assignment, doing graduate work, taking more courses which eventually led to the BS degree.

MERTZ:

That was in '39 and '40.

WOO:

Was there a greater degree of specialization?

WOO:

No, not really, no.

MERTZ:

But were these generally physics courses?

WOO:

I really can't remember what exact courses I took, but normally it required eight courses of which I fulfilled 4 or 5 the first year and the second, and then getting ready for some language to fulfill the language requirements, and so on.

MERTZ:

I see. These were primarily in the field of electrodynamics?

WOO:

That's right, yes. I did auditing in quantum mechanics but I did not take physics courses as such, I just sat in.

MERTZ:

I see. If I might just go back a little bit in your training in mathematics. You'd had

differential equations?

WOO:

I had differential equations, yes, and I don't remember whether the first year or second year I had numerical mathematics, or just what, by Howard Aiken.

MERTZ:

So numerical analysis...

WOO:

At that time it was still pretty crude.

MERTZ:

Did this intrigue you?

WOO:

Not particularly, no.

MERTZ:

I take it, this was in a theoretical sense that he was--or was he? He was working on his machine.

WOO:

Well, outside, like the Newton-Raphson's--no, no machines. Numerical computation.

MERTZ:

Did you do any computational problems on hand calculators at all? Fridens or Marchants?

WOO:

No. I haven't done very much now, either. [Chuckle]. I was more interested, really, in the theoretical.

MERTZ:

At the end of the next year--I was also interested, given the war in China and the circumstances, this posed some, perhaps, financial problems in coming to the United

States.

WOO:

I was OK because my family at the time when I came out had--because back in those days things didn't cost as much, \$400 for tuition at Harvard. So I had enough expenses for four years.

MERTZ:

Oh, I see.

WOO:

Beginning the second year, I began to have either some scholarship or fellowship, I was beginning to have some income, so I was all right.

MERTZ:

So that made it possible then for you to continue with your studies. After your first year as a teaching assistant, continuing your graduate studies in '39 and '40. You then went to RCA as a student engineer?

WOO:

RCA as a student engineer. It's part of a--that was actually because at that time the Chinese Government began to buy a lot of material from this country and this was one part of the program where they sent some students to different places and I got in one of those programs.

MERTZ:

It wasn't through Harvard, any connection between Harvard and RCA?

WOO:

No.

MERTZ:

Was there any particular reason why you were interested in being a student engineer at RCA?

WOO:

That was the only way you could even get into a manufacturing plant for a Chinese at

that time.

MERTZ:

Oh, I see. This was the only way in connection with the student visa. I see. And the work there was with vacuum tubes?

WOO:

Actually manufacturing, going to different parts of the plant where different vacuum tubes are made.

MERTZ:

This was quite a change from your earlier, more theoretical background.

WOO:

That's, yes, that's true. Actually the theoretical background was my own interest which I was pursuing myself. The courses are more practical. Of course, back in those days things were much more--even so-called theoretical were not that theoretical.

MERTZ:

But here, this is actually production of components.

WOO:

Yes. In the Chinese--At that time this was the only way we could get--we needed the production more, straight engineering and the production.

MERTZ:

This was with a view toward establishing facilities in China to produce vacuum tube technology. Did this go a full year or was this sort of an academic year?

WOO:

Almost a full year. Actually I only spent nine months or ten months in the tube plant and the rest at the radio receiver in Camden. First was in Harrison and the next summer in Camden, New Jersey.

MERTZ:

This is about the time that RCA, I believe, set up its research facility at Princeton, approximately 1940 or 41.

WOO:

I was not aware.

MERTZ:

I'm not sure of this.

WOO:

I was not aware of that because I really did not have anything to do with it at that time.

MERTZ:

It had been in Camden, I believe, and then it was moved up to Princeton when they built the research facility there. Did you get involved in any testing of tubes.

WOO:

Yes, that was part of it.

MERTZ:

Sort of quality control?

WOO:

Quality control, yes, and also some engineering, engineering production.

MERTZ:

Was this something that was sort of new to you?

WOO:

Yes, very new. There was another man who was with me, there were two of us.

MERTZ:

Oh, I see. Both student engineers?

WOO:

Yes, that's right. He happens to be in the Boston area again. He went into the microwave tubes. He is now quite an authority on the microwave tube.

MERTZ:

I see. Who is he?

WOO:

Dr. C. C. Wang. W-A-N-G. He is not the same Wang. He is now with Sperry-Rand Research Laboratory here.

MERTZ:

Well, then, at the end of this year, the student engineering thing?

WOO:

Then I came back to Harvard.

MERTZ:

Then you came back as a graduate student.

WOO:

As a graduate student. I think I had a half time fellowship.

MERTZ:

Had you finished all your course work by this time?

WOO:

By this time, yes.

MERTZ:

Then you were thinking about your dissertation.

WOO:

My thesis, that's right. It really took a long time for me find any subject on which I'm really, I really wanted to do.

MERTZ:

That is interesting. Did you talk to various professors

WOO:

Yes.

MERTZ:

or had you pretty well, by that time

WOO:

No, I didn't have any

MERTZ:

fixed on

WOO:

No, I didn't have any fix. And then, also, just about that time, the war came, and I was involved in the teaching of the radar school, which was practically full time.

MERTZ:

Yes. So you actually had two activities that you were doing at the same time; one was teaching in the radar school and finishing—

WOO:

And beginning to think about my choice. And there was, I guess, I diddle-daddled quite a long time.

MERTZ:

Were you undecided as to whether you wanted to pursue a theoretical problem?

WOO:

I guess I couldn't find any subject which I was really interested in or which the professor was interested in. My final thing which I wrote, and that's where Howard Aiken's and my path crossed again, his doctoral thesis was on a cylindrical diode, the space charge effect in a cylindrical diode, more or less on the dc steady state condition. And I wrote my thesis also on the cylindrical diode, but a space charge effect on the high freq--the transit time effect. And therefore I used part of his, the DC state, in other words it's going on from there.

MERTZ:

Yes.

WOO:

And it's a numerical problem. So maybe that that was the time when I began to get interested.

MERTZ:

I see.

WOO:

So it's the solution of a nonlinear differential equation using numerical methods. Also looking at this at the present time, it's a very crude way of doing it.

MERTZ:

One can only judge things in terms of what was then the state of things. One thing that is perhaps interesting: Did you come upon this problem--you might want to describe how it was you came upon it.

WOO:

I guess there was a book at that time published by, I don't remember whether it was Luellen [?] or Van Buren [?], a space charge effect on parallel diodes. And, so I took a cylindrical diode.

MERTZ:

Ah, as another case. Did you know that Howard Aiken was actually, was working on, or did you just—

WOO:

Well, on the steady state, yes.

MERTZ:

I see.

WOO:

But I mean that was his, his thesis was available.

MERTZ:

So you were building a little bit on that. When you were teaching, was this for the Navy?

WOO:

It's Army-Navy

MERTZ:

Oh, combined.

WOO:

yes.

MERTZ:

I see.

WOO:

At that time there was a, I think it started in 1942, there were two radar schools, one at MIT which was more advanced and the one at Harvard was one starting really from scratch for the officers, Army-Navy officers. We gave them about three months' training starting from the elementary, most elementary electronics vacuum tube, in fact, it was all vacuum tubes; three months, and then later on they finished at MIT where they had the actual radar.

MERTZ:

I see. Did this bring you into contact at all with any of the people over at the Radiation Laboratory?

WOO:

Not really, because the Radiation Laboratory was under very high security.

MERTZ:

This was a full time job, the radar school?

WOO:

Yes.

MERTZ:

About when did you fix on your dissertation?

WOO:

I guess, it must be about 194-, the latter part of 1942, early, I guess it must be, no, let's see now, about the middle of 1943 I suppose. I guess once I decided it went along pretty fast.

MERTZ:

Pretty fast. Well, I was going to say that you didn't lose any time at all on your master's degree coming from Shanghai.

WOO:

My problem is this. I find myself, I'm very poor in writing. And I just hate to do writing, writing things. And so when it came to writing a thesis I thought this is not a very interesting subject, so what's so great about that, and it was difficult to find something I was really interested in and also interesting enough to put it down.

MERTZ:

Yes, but I was thinking in connection with the earlier part of your program, did you encounter any serious language problems when you came?

WOO:

No, I have no language problem. I have more trouble with Chinese than English.

MERTZ:

But when you came in 1938?

WOO:

Because of my own family situation, English was strong, I was strongly English. Let me put it this way. I was better in English for an American at the same period in college as I was with Chinese.

MERTZ:

I see. Because very often this can be a serious problem where you lose a year or two, a

year or two in more or less acquiring enough facility.

WOO:

In general, at least among the people around here, it's not so. There are many whose English is very bad and they may even have been here ten or twenty years they are still very bad, but usually their reading is pretty good, and usually they will be studying something in which the language itself, or at least the spoken part, is not that important.

MERTZ:

Mathematics.

WOO:

Yes, in mathematics you really don't require too much English.

MERTZ:

But when it comes to writing a thesis or dissertation, this is a problem.

WOO:

In my case my difficulty was not because it was English rather than Chinese. I would have even more trouble if I have to write in Chinese.

MERTZ:

I see. And once you did fix on it you really didn't spend too much time on finishing it. Did you continue throughout all that time to teach at the radar school?

WOO:

Yes.

MERTZ:

So you were doing this, really, as a part-time activity on the side. Who were your principal advisors?

WOO:

Ronald King, but actually he didn't contribute very much. You know, I was pretty much on my own. Howard Aiken was on the final examination committee.

MERTZ:

I see. Now involved in this were some computational problems.

WOO:

I did them by hand.

MERTZ:

You did them by hand. I see. You didn't use

WOO:

Didn't even use calculators.

MERTZ:

Hand calculators, desk calculators. I see.

WOO:

It was a, principally using, solving a differential equation using the Taylor series, integration by Taylor series. It's a partial differential equation and, now I don't even remember, I remember--separate the two variables and solve the motion against time.

MERTZ:

Now, Howard Aiken was on your examining—

WOO:

He was only on the examining committee. He did not help me in the actual work.

MERTZ:

But it was on a subject that he had done work on and it did involve computational problems, so did this attract his attention to you?

WOO:

I don't know whether it did or not, but I guess I was known to him from the very beginning. Whether that contributed more, I don't, I imagine it might.

MERTZ:

So then, you actually completed your degree before the end of the war.

WOO:

That is correct, yes. Then the radar school continued on.

MERTZ:

I see.

WOO:

And then, when the war stopped, there was a change in the radar school and there was a sort of a research laboratory. I guess, looking at it from this point now, it's probably it's part of the demobilization program and so there was a, what was called a Central Scientific Laboratory, something like this, or Central Computation Laboratory run by Harvard right from the end of the war, end of the radar school until about 1945 or '46.

MERTZ:

There is a, well, I was going to ask you, after you completed your doctorate, and did you continue any other activity aside from teaching at the radar school?

WOO:

No.

MERTZ:

Did you have any particular research project?

WOO:

I don't remember now when the radar school actually finished and I did some work on antennas, which was Ronald King's special activity.

MERTZ:

Yes, now, was this in propagation theory?

WOO:

His work, at least in that period, was the current distribution on a linear antenna.

MERTZ:

You worked for him for a while?

WOO:

Yes, that's right. And again I didn't find it very interesting.

MERTZ:

What kind of work?

WOO:

I recall one thing we did was measuring the current distribution on a model airplane, using some probe, trying to measure the current that passed different parts of the airplane. Also what is the directional pattern of a particular way of exciting an antenna or of a particular kind of antenna when it's excited with certain impulses. What is the direction?

MERTZ:

I see. The shape of the—

WOO:

Yes. And using the microwave tube so we can take a measurement on a much smaller scale.

MERTZ:

I see. How long were you involved in this activity?

WOO:

I don't--I guess I was involved until about 1946.

MERTZ:

And this was after the radar school closed?

WOO:

Yes.

MERTZ:

So this was in this center for communications research. Did you continue--now at this point in the development of computers, at the time, several things were happening which became quite well-known generally, such as the ENIAC was running and big plans for other machines were in the mill, so to speak.

WOO:

I didn't get into that area at all. I didn't get into computers until 1947.

MERTZ:

Which is very near the time when the Mark I was running.

WOO:

Mark I was already in existence.

MERTZ:

In existence.

WOO:

Mark I--during the radar school days Mark I was being built down in the basement. My office was up in the so-called Cruft Laboratory. Howard Aiken was building the Mark I computer and I guess using it back in 1942, '43. I didn't even know that was going on. Everything was locked and so on. Then I think it was about 1946, maybe '45 or so, the wraps were taken off. Let me give you more names so I don't forget. One man who was very much involved with Mark I is Richard Bloch.

MERTZ:

B-L-O-C-K?

WOO:

B-L-O-C-H.

MERTZ:

C-H.

WOO:

Do you have that name? If you're going to follow that, you must, that name must ... Another name is Bob Campbell. C-A-M-P-B-E-L-L.

MERTZ:

I see. And now, Bloch was an engineer?

WOO:

He was a mathematician. Actually he had a BA in math; a major in mathematics, I guess.

MERTZ:

Is he still in the Boston area?

WOO:

He lives in the Boston area and he was a very senior man in the GE computer group. His name will come back again. Campbell, the last I heard, is now at Mitre.

MERTZ:

Out at Bedford.

WOO:

Yes. Both Campbell and Bloch were Navy men, and they were attached to us. Howard Aiken was a Navy man.

MERTZ:

Yes. Well, then in '46 you became much more aware of what was going on in the basement of Cruft, I take it.

WOO:

I guess so. In '46, I was about to leave Harvard,

MERTZ:

I see.

WOO:

and I was about to go to Bell Telephone Labs to work in the field of--something to do with propagation, they were starting a laboratory in Homeville. At that time I was playing with the microwave thing and I got a job offer, and I quit Harvard, and I was all ready to go. Then in the physical examination they found I had TB, so there was the interruption. So I came back to Harvard and I think I was, I don't even know what position I held, and in early '47 I went to the hospital for about four months.

MERTZ:

Oh, I see, you also, I believe got married

WOO:

Yes, 1944. That's right.

MERTZ:

about the time. Was it after you graduated or just before you graduated?

WOO:

In 1944. We were married in June and that was the time I also received my degree. I went to the commencement exercises right after we were married, married about a week.

MERTZ:

So those two events were quite close in time. When you decided to go to Bell, this was the first you learned of the TB?

WOO:

That's right. Right after the war ended we thought we might be going back.

MERTZ:

I meant to ask this question about your student visa.

WOO:

The visa at that point was not too much of a--by that time I was teaching and had teaching status, so I guess I was not on a student visa any more. I don't remember, apparently, at that time I didn't have any trouble to remain.

MERTZ:

Did they have some sort of exception for scientists?

WOO:

I think that was beginning to happen. I just can't recall why no one told me it was time for me to go back. I guess at that time the situation was still quite in turmoil.

MERTZ:

In 1946-47. In China it was.

WOO:

I guess at that time I was about ready to go back and my father wrote me, don't come back. Everything is not so good.

MERTZ:

Did any members of your family come with you to the United States.

WOO:

No.

MERTZ:

You came alone then. Were you able to keep in touch with them throughout most of this time?

WOO:

During the war? Well, during the war I guess for a while I didn't have any news until around 1942 or so, there was some correspondence via International Red Cross, 1943 or 1944 there were some letters, one or two letters.

MERTZ:

So you did finally get some letters.

WOO:

That's right, yes.

MERTZ:

So then your father wrote you and advised you?

WOO:

VJ-Day we thought we might be going home but then my father said "don't come home."

MERTZ:

I see. Then, so that there was no problem here apparently.

WOO:

That's right.

MERTZ:

Did you have to go anywhere in particular when it was learned that you did have TB?

WOO:

Yes. In 1947 I spent three months or four months in a sanitarium right nearby here.

MERTZ:

I see. Well, apparently they caught it in a fairly early stage, before it developed..

WOO:

That's right. I had another session later on.

MERTZ:

When you completed the stay at the sanitarium...oh

WOO:

Then I was about to go to another job. In fact I was offered the job at Sperry Rand, it was not Sperry Rand at that time it was Sperry Gyroscope Company

MERTZ:

Was this in New York?

WOO:

In New York, Lake Success. I had the offer of a job and I was about ready to go. In fact, I was going to send my acceptance Monday and I think it was the Saturday before, the Friday or Saturday before I was going to write the acceptance that Howard Aiken called me.

MERTZ:

Ah.

WOO:

That's how I

MERTZ:

And he made this?

WOO:

And he offered me a job in the Computation Lab and that's how I got into it.

MERTZ:

One question that comes to mind here. Was his offer economically competitive with what you had been offered?

WOO:

I guess it was.

MERTZ:

That's interesting. Sometimes it isn't. Particularly in academic

WOO:

That's right, yes. It was about \$6,000 a year. I guess when he called and I said I was about ready to go and I had an offer, I guess he said "OK, we'll pay you the same thing." I don't recall the exact figure. I had to take a little sacrifice at a later date, but not at that point.

MERTZ:

What did he envision your doing?

WOO:

Well, he said, "I am building a computer," and I didn't know anything about a computer at that time.

MERTZ:

He wasn't talking about the Mark I, because that was already running.

WOO:

That's right. It was the Mark III.

MERTZ:

So then you were well enough to accept it.

WOO:

That's right. I joined him about August or September.

MERTZ:

And was this a fairly sizeable group?

[Recorder off]

MERTZ:

This is the commencement of side two.

WOO:

Let's see, now, where are we. We are talking about 1947.

MERTZ:

You had accepted Howard Aiken's offer.

WOO:

Yes. OK. When I joined the Computer Laboratory we were working on the Mark III and I think the Mark II was just about being readied for shipment. I may be wrong but I think this is right. The Mark I was sitting in the--at that time there was a new laboratory which is now called Howard Aiken Laboratory, but at that time it was called Computation Laboratory. Mark I was sitting there and Mark II, I believe, was being readied for shipment. There was a crew who was to maintain the Mark II, and there are some names in which you might be interested. One was them was Frederick Miller. M-I-L-L-E-R. He is now a Vice President at the Honeywell Information Systems. Robert Rouse, who is also a, he is not a vice president but he is in charge of quite a big group at Honeywell, plus some other men and they were about to move to Dahlgren where the Mark II was destined to go.

MERTZ:

I see. Had they been associated in the design and building of the Mark II or were they largely, primarily in terms of maintaining it.

WOO:

I rather doubt they were involved in the design, but I don't know. Now, Both Fred Miller and Bob Rouse are in this area.

MERTZ:

In the Boston area?

WOO:

In the Boston area.

MERTZ:

How far along was the Mark III when you joined them?

WOO:

Very rudimentary, just had somewhere the idea. It was a paper machine. It was decided to be a drum calculator. I think the organization of the computer was pretty much set.

MERTZ:

The logic of the machine?

WOO:

The logic, the over-all system: We will have some tape, we will have a drum, and we will have so many numbers of storage,

MERTZ:

The word length would be?

WOO:

Yes, that was all decided by the time I joined.

MERTZ:

Who was already associated with the project at that time?

WOO:

The second in command at the time when I joined was Dr. Benjamin Moore.

M-O-O-R-E. I think he is still at Los Alamos, He is a physicist, and I know at least two to three years ago he was still there. ... I believe he is still there. He was the Associate Director. Some people who were already there: Charles Coolidge and Marshall Kincaid. They now have a company called C&K; Coolidge and Kincaid. Another man that was there was Richard Hofheimer. H-O-F-H-E-I-M-E-R. The last I heard, about 5 or 6 years ago, he was in the Los Angeles area, I think it's now linear system or something, something to do with a digital alternator.

MERTZ:

I see. Was the work on the Mark III broken down in any particular way at this time?

WOO:

Not really. Mostly we got involved with everything.

MERTZ:

I see. Well, this, for you, was a sort of educational experience as well as a research experience.

WOO:

That's right. I learned and I did. I think I was probably the senior technical man. Ben Moore and myself. Aiken had his ideas, more on the logic, and then we actually went out and designed and built the thing.

MERTZ:

I see. Well now, this was something of a change for you.

WOO:

That's right. I had to do almost everything.

MERTZ:

Where did you turn to acquire your expertise? I gather you couldn't turn to Mark I, really.

WOO:

Well, actually we pretty much tried to figure it out ourselves.

MERTZ:

In that connection, was circuitry, I take it, and

WOO:

We developed our circuitry and we had to develop our logical, the detail of logical design.

MERTZ:

The general logical design had already been decided on.

WOO:

The system design had been decided upon, but we had to work out all the details.

MERTZ:

So in that regard Moore was more responsible for the—

WOO:

He partly had to handle the administrative work, and he and I sat in the same office and we really were, I think I was probably more involved in the technical end.

MERTZ:

If there were a position such as chief engineer on the project

WOO:

yeah, I might be called that.

MERTZ:

You might be called that. I see. Was the group at first a fairly small group of people?

WOO:

Yes, I would say six to eight people. Another name is Robert Wilkins.

MERTZ:

W-I-L-K-I-N-S?

WOO:

Yes. He is now presently with Honeywell.

MERTZ:

Now, most of these people were already there?

WOO:

These people were there already. There's another man, and I don't know where he is now, named Frank Innes. The last I heard, which was about ten years ago, he was with Burroughs.

MERTZ:

Auerbach might know.

WOO:

He may or may not know.

MERTZ:

We have a Burroughs guidance computer at the Smithsonian, so someone at Burroughs would know. This formed the nucleus more or less of the group.

WOO:

I guess I have named about all the professional men. Back in those days things can happen faster and easier than they can now.

MERTZ:

Did you have relations, or was it Moore's position, relations primarily with, for the industrial support for the project?

WOO:

I don't understand. Say that again.

MERTZ:

Well, for the support for the project, that is to say, did you get components from industry?

WOO:

Actually, it was a government sponsored--actually, the government paid for the computer and whatever R&D work that went into it.

MERTZ:

The procurement was handled primarily by Moore?

WOO:

Don't know. I don't think Moore himself would be involved. I think probably Howard Aiken did the initial handling. The detail was handled, at that time at Harvard, there was a government contract group which handled details like that.

MERTZ:

I see. Thus leaving you and the others on the project more or less free.

WOO:

We didn't have to worry about accounting and all that.

MERTZ:

How did the project proceed in terms of people, what they finally, eventually did on each area of activity. Did they become more, concentrate more on specific problems as time went on?

WOO:

Well, I guess so.

MERTZ:

First of all, may I ask, what did you view initially after you familiarized yourself with the Mark III and its general system as the key problems associated with the machine?

WOO:

One, of course, was to use the drum as a storage, getting information on and off the drum. At the time when I joined, Harvard certainly had not--and I don't know whether other people had, I suspect they did not, but maybe independently somebody else might have had it--but later on there was a patent involved on drums and so on.

MERTZ:

Was this the random access—

WOO:

No. The random, the core is another subject. The drum was a subject which .. at the time when I joined, Harvard certainly hadn't one.

MERTZ:

Well, ERA, didn't they have a buffered drum?

WOO:

No. They came later. In fact, their people came and I don't remember—

MERTZ:

It was later, yes.

WOO:

They came to visit us and I think Norris was one of them. I don't remember now. Oh, another name is Rubinoff. Rubinoff was there at the time and he was another senior man, and he was senior more to me because he was there a little bit. I guess he left a little before me too. He was not a 100 percent Computer Laboratory staff.

Now, as I said, the system organization was pretty much defined by Howard Aiken. Let me digress for one moment. Howard Aiken is a very strong personality. Therefore this was the way he visualized it and this was the way the machine was going to be. Therefore I would say that I myself contributed very little and probably Bill Moore, and so on didn't contribute very much either on the system organization. But as far as implementation on the hardware was concerned, that was being done all for the first time. I recall some--certainly at the time I joined it was not an accomplished fact that you could put information on the drum and take information off. The idea of having a synchronizing clock pulse I think was there before I joined. So we recorded information using the clock pulses, but it had never been accomplished until I got there and I recall one of the experiments which I was involved in was to put one bit on there and try to circulate it. Put on the information bit and then--in this particular case in the drum one of the things required was regeneration, so the access time is less than a full revolution. The registers consist of a re-circulating loop on a drum, on a section of the drum.

MERTZ:

And read-out erased it?

WOO:

Read out and then write it by the writing head, which is one-twelfth or one-twentieth of a revolution.

MERTZ:

Aha. But, excuse me, in the process of reading out it would erase.

WOO:

The writing is writing on top of that, so there is no erasing. It is writing over the old information. There was no erasing in the Mark III drum calculator. The idea of using the clock pulses and to regenerate, that's all there before I arrived, by the time I was involved in it, it was all there. But it had never been accomplished, to get the information out and to re-circulate it. I think I recall that I'm the one that made it work.

At that time we were having a mysterious situation where a bit somehow got lost. You put a one in there and let it re-circulate and every once in a while you find the thing is gone. I don't remember the details, but I remember I was the one that finally diagnosed why it did so and from that point on it became possible. It had something to do with, I think I finally pinned down how it really got lost and therefore from which you can get a remedy. I think what I did was I finally devised some experiments to see, to observe how you have become marginal and eventually lose it.

MERTZ:

I see.

WOO:

Even though it's very slow, we're talking about milliseconds, in terms of the experiment, you turn it on and later on it's gone. I was the one who pinned down the process of how it was lost and therefore fixed the thing. I think it was a question of timing. The spacing of the tube head and the timing.

MERTZ:

I see. This then was something you were working on in 1948.

WOO:

I guess it must have been early 1948. In late 1947 I joined in September or something like that of '47.

MERTZ:

There were several other computer projects going on in the country at the time. They

also faced one of the big problems at the time, storage or memory, both access to it and the problem of synchronous machine. Then to use this clock pulse. The reliance up to that time and even then was still placed on external memories that were asynchronous, or the acoustic delay.

WOO:

That's right. I didn't know that acoustic delay line was being worked on at that time. That was 1947, I don't remember now.

MERTZ:

At least there was some talk of this, but it essentially was slow and required serial machines.

WOO:

We were then working on serial machines.

MERTZ:

But also the other problem was that it was asynchronous to get to that memory so it was essentially an external memory. About when was this actually working?

WOO:

When we finally found we could get the information on or off I would suspect it must have been the spring of '48. I am very poor in keeping records of dates and even in most cases I didn't work on it directly. It was usually somebody else working on it and then I'd watch them and tell them what to do. I don't remember who it was that actually worked on that.

MERTZ:

Oh, I see. Well, would they have written some reports at all?

WOO:

I don't remember now. Later on there was. At that time I was already away from there, but in 1952-53 there was a question on the patent of the drum storage. Who had the first one. I think it was Burroughs who claimed it first. And then, Howard Aiken has an aversion to talking about patents, so he didn't want to talk about patents at all. So I think Harvard by its action had given up everything. Whether it was really antecedent to the other one I really don't know.

MERTZ:

Aiken's disinterest in this didn't help make more accurate who was first.

WOO:

All Aiken wanted was the thing to work.

MERTZ:

It didn't make any difference whether it was patented or not.

WOO:

I don't know whether there was a notebook that's being kept by anybody or not.

MERTZ:

Did you use graduate students to work on it?

WOO:

Not very much. It could be Coolidge or Kincaid or Frank Innes and/or Richard Hofheimer. It's, probably, it's one of the four that were involved in actually doing it. Coolidge went on to get a PhD degree; the others did not. You might say they were sort of equivalent to a graduate student, but they were not actually at that time taking courses.

MERTZ:

So they were practicing engineers.

WOO:

That's right. yes.

MERTZ:

Were there any other areas, problem areas that you recall, or resolutions, of Mark III?

WOO:

I think I recall that I myself personally developed the input-output using the recirculation way, how to get it in the, what do you call it? In one way it is re-circulating and then you pick one out so the thing advanced. A way of getting out on an external thing and a thing which is much lower rate. So you pick out a digit and then later on, when it's ready, pick out another digit. Every time you pick out a digit the thing advanced a stage. A sort of shifting. I think I remember I did some--I guess I was masterminding how it's done

without actually working out the details.

Now one interesting anecdote about that time, I don't know that was late '48 or possibly early '49, it must be late '48, I guess, where we were beginning to have, actually making the big drums. The bits per inch, the track density, and so on, they were all fixed by Aiken before I went, at least I remember I did not make too much argument about it. And because of the very low density--I was trying to think about this last night as a matter of fact, whether it was ten bits per inch, or whether it was twenty bits per inch I don't remember. It should be in a book that was written, which would describe how many bits per inch, how many tracks per linear inch. Anyway for the amount of storage required we ended up using eight drums and each drum was three feet long, about eight inches long. I think four of them were driven by one motor. It's supposed to be all moving synchronously and I don't now remember how eight drums were tied together. I remember four were driven through some kind of gearing, but how this four and the other four moved together, I don't remember. But anyway, that was a very big piece when you think about it. Three foot long drum. I think the first experimental one was made of aluminum and then somehow Aiken thought it should be made of more plastic material, by plastic I mean a very gentle, something like Bakelite, I don't remember what the material it was.

MERTZ:

But a non-metallic

WOO:

Nonmetallic. I don't remember why he wanted to try that, but in any case one of the things I was involved in at that point for quite a while was the dynamic balancing caused by this thing. When the thing is moving there is some sort of a lateral expansion and a whipping kind of thing and we all had to use whatever knowledge of physics we had to try to apply to it and I guess finally we abandoned the plastic material, the nonmetallic material and I think the arm control was stainless steel.

And then also we didn't know how to coat a drum. The drum was to be coated with magnetic drop sites. And I recall that sometime during the middle of '48 or early '49 we had asked Minnesota Mining to help us and they sent a girl down with a paint brush and painted the surfaces of the drum. And then we had one of the bachelor men entertain the girl and I think it was Frank Innes who did that.

MERTZ:

Cupid in the computer.

WOO:

I think she spent two or three days here and that's not the way that we finally did it.

MERTZ:

That was not a uniform

WOO:

That's right.

MERTZ:

Problems I suppose. Who did you rely on mostly to produce, to manufacture?

WOO:

Well, the mechanical engineer was Robert Wilkins.

MERTZ:

Was this done in-house or did you go outside?

WOO:

The fabrication? It was done outside, yes.

MERTZ:

Was it done locally in Boston?

WOO:

I don't know. Robert Wilkins would know.

MERTZ:

They drew up the specifications?

WOO:

I guess so, yes.

MERTZ:

Were there any other problems in circuitry or had those been pretty well worked out?

WOO:

I think that we had the format of the circuitry, using a double triode for flip-flop gate and using a pentode as a tube AND gate.

MERTZ:

As to tube reliability ..

WOO:

I don't remember that we did very much study on that.

MERTZ:

But that would be certainly a consideration.

WOO:

It would be a consideration and I think Howard Aiken's philosophy was that everything, just make it an ultra-conservative kind of thing, which may not be the right thing to do when you look backward. But I don't recall that we did anything statistically on tube reliability.

MERTZ:

Do you recall the principal tubes that were used in the flip-flops?

WOO:

I don't recall, it could be one of the 6SN7, I think it was one of the 6NS7, but that should be very easy if we can find the Harvard book on how the Mark III calculator was made.

MERTZ:

So the gate circuitry and the flip-flop circuitry was not a problem.

WOO:

I don't think it was original with Harvard.

MERTZ:

Now one question would be, for example, certain other things. How about the circuitry for the memory, for the drum, the access?

WOO:

This we developed.

MERTZ:

How about the circuitry for the pulse transformer, and this?

WOO:

We used very little pulse transformers. Aiken had an aversion to use of inductances and capacities. He believed in direct coupling.

MERTZ:

Aha.

WOO:

Now I don't remember whether we used capacities in modifying or not, I'm sure we must have used the tube to get certain timing, but he didn't believe in that. And diodes, he didn't believe in them, at least in the early days, the Mark III days. Later on, of course he changed.

MERTZ:

So the arithmetic of the machines was ..

WOO:

Decimel arithmetic machines.

MERTZ:

It was decimal. But it didn't cause any particular big problem as such?

WOO:

You mean in the hardware area?

MERTZ:

In terms of hardware or circuitry or design.

WOO:

I don't recall.

MERTZ:

The memory was transformer memory, I assume.

WOO:

We also had some of the output going to a tape.

MERTZ:

Aha. Yes, I was going to

WOO:

Tape reader and so on. That was one of the problems I was involved in.

MERTZ:

How about input. Were there any particular problems so far as input was concerned?

WOO:

Input ..

MERTZ:

Well, you did mention an external memory.

WOO:

Goes into the paper tape. At that time the machine [was] delivered with a tape on a paper base as I recall. We had to design our own tape transport, of course.

MERTZ:

About how long was it until the machine was fully operational, running problems. By that I mean not test problems or demonstration.

WOO:

We had a symposium in September 1949 and I certainly recall at that point it was operational. Now how far back it could be considered as operating I don't remember. I do remember one occasion when Von Neumann came and he looked at the machine and said "is it really adding"?

MERTZ:

He was fascinated by the activities at many bureaus. At this time were you also doing any teaching?

WOO:

No, I did not. I did in 1949, I did teach.

MERTZ:

'49. So, for the first couple of years, '47-48-49 you were primarily full-time working in research, working on the machine itself. Then in '49 you started teaching. Is it at that point you were appointed assistant professor in applied physics? And what did you offer at that point?

WOO:

I taught numerical calculus, or numerical mathematics. I never had any myself. I had to work up it all.

MERTZ:

You had been exposed sort of, to Howard Aiken's course some years before, but things had changed a lot.

WOO:

Yes.

MERTZ:

Were you familiar with Hartree or the work of some of the others?

WOO:

Not really. I did meet Hartree on one of his visits.

MERTZ:

There were several, I imagine, from England who came over.

WOO:

Yes. was one of them, and both. There were quite a lot of visitors then, as I say, and I think Norris was one of them. I can't be sure but there was another man who definitely did come, I think it was Jim Myers who did marketing in the very early days of Control

Data, they were part of ERA at that time, this must be about '48 or early '49.

MERTZ:

I see. Now what kinds of problems, if we can talk a little about programming...

WOO:

Very little programming at that time. Everything was done in individual codes. Another person who had a lot to do with the Mark I was Grace Hopper.

MERTZ:

She did some compiler .

WOO:

Yes, and she was involved in the Harvard Mark I. When I joined I think she was also active. I don't remember what was my relationship to her.

MERTZ:

Were there any particular classes of problems that were run on the Mark III initially?

WOO:

There wasn't really much of a problem run on the Mark III by the time the machine it was shipped. It went to Dahlgren and was used for ballistic problems.

MERTZ:

Did they develop any diagnostic procedures for Mark III, so far as error, troubleshooting, was concerned?

WOO:

All that came later.

MERTZ:

I was also wondering about the training of maintenance engineers. Were they trained at Harvard?

WOO:

I don't think so.

MERTZ:

Were there any of them you feel might be interesting to talk about subsequent use of the machine?

WOO:

The man whom I talked about, Fred Miller, he ran the Mark II and Mark III went there too. So therefore he would be the man as well as Wells, Miller and Wells, and they are now both at Honeywell. I do remember at that time we trained some men. I guess one of the men who became quite well known, too, a man by the name of Grant Poorte. P-O-O-R-T-E. I think he's still with RCA. He was one of the technicians who went to Dahlgren, and then later on he left and went to RCA. I think he had something to do, maybe quite a lot to do, with the design of the BIZMAC, or maybe the following BIZMAC, I'm not sure.

MERTZ:

Did you stay on then at Harvard, in '49 and?

WOO:

Now, let's see. There was some other development. Around late '48, around the middle of '48, the Computation Lab got another contract from the Air Force and we were developing certain components. One of the contributions of that was the magnetic shift register and that's a subject all by itself. It was also announced in 1949.

MERTZ:

This is something that you were very directly involved in?

WOO:

Yes.

MERTZ:

And that was published in-

WOO:

That was delivered orally in Physical Society in April 1949.

MERTZ:

Who was associated with you on this work, most closely?

WOO:

This was with Dr. An Wang.

MERTZ:

Was this more or less a joint project?

WOO:

Yes, we had a lot of contact.

MERTZ:

You stayed on at Harvard?

WOO:

In 1949, I think, the Mark III was about ready to be shipped. That's the time I was having trouble with my health.

MERTZ:

Oh, in '49.

WOO:

In '49. So, the first semester I was teaching one course in numerical analysis and that's the time I also was told to be careful.

MERTZ:

This is again the TB?

WOO:

So in 1950 I went into the hospital again, so in 1950, in June I entered the hospital again. For a year, for 15 months. And that's a long time.

MERTZ:

Oh, that's a long time. Was it here in Massachusetts? And did you do any work while you were there?

WOO:

No, I stayed in bed.

MERTZ:

That's very difficult. So that was over a year.

WOO:

That's right. I came out in 1951 and I went back to teach a course. In 1952 I joined them again.

MERTZ:

You returned to Harvard

WOO:

One semester.

MERTZ:

in 1951. This brings us up to a point in your career and also a time limit.

WOO:

So I didn't have very much to do with the Mark IV development. It happened at the time when I was in the hospital and I was very inactive.

MERTZ:

Yes. We might just--in terms of your family, this also covers a period of civil war in China...

WOO:

By that time, the Communists had taken over.

MERTZ:

In 1949. Then did you hear anything more about how your family was?

WOO:

There was still mail that you could get through. We talk less and less about anything,

MERTZ:

only how you are.

WOO:

How you are.

MERTZ:

But they are still well and they survived all the turmoil.

WOO:

Yeah.

MERTZ:

And your own family is growing, I take it.

WOO:

That's right. My first child was born in '45, second one in '48, the third one in 1950, a month or so before I went into the hospital.

MERTZ:

The third is your son, David, who is now a junior at Harvard.

MERTZ:

Do any of your children show any interest in computers?

WOO:

Not in the computer as such. All are pretty scientifically minded and I guess David would be a natural candidate to go into physics or computer but right now he's not

interested in that; he's more interested in social, maybe in social relations. [Laugh].

MERTZ:

Oh, I see. And your two older daughters?

WOO:

The older one is in pharmacology and she hopes to get her PhD before next summer. My second one, she just started first year medical school at Stanford.

MERTZ:

And they are both at Stanford?

WOO:

They are both at Stanford.

MERTZ:

And the other two?

WOO:

Of course at the present time getting a job in the science field, it doesn't seem to be the hot field any more.

MERTZ:

Not right at the moment, but perhaps, as you mentioned earlier, engineering might be.

[End of Interview]