Computer Oral History Collection, 1969-1973, 1977

Interviewee: Sidney Greenwald
Interviewer: Richard R. Mertz
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MERTZ:

This is an interview conducted at the Rabinow Division of the Control Data Corporation in Rockville, Maryland on the 25th of November 1970 by R. R. Mertz. The interviewee is Mr. Sidney Greenwald: G-R-E-E-N-W-A-L-D. Mr. Greenwald, would you like to describe your early training and experience, education, with some indication as to how you eventually got involved with computing machines?

GREENWALD:

Well, I would say, so far as the general field, I think that some of the aspects of getting into it were accidental. I think, as a child, teenager growing up, I had two main interests: one was sort of generally in science and the other was music. And, as a matter of fact, for some time I did consider becoming a professional musician. I studied piano quite intensively; but, what with the depression and so on, and the fact that a lot of things were being automated, recordings were coming into vogue, and the fact that orchestras were being displaced because vaudeville was going out, so it seemed like there was less opportunity, and so for that reason I kind of swung away from that idea, although I still always have had an interest in music, and still to this day it is a very important part of my life actually.

MERTZ:

Could you describe--where did you go to school? Elementary and high school and university?

GREENWALD:

I went to the New York schools. Also, for some time, in New

Jersey. I graduated from Brooklyn College with a degree in physics.

MERTZ:

Did you do any special, take any special course in high school for science, or was it college?

GREENWALD:

No, I just took the general course that led to entrance to college; you know, it generally involved Latin and languages and that kind of thing, which was conventional at that time. I did take physics in high school, and math. Whatever they gave. They didn't give at that time as much as they do now. I think I went up to, like--I think for example solid geometry, which was about as far as you could go. I think they had maybe a year and a half of algebra and some solid geometry.

MERTZ:

Trigonometry?

GREENWALD:

Trigonometry. Generally, in most high schools, generally didn't go very far. They go much further today.

MERTZ:

Which high school did you graduate from?

GREENWALD:

I graduated from Erasmus Hall in Brooklyn.

MERTZ:

In Brooklyn. And then you went to Brooklyn College immediately afterwards?

GREENWALD:

Yes, that's right.

MERTZ:

Did you enroll in a liberal arts course, or was it a science course?

GREENWALD:

Well, in those days they really didn't differentiate an awful lot. It seems like everyone got a bachelor's of arts degree, and you had a particular field of interest. I think it was sort of quite accidental that I got in physics in the first place. I was interested in the physical sciences.

MERTZ:

Had you done in school relatively better in those subjects or did you do well in them?

GREENWALD:

I would say that I seemed to have some aptitude for the science courses, for mathematics. I didn't particularly like languages. I don't know if this is a common pattern.

MERTZ:

But you found science and math--

GREENWALD:

Science and math, yes, I found more to my liking.

MERTZ:

And what year did you graduate from high school?

GREENWALD:

I graduated in 1932.

MERTZ:

'32. This was just about the peak of the depression.

GREENWALD:

That's right.

MERTZ:

Two questions that are not necessarily related. Did you have any jobs that you did, either in the summer or part-time jobs?

GREENWALD:

Well, you see, that's where my music came in. As a pianist, after taking lessons quite intensively and seriously, because, I guess, I had some aptitude for this thing--you know, family think, "well, you go on a concert stage," but the chances of anything like that happening--you know, only one in a million actually gets that far. But I did have an aptitude for music and I took lessons for quite a number of years.

MERTZ:

When did you start on that?

GREENWALD:

I started when I was eight years old.

MERTZ:

And did you study under anyone--

GREENWALD:

Well, I would say no one of any great repute. The last lessons I did take, the last few years I took, were with a man who had come from Germany, who had a school in Brooklyn, sort of a conservatory, he called it, at which many instruments were taught, and he was an outstanding pianist himself. He was a man who wanted to be a concert pianist in a way that never made the grade. So few make the grade. He was--I thought, I mean, looking back, I thought he was a tremendous pianist, but there is only a very few gifted few that get to the peak. And he was below the peak and therefore completely unknown. There are no in-betweens.

MERTZ:

Many are called and few are chosen.

GREENWALD:

That's right. He was, as I say, a very fine pianist. And as I grew and got older and I realized the opportunities seemed to be diminishing in this field, I sort of lost interest in that as a profession; but I did like it so much that I continued to play. And what I did, you see, during the summers I would go to hotels and play with a band. What I did is I went away from classical music into popular music. And so I used to play on weekends, and I used to play during the summer, and this is the way I earned some money.

MERTZ:

I see. And did you do that in high school as well as in college or—

GREENWALD:

I started, you might say, playing for money, actually, when I was thirteen. And I continued that—

MERTZ:

Did you continue it on in college, too?

GREENWALD:

I continued it through college, yes.

MERTZ:

Well, in '32--so that was both an avocation and a vocation, you were both making money from something and enjoying it.

GREENWALD:

That's right. But I did not see it as a--I only saw it as a temporary thing. I saw it in the future as a means of enjoying, but not a professional thing. I felt that the odds were against it.

MERTZ:

Did you have any teachers, aside from this piano teacher, at this time, who were particularly influential in your life, that is, that tended to focus your interest in a particular field or subject? ...

GREENWALD:

Oh, I would say not in high school; although when I was going to high school--I don't know where this came from, but--I was sort of fascinated with electricity. You know, as a kid, it's an awfully mysterious thing. And I started to play with vacuum tubes, and I began to make my own little amplifiers and receivers and that kind of thing. And I'd listen at night to Chicago, or something like that, and I thought this was a great thing. I was always playing with this type of thing. Even when in high school. I did it completely alone. My family was not scientifically oriented at all.

MERTZ:

Did your family have any particular hardships during the depression?

GREENWALD:

Things were, yes, fairly rough. My father owned a store, and he, more or less--he worked seven days a week.

MERTZ:

Did this impose some kind of limitation on where you were going to go to school?

GREENWALD:

Absolutely.

MERTZ:

You could stay at home and go to--

GREENWALD:

There was no question. I couldn't go away to school. It had to be one of the local colleges where everything was paid for except a few lab fees, books, a few things like that. So I commuted daily, and this was quite a hardship. The college didn't even really have a campus. You had to go out into the street from one building to another. And one building might be seven or eight blocks away, and that kind of thing in the snow. It was hardly what you'd call a real campus-type atmosphere.

MERTZ:

More of an urban setting?

GREENWALD:

That's right.

MERTZ:

Urban campus setting. When did you fix on physics as a major?

GREENWALD:

Well, it came about--When I went to college---I don't think I really had as I recall any really outstanding teachers in high school. But as far as college, I didn't--I had taken physics in high school so I had some acquaintance with that. I enjoyed it. When I went

to college, I didn't know quite what--I knew I wanted to major in the physical sciences some way or other, so not knowing anything about chemistry, or little, I thought, well, I would start off with this. And I did, and--

MERTZ:

Had you had high school chemistry?

GREENWALD:

No. I had only high school physics and math, no chemistry. So I said, "I've got to try this." And I tried it for a term; and, I don't know whether it was due to the teachers involved or just what it was, or whether it was the cookbook approach that bothered me, whether it was the lack of a logic to it--but it didn't appeal to me at all. Then I took freshman physics, and I found suddenly, "Gee, this is great. This is marvelous. What a wonderful structure this is. You can see, derive every--derive some abstruse equation from a bunch of other things. All you've got to know is the fundamentals and you can build up on them." And I had what I thought were two very outstanding teachers in freshman physics. And that did it. This was for me.

MERTZ:

Do you remember who your teachers were?

GREENWALD:

I just remember one name, a Dr. Mace, who may be still at Brooklyn College, I don't know. You see, this was back in '32.

MERTZ:

Then under this program you had an opportunity to take electives in physics and complete all the other liberal arts requirements.

GREENWALD:

That's right. Yes, the history and speech; you were very much circumvented at that time. I mean, there were so many things that you were required to take.

MERTZ:

So that the only real freedom of choice you had was in the specialty that you—

GREENWALD:

That's right. Looking back, I wish I could have taken more, but, as I say, the things that people, I think, today don't have to take--there was so much in the way of language and English. Some of this, I think, is good, but I think there is a little more freedom in the college now to pursue your interest than there was then.

MERTZ:

Did you take--how much math did you have? Did you have calculus?

GREENWALD:

Yes.

MERTZ:

Did it go much beyond differential and integral calculus?

GREENWALD:

Not too much, and I, you know, I look back and wish I had had the opportunity to go further. You see, one of the things courses--like today, I see kids who are interested in science and they are already taking calculus in high school. Well, in those days, I had to take a year of, I think, like analytic geometry, and college algebra, which was a year before I even got to calculus. So I was taking calculus in the sophomore year.

MERTZ:

Which meant that your first physics course was a physics without calculus.

GREENWALD:

Without calculus. That's right. So the whole thing is kind of set back—

MERTZ:

But then you did get--in your sophomore year you did get differential--

GREENWALD:

Then I did get differential equations, and I think I took a course in advanced calculus beyond that. And I think that was about it. Which isn't much mathematics by our present--

MERTZ:

But it did supply you with the tools for the more advanced physics courses?

GREENWALD:

Yes, yes.

MERTZ:

What field of physics interested you most?

GREENWALD:

Well, even there, you weren't really specializing. It was all the way the course was set up, if you took a half year, that was devoted to mechanics, that is, one term devoted to mechanics; a term devoted to heat and sound; a term devoted to electricity; a term devoted to optics. You see? So you were moving pretty slowly. Then there was a course in, I think, they called it something like electronic physics or something like this in which you'd study trajectory of an electron under the influence of various fields and that kind of thing; things of that nature. There was a course in modern physics at the time.

MERTZ:

Which was what?

GREENWALD:

Which was very, very novel, because remember, I mean, you think back and here I took a course like that modern physics in 1935 or '36, and this was the year that the first time that they--this was when they first evolved the cyclotron. This was a great thing and this was the first thing in really moving particles at any speed at all.

MERTZ:

Did they give you any quantum mechanics?

GREENWALD:

No. I guess that would have been graduate school.

MERTZ:

Graduate work, right. So when you finished, you finished in '3-?

GREENWALD:

'36.

MERTZ:

'36, that year. Was it in June?

GREENWALD:

June of '36, yes.

MERTZ:

What then did you plan to do and were you thinking of doing?

GREENWALD:

Well, the depression was on us, and it sort of--you didn't know quite what to do. It was hard to say. I wanted to stay in the field. On the other hand, I felt that I owed an obligation to get out and work and try to earn some money, somehow. And, of course, there were very, very few opportunities.

MERTZ:

May I ask, did you have brothers and sisters?

GREENWALD:

Yes, I had two younger sisters.

MERTZ:

Two younger sisters, I see.

GREENWALD:

They had no interest in science.

MERTZ:

Did you continue to play the piano all through college?

GREENWALD:

Oh yes, yes. This is the way I earned a little money. In fact, it took a lot of time, because as a musician in an orchestra playing at dances and things like that, which I did, I mean,

you'd get home at two or three in the morning, and it's not the best environment for trying to go to school, too. I was trying to do both things.

MERTZ:

Didn't it, relatively speaking, pay better than other jobs --other comparable jobs in terms of time?

GREENWALD:

Well, I don't know. It just was hard to--it was hard and this was something I could do. And this usually involved--in other words, these were always things in the evening, so that you didn't conflict, but, of course, you were tired the next morning.

MERTZ:

So the first concern at that point was the economic situation of the family, when you graduated.

GREENWALD:

That's right. Now I might say another thing about it. And you look back and say, "gee, why did I do this?" If I look back I would have done things differently. I decided that I was interested in physics. I guess I didn't have the friends or the associates that might have pushed me perhaps in the right direction. But I thought in terms of physics not so much as becoming a physicist eventually, but I thought perhaps I could teach this in the school, and become a physics teacher. So one of the things I did, I spent what I thought were some very valuable credit hours with the required teaching courses, which I, today, I wish I had spent in mathematics.

MERTZ:

Because you were required to get a certificate for teaching?

GREENWALD:

Absolutely. There is no other way to do it.

MERTZ:

Still.

GREENWALD:

That's right. And this takes a number of valuable hours. The problem, though, is when I

got out, got my degree, I found that they were not giving any more examinations in physics. I don't know what they were doing in other fields. There just was no outlet. And there were so many roadblocks in the way of becoming a high school teacher that it seemed like a virtual impossibility. I mean, it seemed completely futile.

MERTZ:

There weren't any openings or--

GREENWALD:

No, there were no openings at all. There was very little demand for it. As a matter of fact, I might say there was very little interest in physics even at the school. In fact, I remember that one of the more important professors, who was sort of second in command of the department, which was a very nice little department, it wasn't a--begging people to take courses because they had a certain minimal number before they could give a course. In other words, if they could get this quorum, they could give this advanced course. And there just wasn't that tremendous interest in science that came later; that, you know, came as the result of the War and Sputnik and all the rest. At that time you just didn't find too many people interested in it. I was interested in it, but I got out of school and said, "well, what can I do with it now?"

MERTZ:

Did you give any thought at the time you graduated, or just before, to a year of going to graduate school? Or was that pretty well ruled out?

GREENWALD:

Well, I saw it as pretty well ruled out, because I thought it was very important for me to try to earn a living. Get a job. And it turned out the thing that I thought I could most readily go into, which was teaching physics in the high school, for example, that was out.

MERTZ:

What avenue did that leave as a possibility?

GREENWALD:

So when I said to myself, "what can I do in a city like this? There doesn't seem to be very much interest in science. What shall I do?" And I said to myself, "well, maybe the only thing is"--see, this is a depression-oriented point of view--"what can I do? The main thing is to try to earn a living here. I have to set aside the things that I really like." So what I did was, I decided to take some courses in typing, shorthand, and bookkeeping. I said: "This was a business city. If there is any way of getting a job it's in business." And

this is what I did. I spent about eight, nine months or something taking intensive courses in—

MERTZ:

Was this in Brooklyn College?

GREENWALD:

No. No, this was, I guess, a secretarial school; mainly it's girls who go to this kind of thing. I felt this, at least, would give me some skills--because, you know, physics didn't give me any entree into anything. And I felt the most important thing was to try to earn a living. So I did that, and at the same time I thought perhaps Civil Service might be an answer to something too. And that was one thing where you didn't have to depend on knowing somebody who knew somebody, as with most private firms. Kids then were doing anything to get a job. A fellow got out of college, and if he could be an office boy that was great stuff, or a messenger, or anything, or if he could rake leaves in the park, you know. Anything. You didn't think, "What does this do to my future?" It was, "how can I survive?" This was the thing. So I started to take a lot of Civil Service tests in the city.

MERTZ:

This was in '37?

GREENWALD:

This was in '36,'37, yeah. And, of course, with a college education, taking those tests--plus physics, which gives you such a good command of math and reasoning, I think, plus the fact that I had now these typing skills and I knew something about bookkeeping--I eventually got a job, after waiting and working for the City of New York. In an accounting office, of all things.

MERTZ:

This was in the city government?

GREENWALD:

This was in the city government.

MERTZ:

I see. Which patterned itself to a large extent after Federal Civil Service.

GREENWALD:

That's right. There was no, I mean, there was no favor. You took an exam, you got on the list. You got a number and when your time came... that was it.

MERTZ:

So you worked then in an accounting office?

GREENWALD:

So I worked in an accounting office in Manhattan. And I stayed with the City for four years.

MERTZ:

Did you continue to play...on the side?

GREENWALD:

I continued to play, but somewhat less, since now I was beginning to earn money. Physics was sort of by the board. I still played with vacuum tubes and so on, but that was just on the side. Then, of course, what happened then was that the War happened.

MERTZ:

If you were with the City--for about how long at this time?

GREENWALD:

I guess, I was twenty-two when I got out of school. I guess, I must have been with the City for four years.

MERTZ:

Twenty-six or seven.

GREENWALD:

Twenty-six, I believe.

MERTZ:

Well now, that four years goes up, brings us up to 1941.

GREENWALD:

Yes.

MERTZ:

Did you do any studying on the side?

GREENWALD:

The only thing I did--again I was thinking in terms--again, I said, music was out, and physics, I felt, was out now--so what I did then, I figured: "Well, since I'm in a City Department here, perhaps I can use my mathematics some." They did a lot of statistical analysis, so I took some courses at Columbia University at night. Again, it's a very difficult thing to do. You spend all your time traveling and going to school.

MERTZ:

Did you continue to live in Brooklyn?

GREENWALD:

I lived in Brooklyn, worked in Manhattan, on Lower Manhattan, and went uptown Manhattan to Columbia; and I was a very tired fellow. [Laughter]. I took about four terms of statistics thinking that this would help.

MERTZ:

This was in the late thirties? How far along did you get? There were some rather distinguished mathematical statisticians in the late thirties, at Columbia. One is a man named Wald, Abraham Wald. I wonder if you ever encountered him.

GREENWALD:

No. This was...it more oriented toward business statistics.

MERTZ:

Oh, I see. Again, the main thrust was still--

GREENWALD:

...In other words, I felt perhaps this was going to be my niche, and how can I best perform in this kind of thing. In other words, it was sort of a narrowly accounting, statistical kind of environment.

MERTZ:

Right. Then I assume that there were some prospects in the City government for advancement.

GREENWALD:

That's right.

MERTZ:

So the job you were hired in wasn't necessarily the end of the road.

GREENWALD:

Oh, no. They had a whole hierarchy of positions. Each one you had to be in your lower position so many--so much time, and then you took a test in competition with other people, and this is the way up the ladder.

MERTZ:

So there was a way out.

GREENWALD:

It was a long--but there was possibility. And I felt that with some training in mathematics, that kind of background perhaps--you know, statistics--would give me an outlet to challenge me somewhat.

MERTZ:

The four years would have been '37,-8,-9,'40, or 1940 or?..

GREENWALD:

Yes, around that time.

MERTZ:

Which is--well, the war had already broken out in Europe, and the United States was then beginning to mobilize.

GREENWALD:

That's correct.

MERTZ:

Did you stay with the City, New York City, and government up until the outbreak of the War?

GREENWALD:

I'm not too certain about the dates now. What happened at that point, the War came and it seemed to me there were much more urgent things than working in the city job with statistics and things like that--war fervor and so on--and so I thought, "maybe I'll get out and try to get into something different, closer to what I like."

MERTZ:

You were also eligible for the draft?

GREENWALD:

And I was eligible for the draft that was correct. I wasn't called immediately.

MERTZ:

There wasn't any prospect in continuing to work for the city government--that would in any way exempt you from the draft?

GREENWALD:

No.

MERTZ:

But there were a lot of war-related activities--defense-related activities...

GREENWALD:

That's right. Yeah. But what I did was, I inquired, again I was being--I guess I was civil-service oriented at that time--there were some opportunity to work for--there was a tremendous expansion of schools that were teaching radio and mechanics to GIs, and so I thought maybe this would give me a chance to do something more like what I want to do, try it anyway. So I applied for a position as a teacher at what they called, I guess, Air Force Technical School--I don't know the exact name.

MERTZ:

Was it the Army Air Force?

GREENWALD:

It was the Army Air Force at the time.

MERTZ:

The Navy had similar—

GREENWALD:

Yes. There was no--the Air Force was not separate at this time. It was an Army function. I applied for this.

MERTZ:

As an instructor?

GREENWALD:

As an instructor.

MERTZ:

In which? In physics?

GREENWALD:

Not in physics, but--well, this is kind of peculiar. They had openings in a number of things. Of all things, aircraft mechanics and radio. So what I did was--and again this is kind of peculiar--I applied for this. They didn't--I guess due to the dearth of people they could get, I got involved in aircraft mechanics. But, of course, this was duck soup for me, because with my physics background and mechanics and interest in radio, this was very easy for me to assimilate. I got involved in a correspondence school

[Recorder Off]

OK. Of course there were a number of schools that were training GIs in aircraft mechanics and radio and so on, because all these planes have to be serviced in the field and so on. But among the functions, there was one small place located out at Scott Field that was a correspondence school that was trying to teach GIs who were already out in the field things about airplanes and radio, that kind of thing. Some of these GI's were on isolated islands, and, you know, they might be in a communications type deal with very

few people there and they had a lot of spare time, and this gave them something to do and something to learn, and that was the idea of the school, was to try to upgrade the soldiers that were already in the field. This was Army Air Force.

MERTZ:

And this was to increase their proficiency?

GREENWALD:

In their proficiency and knowing more about how a carburetor worked and what have you; or a radio receiver. So I was accepted for this particular school. This, the only one that I know of, was at Scott Field in Illinois. And I stayed there for, I guess, about a year. This was not a draft-deferred occupation, either. And I was drafted at that time, and I went into the Army Air Force.

MERTZ:

Now when you went into the Army Air Force, did you continue in this activity?

GREENWALD:

No, I did not. What happened was, I now became--

MERTZ:

Excuse me, when was this?

GREENWALD:

This must be, I guess, we're getting to '42 now.

MERTZ:

You were drafted in 1942?

GREENWALD:

I believe that's the date. I think very early.

MERTZ:

During winter?

GREENWALD:

I think it was during the winter, January, February, something like that, but early in the year.

MERTZ:

This was shortly after Pearl Harbor?

GREENWALD:

It wasn't too much later. But I don't remember the dates exactly. Anyway, because of the fact that I'd had this training now as an instructor, and because of my background--in other words, here I had this training as an instructor, albeit in correspondence school, that was the last thing I thought I'd end up with--but this happened to be the opening. I was so glad to get into something technical after four years of, you know, accounting, statistics kind of thing, this was certainly nearer to what I originally wanted to do. So when I was drafted, they took me in at that same field, but now as an on-line instructor with real classes, real people, and the whole thing. Teaching.

MERTZ:

The same subject?

GREENWALD:

No. In the correspondence school I was more or less involved with mechanics of one kind or another. Here I was involved with radio.

MERTZ:

I see. This was in electricity and radio?

GREENWALD:

That's right. Really I had much more background and interest because for years I had been doing things on my own.

MERTZ:

Did you have a period of basic training you had to go through before you went in as an instructor?

GREENWALD:

Oh yes. Yes. I had to go through--yeah, the usual drill and all that. I had that. And then

for a short time I became an instructor. Presently--I hope it was because of ability--I rose very quickly. It was just amazing; I was just putting on stripes and taking them off. [Laugh]. I went up to a buck sergeant very quickly. I hope this had something to do with ability. I don't know. At any rate, I decided at that point that perhaps what I would like to do if I had the opportunity was to become an officer. So I asked to be sent to the OCS school, as an aviation cadet. And I remember you had to get a whole lot of recommendations for this kind of thing, and I did get them--they went back to the professors at school, you know. I did get these recommendations, and was accepted, and went through six months of training, both, you know, military training and technical training. This was for kind of radar and communications, that kind of thing, in the Air Force, as an officer.

MERTZ:

I see. And this was in 1942, '43?

GREENWALD:

Well, I guess we're getting into '42,'43.

MERTZ:

The next winter after--

GREENWALD:

I guess so. The dates are kind of--I don't know exactly, without referring to the papers.

MERTZ:

Where were you assigned for your training?

GREENWALD:

The training, as I recall, the military training was at Boca Raton, Florida. That's where we had all the formations and the marching and the rifle practice and all the rest. The technical training was at Yale University. We continued some of the military activities; there was a school there for learning something about the various sets and things of that nature.

MERTZ:

And this was training in--

GREENWALD:

This was in radio. This was really aiming toward both--you might say primarily communications, I guess, though. Well, what they did--of course, they were trying to bootstrap. This thing was mushrooming. The number of people getting involved was just mushrooming at a tremendous rate. The number of people coming in and people being sent overseas, again to service planes, and do all the things you need to, all over the world, because you know this was going on every continent, and so on. And so when I finished that, I guess, I had an excellent record there. Of course, I mean, you get all kinds of people, some people with backgrounds that don't really fit it at all, and they can sort of do the job, and sometimes you get someone with a good background. Well, because of my record, they asked me to stay and teach at the school,

MERTZ:

This was at Yale?

GREENWALD:

for a while. You have no idea what is going to happen or for how long. So, for a very short time I was then teaching cadets in the radio field. For a short while.

MERTZ:

In New Haven?

GREENWALD:

Yeah. And then I don't know how exactly it was. There was an opportunity to get into radar work. And the Army, the Navy, the Marines had a very excellent school for this at Harvard and MIT. I have never seen the likes of it, really, and I was given the opportunity to go there after, as I said, teaching for a short while at Yale. And this was just tremendous. It amounted to three [months] of rather rugged training at Harvard and about three months at MIT. And this was not like the schools before. This was at an upper college level, you might say. This was mathematically rigorous. At Harvard they had renowned professors. I remember we had, you know: this week you would take--you would take a series of courses which involved filter theory, you know, vacuum tube amplifiers and oscillators. And they assumed a reasonable amount of mathematics in this, too. It was an excellent course. Some of these people were renowned in engineering, in physics. We had, for example, Dr. Chaffee, a pioneer in the vacuum tube field, as one of the instructors, that kind of thing. LeCorbeiller in filter theory. I mean, these were men of great repute. This was the kind of thing, and at a fairly good level. Much above--

MERTZ:

How many--how large were the classes?

GREENWALD:

The classes varied. They could be--as I recall, it's difficult: they had very large lectures, like 200, 250 people. That kind of thing. And they had labs which were broken down more individually. And then they also had--I don't know what you would call it today--kind of a seminar with perhaps twelve or fifteen people involved. And the classes that you had, the large classes, they had a single man and this was his field. They might have an Englishman, for example, who was terrifically good at this particular thing, and he would teach this one class to these 200-odd people. And you had many of these teachers. But when it came to this seminar type of discussion, we had one man. I had this chap who has written a definitive work on filter theory with LeCorbeiller, and he was the man that I went through with, who went over everything, you see, and I think I was rather fortunate to get this particular individual.

MERTZ:

And that went on for about?

GREENWALD:

That went on for three months. Very intensive, and examinations every week--open book, closed book--involving equations. Very difficult. I mean, it was as though you were working for an advanced degree. It was very difficult. Very intensive. I probably never worked so hard in my life. Because the things just were thrown at you at that rate.

MERTZ:

How long was that?

GREENWALD:

This was about three months.

MERTZ:

At Harvard?

GREENWALD:

At Harvard.

MERTZ:

Then you went to MIT?

GREENWALD:

Then I went to MIT. At MIT.

[End of Tape 1, Side 1]

[Start Tape 1, Side 2]

GREENWALD:

At MIT, again, this was very intensive. And again, very high level training. And, while the training at Harvard was in general in electronics--you know, in other words, you were studying amplifiers and general electronic theory, trying to make up for an education in electrical engineering in three months--at MIT this was strictly oriented toward radar training. And this was trying to learn a completely new language and new technique with timing circuits and synchronizers and magnetrons and the whole deal at a mathematical level, knowing what was going on and why.

MERTZ:

How much time did you have there?

GREENWALD:

It was three months. Again, and again with a very high level of instruction and extremely intensive. You had a very difficult situation. This was an all-day learning kind of thing, and Saturdays, too. And I don't know how a lot of people could really take this, and some did drop out. But I went through three months of that. One of the problems you had was that this was considered confidential, secret work, so you could take nothing home. You came in with nothing, you left--in other words, there were no papers that were allowed to be taken in or out. Everything had to be done on-site. There was nothing you could do. You could think about things, but that's about all. And there were no texts or anything available at the time. As far as I can say, those six months were the most intensive training I've ever had, and I think were just terrific. And I think whoever devised that--I give that rad group a lot of credit.

MERTZ:

Let's see, about how old were you? This was 1944?

GREENWALD:

I guess this was '43,'44. I guess I was thirty by that time.

MERTZ:

Well, then what happened after you completed the

GREENWALD:

After that, people went off in various directions. This was a school that developed, as I said, everyone, including Signal Corps and so on. I mean, all services were involved in it: Navy, Army, Air force, Marines and so on. From there the thing was to go to a specialty for training and then overseas. And you had really no choice of where you would end up. I wouldn't know what I would want, anyway. And it so happened that I was sent for training with GCA: Ground Control Approach. What this is a system for landing planes in the worst weather, in the worst conditions. And sometimes the planes were disabled and they can't make many passes at the field, and they're just a very dire emergency kind of thing. This was radar equipment that had been developed in the States. It was really a combination of really a number of radar equipments--precision radar, approach radar, a great deal of communications gear--all in one van with a crew of some, say, five people at a time manning the truck, the facilities that would be available on a twenty-four hour basis at a field for bringing these people in, who were coming in from missions and what have you, under all kinds of conditions. And so as an officer, I would be in charge of one of these groups. And this group of men, too. I guess a GCA group would involve something like perhaps the officer in charge, a crew chief, perhaps something like a dozen men who'd man the radar and keep it--and the communications gear--and keep it running. And this truck which contained all this equipment, you know, packaged quite intensively. It was a large truck. It would sit on the side of the field and you would set up all your radar and get everything lined up, and so on, and go to work. And you were on duty twenty-four hours a day. This is what I was slated for. So, I picked up a crew that was mine.

MERTZ:

Where did you get the training in the GCA?

GREENWALD:

GCA training was done at a number of fields. It was done partly at Boca Raton, Columbia Air Force Base in South Carolina, Shaw Field--

MERTZ:

How long was this?

GREENWALD:

Not too long. These were all like; you know, like two months here, one month there, that kind of thing. I only ended up at Fort Dix for the last training on this thing. And with my crew, and we went through our exercises there for a few weeks. And then, lo and behold! The war ended. I think we were due for overseas duty right after that.

MERTZ:

Was this the war in Japan or the war in Europe?

GREENWALD:

I think it was the war in Japan was over just about the time--In other words, you see, they had set up these people I had gone through ECA with. We all got picked up by crews, and some were a couple of weeks ahead, and people a couple of weeks ahead of me ended up in Asia, and so on. I got there at the moment when they said, "OK, this is it."

MERTZ:

So then you were faced with demobilization. Did this happen rather rapidly?

GREENWALD:

When demobilization took place--and it was explosive: the rate at which people left, and the whole thing disbanded rather quickly. They had a point system, of course, for getting out. People were so anxious to get out--and they were so anxious to get you out--that it wasn't very long before I found myself at Mitchell Field. I signed up for the reserves for a number of years there, and that was the end of my part in the military.

MERTZ:

Then you were also faced with the problem of becoming a civilian.

GREENWALD:

Now we have the problem of job again. I could have, of course, gone back to Civil Service and back to statistics, and so on, but I'd had a taste of what I wanted in this program, and I said, particularly, this experience at Harvard and MIT that really opened my eyes, and I just ate it up. And I said, "This is what I want to get into. This is for me, if I possibly can." But we have a problem: I had a degree in physics, I had this electronic training in engineering, and I had, of course, been working with equipment in the field with this GCA, and the question was now--I decided this is what I'm going to go for. And I thought--I didn't know quite--You know, you don't know who to talk to or just what to do. I thought perhaps the airlines would be a good place for me to be with. But it turns out that there was very little opportunity in the airlines for someone with my background. The only thing they were looking for, I guess, was, perhaps, pilots. Any

work in radar or communications techniques and so on was not their cup of tea. I didn't realize at the time--

MERTZ:

It wasn't the day of the great need of the air traffic controller.

GREENWALD:

So I did make some more inquiries, and a friend of mine had gotten a job with Sperry Gyroscope. And I spoke to him and he said there might be some opposition--Actually, there was a little depression at the time, because here was an outpouring of people, suddenly, the war ended, and again--I mean, I had it in the thirties, and it looked like I was going to get it again. But I went out for an interview, and I didn't know electrical engineering, see, I was not an electrical engineer, and this was what I applied for. Now, I was not a physicist, certainly, by this time. Physics was now a different field. Tremendous progress, you know, between '36 and '46, ten years. It made all the difference in the world.

MERTZ:

An [?] an hour at a time.

GREENWALD:

So, that's right. And I decided to see if I could get a job at this place. I was interviewed. It turned out that perhaps a few people that had been at MIT who had been instructors there, knew what the background had been, and I was recognized; so this sort of gave me a little recommendation. They didn't say "oh well, this is just another GI school or something." So I was taken on and—

MERTZ:

At Sperry Gyroscope?

GREENWALD:

At Sperry Gyroscope.

MERTZ:

Is it in New York?

GREENWALD:

In--New Hyde Park, Lake Success, which became the site of the UN for a while. In fact, the UN occupied part of the building we were in. It was completely isolated, but it was a huge, huge building. And they occupied one little section of the building--I guess which would have been the administrative part of it. They took offices and so on, and Sperry had the rest of the building, which was manufacturing. And I got into what was a small research group which was primarily involved in military electronics and radar.

MERTZ:

This group--who was--I take it the man in charge of this group was the one who interviewed you for the job?

GREENWALD:

Yes. I'm not sure of the name. I think the head of all research at Sperry's was, I think, a man by the name of Barrow.

MERTZ:

Barrow?

GREENWALD:

Barrow, I believe, that was. And more, I think he was sort of over all. And then there was another man under him who was somewhat more limited in responsibility, may have been responsible, perhaps, just for that particular research area. I'm thinking, I believe his name was White. Names kind of escape me after all these years. I believe that was the setup. They gave me a pretty hard interview, but I was accepted, and I got my first job as an engineer.

MERTZ:

Now this was--how many were there?

GREENWALD:

I would say roughly, you see, this was a very, very large plant. A lot of it had to do with manufacturing and so on. And there was also commercial development, but this was a research group and, as far as I know, it was in the military area only. It was kind of set aside, you know, there were guards. It was an isolated little island. I think it was kind of a couple of hundred people, as far as I could tell.

MERTZ:

What kind of--what areas of research--

GREENWALD:

I don't know all that went on because, again, it was an environment where you didn't--You talked to the people that were involved in your own project, and you didn't necessarily mingle on a technical level with people that were doing other things.

MERTZ:

Well, in your own project, what was?

GREENWALD:

In my own project, this was involved with radar equipment; and the kind of equipment that they were working on was gun laying--radar gun laying equipment.

MERTZ:

This was in '46 or '4-

GREENWALD:

'46, yeah, 1946. That's right. Yeah, so I worked on--in the time I was there I was given all kinds of jobs. I was sort of a factotum, I guess. First I--I was given so many miscellaneous jobs. I was there for one year only, but given quite a bit of responsibility, actually, for someone who, you know, I don't think I had that much experience. They asked me--the first thing I got when I was there was to rewrite a radar manual. It seems that they had changed equipment. One thing, they had gone from S-band to X-band. and they had done some other changes, and I was given responsibility for rewriting this text: Go to people, find out what had been done, and then describe it. And that was it. I had no help. It was up to me to do it.

MERTZ:

It was a good way to learn.

GREENWALD:

Yeah. I was on my own. I was asked to look into, at one time, the possibility of a small analog computer. Again, I had no experience in this. I came up with some ideas in a report. I don't know what happened to it. I went on to something else. I was asked to help a project engineer who was working on a gun laying radar. This was the kind of thing with a huge antenna and a man sits, and he slews it on target, you know, and there is information on--once you sight on the target, then the radar automatically locks in, and this information goes to a computer, and these computers at the time were

electromechanical sort of devices with all kinds of wheels turning and so on.

MERTZ:

Like the gun directors in fire control.

GREENWALD:

Yes. And my job was to help the project engineer on the radar portion of the thing getting it ready for tests; so I worked on that a while.

MERTZ:

I believe that was actually the wedding of radar to the computerized gun-laying; fire control apparatus occurred almost too late in the War to begin, was just being experimented with at the end of the War.

GREENWALD:

Yeah.

MERTZ:

If I'm not mistaken.

GREENWALD:

You see, the thing was, today when we think of computation of trajectories, and so on, well, you can do it with an analog computer, or you can probably do it partly with a small digital computer. It would be all electronic. But as I recall--again I didn't get into this; you didn't pry too much into what other people were doing. It was confidential, secret information, and you just worked on your own thing with your own little group. But I remember that these things were primarily mechanical types of devices. Mechanical servos, and so on, rather than electrical, the way we do it today.

MERTZ:

And you were there at Lake Success for a year?

GREENWALD:

I was there for a year. Then finally I was put on a project that was, instead--I was looking for something to dig my teeth into, and I was made sort of assistant to a project leader on new radar equipment they were developing. It was a little more advanced than the other one, and I think everything was sort of on one platform, and it was compact and,

I think it was supposed to be more accurate, but I sort of got in a little earlier on this thing, although it was already ongoing. And I sort of acted as a sort of factotum to the man who was directing this whole project, which involved the computer and the radar and the power equipment, and so on, and he gave me all kinds of jobs to do. You know: "They have a shock problem. What kind of lamps shall we use? Find out about lamps." So I'd have to look at lamps and devise shape tests. Sperry had all kinds of facilities. So I would get the devices and get the tests done, and report back, and so on. And say: "Well, we need a clutch for such-and-such, and nobody is working--." It was all very much compartmentalized. You know, one man would be working on a supernozz [?], another man would be working on power supplies, another man on video, another man on IF strips, and that kind of thing. "What ...[are we going to do] for a magnetic clutch they needed, so go devise a clutch." Again, very little in the way of help; you know, "these are the constraints just go and do it." And this was the kind of thing I got involved with. It was a lot of responsibility. Here we had a lot of pieces, and we normally said "it's got to fit into a skin, so, you know, of these dimensions. You know, nobody's really paid any attention to this too much, you better go find out whether everything fits." All right, so you round up all the engineers and make sketches and see whether you've got something that goes together, you know.. We got all these things. Well, it was interesting. I was learning. But it was nothing consistent to the pattern you used. And it got a little dull there. ... ... And I--someone told me computers. Computers, what are they? Electronic digital computers. Sounded like kind of a weird thing. I heard there was some work going on in Washington at the Bureau, from a friend of mine in the Army.

MERTZ:

Is this the friend that had--is that the one that introduced you to Sperry?

GREENWALD:

No. This was someone else. And I think he eventually ended up working for the FAA. He mentioned this work going on. I said, "Gee, this is fascinating. How do you-- how do you compute? What doe it mean? This is tremendous. Fantastic. Talk about fantastic speeds, and I feel I'd like to--that sounds great. This is something that is starting. Gee, I'd like to get into it." You know, radar was already a well established field. And Sperry had all these experts for this, that and the other. And, while I was doing useful work, it didn't seem to be leading anywhere. It was--you know, if a gap had to be filled somewhere, "okay, do this do that," and so on. I felt, "Gee, I'd like to get in on the ground floor and really learn something well. So I enquired about it. I wrote to the Bureau of Standards. Communications were kind of slow by the time you got answers, and so on. I ended up by going--

MERTZ:

Did you know anybody to whom you should write there? Did he give you a name?

GREENWALD:

No, I think, I just had--I don't know if I had any. Maybe the name of a personnel officer. But I ended up by going down to--coming to Washington. I remember: dead of winter, snow all over the place.

MERTZ:

This was in '47?

GREENWALD:

This was in '47, probably January, February, in dead of winter with snow piled up all ever the place. A strange city. And I took--I guess it was a street car; it must have been at the time.

MERTZ:

A trolley bus of some kind?

GREENWALD:

No, I think there were still street cars.

MERTZ:

Is this out Connecticut to Van Ness Street?

GREENWALD:

Out to Van Ness Street. And I went to talk to the people at the Bureau. What was involved? What was the physical situation? What were the openings? Who would I work for? What would I do? And so on. And I was interviewed by--I don't know whether I was interviewed by Sam Alexander. I don't think so. I think I was interviewed by a man by the name of Orden, Alex Orden, who was sort of a--I guess he was a partly technical man and sort of administrative assistant. I don't know quite what his function was, because, I know, he didn't seem to do any technical work. But he did interview me. And he was the one that answered inquiries. There was a little correspondence back and forth, you know.

MERTZ:

Did they know at Sperry that you were looking?

GREENWALD:

No, they did not, and I don't think I, I think it was not a good idea to say much. Jobs were not that easy to come by. It wasn't that I was that dissatisfied, because, I said, I was doing useful work; but, as I said, it wasn't directed, and it didn't seem to be leading consistently. And, I didn't seem to get on the ground floor of something. This kind of bothered me. And another thing that kind of bothered me about this, to be frank, was: I can live under the security arrangement in the Army, with the radar equipment. This was highly secret, and this is the rules of the game. And I live by the rules of the game. But I did want to get--and, as I said, I did want to get into a field that was new, and I did want to get into a field where I could talk to people. Because you--I mean this was strictly that if you got home, you couldn't talk to anybody. This was strictly that security-type environment, and I'd had it during the war and now I had it again in this. And I felt I would like to have a normal environment if I could. And I think this was part of another reason for looking for something. And computers was a completely civilian type thing, you might say, where there is a good deal of freedom.

MERTZ:

And this was for the Bureau of Standards?

GREENWALD:

Yes, that's right, and it was for the Bureau of Standards. So this was another reason for doing it. Anyway, I found myself then finally, in 1947, in Washington.

MERTZ:

When did you finally come to this job?

GREENWALD:

I think it was--I believe it was May of 1947.

MERTZ:

I see. And had you met Alexander before you came or did you meet him after you got here?

GREENWALD:

I can't be sure. Perhaps I did meet him, and it may have been for a short time. I don't really remember.

MERTZ:

When you reported for duty at the Bureau of Standards, what was your first assignment? With whom did you work?

GREENWALD:

Well, let's see. What I might say, I was very well liked. I mean, at the previous job I got a big send-off and everything. They painted a little picture for me. And they had heard about WWV at the Bureau of Standards, and they gave me a transmitting tube. And they had a picture of someone at the key sending out messages over WWV. It was a very amicable kind of thing. And they even asked me later on to come back. But I wanted to get into this new field. Well anyway, I--the work at the--it's--Mr. Alexander was head of a group. I don't know quite just how it fitted in. It was not a major division of the Bureau; it was--I don't know.

MERTZ:

Was this under ordnance?

GREENWALD:

I think this was still under ordnance.

MERTZ:

How many people were there at the time you came aboard? Was the project a fairly large one?

GREENWALD:

No, it was a rather small group. I don't think there were more than perhaps [pause] perhaps nine or ten people. Something on that order, as I recall. Quite small. I don't know what the major divisions were in the Bureau. But Sam Alexander was the head of the group at the time. And their function as far as I could tell, was to--it wasn't really directed toward any real, narrow mission at all, as far as I could tell. It seemed first that they wanted some people to gain some competence in this new field--to know something about what was going on, what these components were, and, you know, what computer components meant, what they can do. I think part of it was, I guess, the realization that if you're going to act as an advisor, and I think, you see--for example, the Bureau was acting at that time as an advisor to the Bureau of Census. I didn't realize it, but they were acting as advisors on this computer program. There was also another program at the Raytheon Company involved; again, the Bureau was acting as advisor.

MERTZ:

Was this the Hurricane?

GREENWALD:

I think this is what eventually became RAYDAC.

MERTZ:

Ah yes.

GREENWALD:

You see, I have to be rather vague about this because I was not in the inner circles. I was just a very low order engineer.

MERTZ:

Junior engineer?

GREENWALD:

Junior engineer, to give projects or assignments, with no idea of the grand purpose involved. As far as I could tell—

MERTZ:

What were some of these assignments that you were given when you first started?

GREENWALD:

Well, again, it got to be a bunch of miscellaneous assignments. For example, one of the first things I was asked to look at was some magnetic recording on wire, because this could be used as a--could be used to store digital information.

MERTZ:

Who was it that gave you that asked you to do that?

GREENWALD:

This would be Sam Alexander.

MERTZ:

I see. So he pretty much--since the group wasn't that large, he was directly involved.

GREENWALD:

He was directly involved in it, although Sam was, of course, Sam was not, what I would say, had [no] prime interest in deep technical details. I mean, he was interested in the results and the general use of things and so on, not so much in the details. But he still was in charge of the laboratory and what was going on there. Well, as I say, one thing I got involved with was this magnetic tape.

MERTZ:

Wire, was it?

GREENWALD:

Wire, wire. Not tape, just magnetic wire. Its properties as a digital type device. I--they were interested in diodes, I remember, and I performed some experiments on that kind of thing.

MERTZ:

What did you do with the wire?

GREENWALD:

This was to learn something about packing density, and so on, and interference and noise, and that kind of thing.

MERTZ:

And was this with a view toward considering its merits and demerits as far as a storage medium was concerned?

GREENWALD:

I guess so. As I say, I was a little puzzled myself while I was working there in this first year as to just what, what the aim was. And as far as I could see, part of it was a training ground to give a base. In other words, how do you tell people what they should do or whether a particular thing has merit, if you haven't done any of it yourself? And I guess we were getting our wings flapping, we were learning something about it. It may not have been the most satisfactory thing in the world, this from the point of view of an engineer. What are you really there for, what is your goal? I mean it wasn't that well defined.

MERTZ:

Well, now these diode tests, were they on tube reliability?

GREENWALD:

You see, at that time, this was really the age of vacuum tubes. The vacuum tube was king, and they had hundreds of varieties. But we were considering the use of these things as a logic complement, as a way of building a matrix and seeing to perform, say, going from one code to another code, and so on. Now if you could do it with semiconductor diodes, which were just coming on the horizon, what a better way this would be than to use tube diodes, which involved filaments and power and glass, and took so much energy and so much space. So I remember doing some work to see what the limitations were on these new semiconductor diodes. By modern-day standards, they were pretty poor components.

MERTZ:

These were the things that were developed at the Bell Laboratories?

GREENWALD:

This was aluminum 34 [?], sort of the forerunner of--This was I guess, really the first main commercial germanium diode that was made in large quantities. It didn't even have a vacuum seal. I think they sort of encased it in gel--it was a pretty big tube and I think they encased it in gel ... and so on. It was a pretty poor kind of thing. But the advantages were so tremendous, as I say, from the point of view of power, space, and so on, heat dissipation, this was a great thing if, you know, if this were feasible. I remember working on matrices to see what kind of results--what the problems were.

MERTZ:

There seemed to be ... problems with this germanium ...

GREENWALD:

Well, as I recall, I believe one of the problems was that they were not very stable. They tend to change with time. And I guess this was partly because of the way they were produced, and the fact that they were not really well protected. The surfaces were not really well protected from the outside environment. They tended to be quite different one from another. And that sort of thing. I worked on that. Later, as I recall, I worked for a man by the name of Senf for a very short while, who had come from, I think, the Naval Research Lab.

MERTZ:

How do you spell his name?

GREENWALD:

S-E-N-F. He came a littler later, after I did, and he tried to give a little more direction. I became part of his group, I think, perhaps we, just the two, perhaps, eventually got to a group of three before he left. He didn't stay there too long. But he tried to give it a little more direction, and the thing he was mostly interested in was development of very, very fast components. I don't know why the emphasis was set on this at the time, because, looking back, it doesn't seem to me that was the most important thing. But we were straining at the time to try to build the fastest possible flip-flop that you could, and just taking the best tube that was available at the time, and designing the circuit to just make this thing go as fast as you could. Looking back, I say now, "Why," you know, "why is this necessary?" but I guess the feeling was at the time that one had to go through so many steps in a computing machine that, unless you did this at extremely fast speeds, that it would not be obvious--really as valuable. And so, I was trying to develop pulse generators with the fastest rise and fall times, and he was trying to develop flip-flops which go at maximum rates, not necessarily for putting this into any machine. There was no machine toward which this was aimed. It was merely something about complements [?]. And the idea seemed to be at the time, at least in that little group, was how fast can you do something: "We've got to get that rate up."

MERTZ:

Did you find that radar training was a useful background?

GREENWALD:

Oh, yes. This flowed right in from the pulse techniques, radar, and right into this sort of thing.

MERTZ:

What kinds of problems did you encounter initially that didn't involve ... radar?

GREENWALD:

Well, for example, the ... semiconductors didn't have...

MERTZ:

In terms of the specifically pulse generating equipment... did this involve any technical problems that were a bit different from... radar--any particular change in emphasis between what you had been exposed to and...these specific things that you were supposed to try to operate?

GREENWALD:

I would say they led rather directly--I think the transition was just fine. Of course, as I say, there were a few things that the training there would not have been a background for, for example, work with magnetic ...[?], with semiconductors there was no background there at all.

MERTZ:

Flip-flop circuits.

GREENWALD:

That's right. But flip-flop circuits were something that we had analyzed at MIT in very great detail: how they worked and the calculations, and so on. We had to sit down and mathematically figure out what was going to happen and when all these rise times and fall times and amplitudes were going to be, beforehand.

MERTZ:

Was the idea here possibly applying--in your small group--to a synchronous kind of machine?

GREENWALD:

Well, no. As I say, early in the game--for the first year that I was there--I again did a lot of miscellaneous work, as I've mentioned: all relating to the computer field, but not necessarily toward any common purpose. And, to be perfectly truthful, I was beginning to be a little disappointed, because, again, I felt, you know, we should be doing something with these things rather than just trying to learn something about it and not apply. In other words, what I wanted to do was, hopefully, to apply this to something or other. Well, about a year after I had been there this came on, and it came on fast, and this is when we really got going.

MERTZ:

Was there any other activity that you worked on, aside from doing this sort of familiarization in wire recording you mentioned, pulse [?] and the flip-flop circuits. Was there any work, say, on gate circuits?

GREENWALD:

No. Only matrices, really. I did a little. I did some work, for example, in pulse generating, using gas tubes and so on, but--we found we could generate very, very fast pulses this way.

MERTZ:

This is then about the spring of '47 or so; or '48?

GREENWALD:

Probably so. Maybe the spring of '48 or something like that.

MERTZ:

Then what happened? Was Senf still--

GREENWALD:

Suddenly--I think Senf stayed there, but he didn't stay there much longer. He was [a] very highly confident man. He was, I thought, an excellent leader, and I was kind of sorry to see him go. A number of things. Some of it was personal; some of it was--it had nothing to do with me, because my regard for the man was just tops. And he did get some kind of opportunity to work at one of the--some important committee, I don't know what it was about, in downtown Washington, which had to do with overall science planning or engineering planning

MERTZ:

What was his first name?

GREENWALD:

Harry Senf. Where he is today, I don't know. He ended up in California, I know.

[End of Tape 1, Side 2]

[Start Tape 2, Side 1]

MERTZ:

Well, after this first year of focused investigation onto different components which played a part in the development of electronic computers, the research effort under Sam Alexander took a more specific form. Do you recall what some of the elements were that made this possible?

GREENWALD:

Well, as far as I could tell, as I said before, I was really not in a position to see what was

happening from the bottom, so some of these things are more or less impressions. We were, as NBS--the small group was acting, particularly Sam in his position was acting, as a consultant to the Bureau of Census. And as things turned out it seemed like the machine that was supposed to be produced was forever in coming out. It was sort of a standing joke about when a first computer would be delivered, you know.

MERTZ:

Was this the UNIVAC I?

GREENWALD:

Yes, this was the very early UNIVAC. And it seemed like it was a standing joke that when you asked when was this going to be delivered, it was eighteen months from whenever the question was asked. This was going on and on. So I think, somewhere along the line, "by golly, we'll get a team together at the Bureau and see what we can do. Let's get something going." I think the "we," as I recall, was more or less the motivation. There was the money for it and the chance to--really, "Let's do something," because it didn't seem to be coming fast enough from commercial sources. "Let's let the government, and the Bureau in particular, get going on it."

MERTZ:

Was this seen similarly from the Bureau of the Census?

GREENWALD:

No, I don't think so. I don't think this was the Bureau of the Census. I think this was more or less--I think the sponsorship was coming still from--I think this was Air Force at this time.

MERTZ:

So it was defense-related?

GREENWALD:

It was defense related but it was not a classified type of thing. Sort of a general progress in the computer field that this was. So suddenly, we had now a real focus. We were going to do something, build something, see what we can do, how good it was going to be, and suddenly, there was a large staff. I say a large staff by comparison with what we had before. I don't remember how many people were involved. Maybe there were twenty-five.

MERTZ:

Maybe three or four times as many as--

GREENWALD:

Well, it was obviously a big jump over what had gone before. We didn't have an awful lot of money. Whatever had to be done had to be done economically, and, hopefully, quickly, and we had just no idea of what was going to come out of this, really. It was--the outcome was a great big question mark, really.

MERTZ:

How was the problem originally defined? What were you going to--?

GREENWALD:

Well, we were going to build a digital computer. What kind of technology was in it was not really known. What kind of structure this was going to be, what kind of components there would be, was completely unknown? There wasn't much to go by, really. I don't think the people involved really had that much experience in the field. There was nowhere really to get experience. But the point was that there was a mission. We were going to do something. We were going to get something built. I don't think there were any hard and fast dates particularly. You weren't building this for a client; you were building it for yourself. It was sort of feasibility, but it was focused on a digital computer that was going to be self-programmed, and so on. We were going to use whatever components we felt were needed. It was going to be fully electronic and it was going to be completely--we were going to design this from the ground up. We'd learn, following wholesale from whatever other people were doing. We didn't know too much about what other people were doing.

MERTZ:

At this point a number of other questions hadn't been resolved as to whether it was going to be binary or decimal, synchronous or asynchronous or--

GREENWALD:

No, I don't think there was. Again, because of my position--I wish I'd known more about what the inputs were at this time. I do know that a number of people came into our project, some minor, some major. A man by the name of Sam Lubkin came into the picture.

MERTZ:

Was this around '48, the spring of '48?

GREENWALD:

This was '48, 1948. A man who was quite famous in the computer field also came in, his name is, I think, Harold Huskey. He has been associated with the IEEE, the IRE for many years. A man by the name of Ralph Slutz was associated with this. And other junior engineers. I also recall the two fellows that came from California to help us. I don't know quite how they got involved. I think they were just going to give a hand for a little while. One fellow's name was Bill Martin; I remember him. Another's name was George Gourich.

MERTZ:

Is that G-u-r-e-?

GREENWALD:

I think it's G-O-U-R-I-C-H, something on that order. I think George Gourich got out of the field later on. I don't know what he went into, but I think he got out of the field completely. Martin was a very good man and contributed to our program, and later on became--worked for private industry out on the West Coast in a fairly responsible position, as I recall.

MERTZ:

Can you recall where he was?

GREENWALD:

I think he ended up--I don't know where he is now. I haven't the faintest idea. But I think he--years ago--I think he was at Beckman Instrument. So we had this staff of sort of senior people and junior people, and we went about with a will to get things going. Now it seemed like at the very start of this thing, I think it was Dr. Huskey--I don't know--whether it's Mr., Dr.?

MERTZ:

Did Huskey have a particular position?

GREENWALD:

It was hard to say for some of these people. Whether they were consultants or just one of us. I know that Lubkin specifically was a consultant. Just exactly what Huskey's position was I don't know. But Slutz was a supervisory employee.

MERTZ:

By the way, do you recall, did Senf go out to the West Coast?

GREENWALD:

Yes, he went to the West Coast. He worked for Hughes, I know, for a while. I don't know where he is today.

MERTZ:

That was after he went down to this committee.

GREENWALD:

Yes. After that he went out to the West Coast. He asked me to join him later, but I felt I wanted to stay here.

MERTZ:

And Slutz?

GREENWALD:

Slutz, as far as I know, is probably still at the Bureau of Standards. Again, I can't say. The last I knew he was out in Boulder, Colorado. With, well, I don't know, is it NBS anymore?

MERTZ:

Well, they have a facility there which is—

GREENWALD:

I'm trying to think. Isn't there an Environmental Sciences? He might be at that.

MERTZ:

I think I have his address. Now, George Gourich: do you recall him?

GREENWALD:

I don't know. He was primarily a mathematician, and so his interest would be more, perhaps, in the sort of general logic, perhaps, and mathematics. Let's see. Martin was more--he was an electronic engineer, so his interest was more in hardware. Slutz was a

physicist whose interest was just very wide. I mean, not only circuits, but programming and, actually, the use of computers. And, actually, I think, over the years his emphasis changed; as things came into being he went more into programming and then into the uses of machines.

MERTZ:

But his initial interest was actually in putting one together.

GREENWALD:

That's right. And I would say he was probably the prime mover under Sam in putting this machine together.

MERTZ:

And Huskey?

GREENWALD:

Now, what happened there I thought was kind of funny. It may be that--again it's hard to say. Huskey came in with his own ideas. I remember seeing some old diagrams. And this seemed to be--involved sort of asynchronous machines using conventional flip-flops and that kind of thing and going through logic. I remember seeing some old drawings. I remember George Gourich poring over them and trying to understand what was going on. But somewhere along the line, it seems that there must have been two different kinds of philosophies. It must have been, perhaps, a Lubkin-Slutz philosophy versus, maybe, a Huskey philosophy, and before you knew it, Huskey was no longer involved in the program. I just remember him being there a short time. Huskey eventually went out to the West Coast to work for the--I think it was the Institute for Numerical Analysis, which was part of the Bureau of Standards at that time.

MERTZ:

And the SWAC.

GREENWALD:

And the SWAC is an outcome of his going there to build something along his particular formulation.

MERTZ:

As distinct from—

GREENWALD:

As distinct from what we did, yeah.

MERTZ:

Most of these people you are describing now, except for Henry Senf, I guess,

GREENWALD:

Henry Senf did not stay—

MERTZ:

but most of these others--came on about the time Henry Senf was leaving. Is that right?

GREENWALD:

Yes. There was a little bit of overlap. I don't think Senf was there more than perhaps a year or so. I don't think it was much more than that. You see, he arrived after I came and didn't stay too long, but long enough to see some of this program starting.

MERTZ:

How about the work he did on flip-flops?

GREENWALD:

Well, actually, I don't think that any of that--Remember, I said there was a lot of emphasis on trying to get very high speed flip-flops you could get at the time, and his trying to design these things to see what the limits were? This was actually never used. So we have then, we have Lubkin there and Ralph Slutz came in. We had Martin there for a while. And some junior engineers.

MERTZ:

With whom of these did you work most closely

GREENWALD:

Well, I guess I worked most closely with--well, Ralph was really my boss, I guess. And we set about to find out a--see, the essence there seemed to be, as nearly as I could see, was to design a good basic stage upon which a computer could be built. That seemed to be one of the essences of this program. In other words, if we could get something that was really good, really understood, which could serve as a building block that could

perform the logic and operate at the speeds that we were interested in, which we thoroughly knew, so that we could put together a device here with thousands and thousands and thousands of components, then we'd be in a position to be able to predict what was going to happen, so that this whole thing wouldn't just fall on its face. So that was where one of the big emphases was. And so, my part at first was involved in this basic stage, learning something about getting this part going.

MERTZ:

By that, do you mean, would this be the main arithmetic component?

GREENWALD:

Well, I'm not talking so much about the logic as the pieces that you could put together that would perform the logic. In other words, your machine has to be able to perform AND functions and OR functions. It has to be able to perform inhibit functions. It has to be able to combine signals. It has to be able to take these signals, combine them, and from this to drive other things, which are combined with other things. In other words, it is like a huge tree that's growing in on itself, with one branch joining with another branch, which joins with something else, all at different points, and which has feedback upon itself. And, you've got to have something so that you know at any precise moment exactly what is going to happen, regardless of the fact that components can vary, components can age, and that, if you put in something you're not going to have--if you put in a resistance, and you say, "I want this resistance to be 10,000 ohms," you don't get 10,000 ohms. You may get 10,500 or 9,500. And there are many of these things. And yet, in spite of all this variety of conditions, and in spite of the fact that one circuit here is joined perhaps to one a few inches down and at the same time it may be joined to something which is twenty feet away, you still want all of these to operate as one unit and correctly without error. One of the most important things is to design a basic building block that we knew thoroughly, is thoroughly engineered, and which we could depend upon. That was my first real involvement, was to--was concerned with the engineering of that building block.

MERTZ:

What was in this? If you could describe what was in it, what kind of circuits? Gating circuits, flip-flop circuits...diode matrices?

GREENWALD:

This was a little different really than I think what had gone on before. From that point of view, I think this Bureau group made an original contribution. What we ended up with was a gating logic which was what we called dynamic--at the stage at which it evolved--what we called dynamic circuitry. I think machines in general that had been thought of in those times--Huskey's ideas, I think, were in terms of levels. In other

words, in the binary system a particular level represents a ONE and another level represents a ZERO in your system. And all over this machine things are making transfers from one level to another at particular times. Well, the circuitry that we finally ended up with was the so-called dynamic. And what it amounted to was this: the circuit put out a series of pulses at very specific times, and these pulses would give you a complete excursion from your baseline to certain minimum amplitude. OK? And if there were, let's say, a run in the system, then this pulsing would be going on at a particular rate, on-off, on-off, on-off, continually, at this particular clock rate that the whole machine was working at.

MERTZ:

This was synchronous.

GREENWALD:

It was a fully synchronous clock machine. And if there were a ZERO then there was absolutely nothing going on, you see. In other words—

MERTZ:

Was the signal interrupted?

GREENWALD:

then there would be nothing going on. You see what I mean? Either there was a series of pulses, that would be one form, or you could have nothing happening, merely a baseline. Of course, you can have all kinds of varieties. For example, in this particular system that we meant, if you took the basic building block, and you connected up--you see, you could connect this building block up in many ways, it was extremely flexible, so this one building block did everything. That was another virtue. You didn't try to build fifteen different kinds of circuits, one circuit to do this, the other circuit to do this. This was one circuit that did everything, extremely flexible.

MERTZ:

But contained in this circuit were sub circuits?

GREENWALD:

Circuits which had memory, logic, gain, and extremely accurate level control--everything was in this thing, so that you could make a gating circuit out of it, you could make a memory circuit out of it, you could make a flip-flop out of it; you could end things, you could order things, and so on.

MERTZ:

What did you have to do to change this from a gating, strictly external wiring?

GREENWALD:

It was the way you did the external wiring to.

MERTZ:

In other words, you didn't alter the internal circuitry.

GREENWALD:

Internally, there was one basic building block that was convertible to anything you want, and this we knew with absolute precision what it would do.

MERTZ:

And what were you striving for with this basic building block? Speed?

GREENWALD:

Well, we were interested in speed and reliability, and knowing positively what would happen under all circumstances.

MERTZ:

And the kind of response you'd get is GO/NO-GO.

GREENWALD:

Yes. Well see, for example, you take a flip-flop--or now you make me think of it in some of our more conventional logic today: if a flip-flop is, let's say, in the ON state or the ONE state then it is at a particular voltage level. If it is at a ZERO state, its output is at a different level. A flip-flop in the SEAC, in this building block that we developed, if it was in the ONE state then it was continually putting out these pulses: beep beep beep beep beep beep, continuously. If it was in the ZERO state, there was nothing coming out. That was the difference.

MERTZ:

Did this then imply that all building blocks had to be parallel, in terms of wiring building blocks, combining them?

GREENWALD:

No, this was all sequential.

MERTZ:

It was all sequential. So there is a way then of externally wiring it so that you didn't interrupt the circuit. ...

GREENWALD:

No. You see, for example, if you wanted to tell--for example, a very simple thing is, suppose you wanted to know if there was a coincidence of two bits of information. There might be information coming down from line A, and information from line B. Perhaps just a simple pulse, just one. OK? Now, if these two came along together you would get an output which was capable of doing that. Let's say on the A line you had a train of pulses coming all the time, and then on the B you only had a single pulse, then the circuit would gate out only one of those pulses, you see. In other words, it was done--

MERTZ:

What was the input and output of these building blocks?

GREENWALD:

The same kind of output--you know, the same kind of dynamic inputs came in as went out. You see, what this thing did was the following: First of all, you could perform logic. In other words, you could perform AND/OR logic, and, you could do it in three layers. In other words, whereas a lot of modern-day things--well, you take a circuit and the only thing it will do is OR logic. Then you have another building block, and the next one does AND logic, and the next one can do OR logic. You know what I mean? It's one layer. In this particular building block, we felt it was more economical--because of the state of the art and the cost of amplifiers, and so on--to have three levels of gating, so you could perform an OR, an AND/OR function all in this one building block stage.

MERTZ:

Was this in a sense a kind of cascade type of arrangement?

GREENWALD:

Yeah. It's a cascade without amplification until you came to the end of this pyramid, and then you went. So that's one thing that you were able to do is, you were able to do this very flexible gating.

MERTZ:

What was the size of this physically, in dimensions?

GREENWALD:

Oh, it's hard to say. I'm very sorry I don't have a picture. Because of our particular way of packaging it, it could occupy a varying amount of space. It consisted essentially of a tube and transformer combination, a very small miniature tube.

MERTZ:

What kind of tube was it, do you recall? Pentode?

GREENWALD:

It was a pentode, yes. A very high performance—

MERTZ:

5A tube? 6A?

GREENWALD:

A very high performance pentode, I don't remember the number any more. It was a miniature tube.

MERTZ:

It was. Well, that was something, of course, immediately after the war they didn't have.

GREENWALD:

Yeah. It used a miniature tube. 6AN5. That was it. It was probably one of the most--one of the highest performance tubes of its time. Just an amazing capability within this little bottle. So it consisted then of this transformer, this tube, and then these diodes which performed the gating. And the diodes, in order to--we were trying to, of course, do an awful lot with not much money, and so packaging wasn't very important to us. And you didn't come out with a beautiful cabinet at all. Cabinet was nil. This was the last thing we thought of. Everything was put on aluminum sheet panels and the diodes—

MERTZ:

A bus used? Did you install these in a bus or ...?

GREENWALD:

These were--We took some ordinary electronic racks, and these panels, these were flat panels we put on these racks, and the transformers and the tubes and the diodes which were put inside an octal base--you see, that was very prevalent at the time; you remember, tubes were the big thing at the time and octal tubes were the way of building a tube. We found that we could buy surplus octal bases, these Bakelite bases with eight pins, very, very cheaply, for just a few cents. And you now had eight pins to work with. And we could put diodes in that, and that--those diodes were the things that performed our gating. And so we had various arrangements of diodes to perform the various kinds of logic that we wanted.

MERTZ:

What kind of diodes did you use?

GREENWALD:

This was primarily one amp 34. This was the little beasts that we were working with to find out what we could about--

MERTZ:

Oh, I see, the ones you had been earlier--

GREENWALD:

That's right. So we had the tube, we had the transformer, we had the diodes in these little sockets, and we needed one more thing: In order to get these timed properly, one has to make sure that the delays--in other words, if you're coming from one source, coming from one point to another point, in order to equalize these pulses so that they come at the same time, we also put in what were known as delay lines so that things would mesh at the correct time. And so, for this we found that there was a particular kind of delay cable that had been used in radar work, and we measured this to a fine degree. We found exactly how it could be used, how to use this in our pulse circuitry, what its attenuation characteristics were, how far one could go with this, how much delay one could put in before you had to repeat, and so on. And so, with these elements, they formed the building block, and, naturally, it would vary--depending on how much logical gaining one had to do and from where the pulses were coming. How much utilization in time had to be--

MERTZ:

What was the pulse rate?

GREENWALD:

The pulse rate, the basic pulse rate was one megacycle. We started out pretty fast.

MERTZ:

So everything had to be geared to that.

GREENWALD:

To that, to that level. That is correct.

MERTZ:

You had already a year earlier--pulse transformers--pulse generators, excuse me. Did you have any question about what kind of--

GREENWALD:

No. A year earlier, the only experience there that I think was of real value, I think, was some work with diodes, probably. The idea of our dynamic circuitry and so on had never come up until we really got to work on the nitty-gritty, and this whole effort started.

MERTZ:

Do you happen to know whether--I take it a breadboard of this was ... a number of versions of this.

GREENWALD:

Oh, yes. As a matter of fact, I built--It turned out--you see, one of the things you have to know about such a stage, and one of the things that gave me great confidence as I went along that this has got to go, was that we had learned so much about this stage--we knew intimately exactly what was going to happen. Unlike the way we do it today: we assume so much when we put things together because someone else has done the work, and experience has taught us you can do this sort of thing and you're not going to get in trouble; but then, we didn't know. We knew, for example, as a signal would pass --

[Interruption, recorder off]

MERTZ:

I think you were describing this basic building block, and there were a number of ways of configuring building blocks and then of combining the elements. And approximately how many of the fundamental configurations of the elements, we are talking now of the

way you configure the configurations. That is, of the one, two, three, four variety, as you described.

GREENWALD:

My recollection is that there were perhaps twelve to fifteen basic diode configurations that could be put together in many different ways so that perhaps two, three, four, five of these might serve as a logical input, and, with a tube and transformer, to form a basic logical stage. And these then could be formed in many, many different ways. And, of course, in a computer you try to configure some basic things. Some of these are extremely regular. For example, a machine is composed of a number of registers as one type of element. Where you would find a register you would tend to find the same kind of logical structure repeated; where one stage feeds into another stage, feeds into another stage, and so on, depending on how much delay you want. And there you will find a regular structure. Also, for example, in arithmetic structure, some of this tends to be a little repetitious. But, when you get to the control of a machine and the timing of the machine, things tend to be extremely variable, and this is subject to a great deal of variation.

MERTZ:

And this way of configuring allowed for hundreds of variations.

GREENWALD:

It allowed for literally hundreds of variations that are correct.

MERTZ:

Now after you worked on this--you might want to comment on breadboards of this basic building block, and some of its twelve or fifteen fundamental configurations. Do you know of any that are still around?

GREENWALD:

I don't know. I certainly could enquire. The only thing I have left was a memory element, which has some of these features, but was--it is somewhat different, because its function was to contain a great deal of bits of information in a relatively small space. So it involves some of this technology plus some other technology, which I can talk about later if you wish.

MERTZ:

Yes. Now to go on, what then did you work on after this, ...the building block was fixed upon?

GREENWALD:

I was involved in finding out particularly what this configuration should be. I built an instrument for checking the, what we call, the timing of these circuits, to a large degree. I built a clock which was capable of emitting a number of standard one-megacycle pulses.

MERTZ:

How did you guarantee its regularity?

GREENWALD:

Well, we measured this against, you know, a standard oscillator, so that we knew that the frequency was correct. Because one of the problems we found was, as a result of using a transformer, that the timing of a first pulse was different from the timing of a chain of pulses, and this we had to know in order to make everything come together correctly. So this instrument that I built was used basically in making these measurements.

MERTZ:

I see. What did it consist of?

GREENWALD:

It was really a pulsed one-megacycle oscillator that could be started and stopped at a constant amplitude.

MERTZ:

I see.

GREENWALD:

To simulate the action of a machine which doesn't go on or off gradually. It's an abrupt start and an abrupt end. I built this, and one of the basic timing was tried out on this particular thing.

MERTZ:

Right. Did this have--lead in, directly or indirectly, to the problem of the delay lines and the configuration of lengths and, and their insertion in different configurations as a—

GREENWALD:

Yes. Since we knew the great accuracy--what would--our basic oscillator, incidentally, worked out very well, too. In other words, one has to not only come up with some good ideas, but, I guess, a certain amount of luck comes into this. I said we were rather lucky to put together a machine based on using thousands and thousands of an unknown diode and having it work out, fortunately. Also, our method of clocking I thought was rather good, and I think it was unique for its time. We had a--what it amounted to was we had a small, one-megacycle transmitter, which transmitted sine waves, mind you. This was done in three phases. This almost looked like a small amateur transmitter, but three phases which were equally spaced. These phases were distributed to the entire machine, so that everything was in complete synchronism. It always amazed me--before I got into the computer game--that when one thinks of one megacycle and so on, you think of a broadcast band and so on, very high frequency waves, you know, it was always a sense of wonderment, at least at the beginning, to wire all these things up at a frequency like that without really having a radio transmitter.

MERTZ:

In that connection, what kind of--Did power supplies form any kind of particular problem for you?

GREENWALD:

Not really. I think the power supplies went through a number of modifications. I believe we used several kinds, and I think they were commercial. There was nothing really too--these circuits were quite reliable and so that slight variations in the voltage supplies were not disastrous by any means.

MERTZ:

There are two other related questions. One is on transient phenomena. For example, was there any particular precaution taken so far as shielding from elevators and other kinds of nearby installations that were going to radiate?

GREENWALD:

No, really the criteri[on] here was that we tried to work at rather, very low impedances. We felt that extraneous noise could be disastrous, and so these circuits were built so that we could live through the fact that there were other laboratories around us and their interference, in general, would not bother us. Now, we did have--There were problems with the machine in this respect: if there were gross changes of power. For example, I sort of recall that the particular power line that we were on also had a wind tunnel on it some way or other. When this wind tunnel suddenly went on, power would fall disastrously. And when this went, power supplies would sag and everything would just disappear. We had that kind of problem. But if you're talking about ordinary interference, let's say, from cars outside the buildings, or elevators

MERTZ:

Air conditioner.

GREENWALD:

or air-conditioning, we had no such problem with the basic computer circuits. Now there are other circuits that we dealt with--again, I don't know how much you want to get in--where we were dealing with extremely low level signals, and that was a problem. If you want to get to that, we can at some later time.

MERTZ:

Before we get to that--this was an input problem?

GREENWALD:

Magnetic tape. I worked on the magnetic tape units, also.

MERTZ:

Before we get to that, one other question related to the environment of the machine itself, and that is: With these tubes and the like, you do have sometimes a heat dissipation problem, or at least the problem of having to design your machine in such a way that your tubes get an excellent amount of ventilation. Was that a problem?

GREENWALD:

No, this was not. This was a machine that was sort of wide open. And, because of the fact that there was only a single miniature tube for each flip-flop, and for each logical stage which consisted of, mind you, only one tube for three layers of gating, you see, rather than for each--You see, there was not a tube for each OR gate. There was a tremendous pyramid before each tube, and this tube then reshaped, and gave them more power to go on. But it was all funneled into that one tube, so you didn't have too many tubes in the machine.

MERTZ:

You are speaking now of the order of magnitude of diodes of approximately 25 to 27,000. Was the tube number substantially less?

GREENWALD:

Gosh, I'm going to be going on--I guess I should have done some homework for this. I

would say it was probably under a thousand.

MERTZ:

Under a thousand. So there again the heat dissipation problem was less.

GREENWALD:

Yes, and this was wide open. This was done with conventional open racks at the beginning, everything wide open: the tubes, the diodes, the transformers were all on one side of this sheet, outward of the machine. The machine was sort of built in the form of two parallel lines, if you will; two sets of racks that were closed at one end, sort of forming a U. Now on the outside of this U we had these components. Inside was all wiring. All the connections from one chassis to another were made by flexible wire inside the U.

MERTZ:

Right. Which meant then that the tubes and everything were all exposed.

GREENWALD:

All exposed on the outside.

MERTZ:

Right.

[End of Tape 2, Side 1]

[Start Tape 2, Side 2]

GREENWALD:

Generally, I would say that Sam Alexander was the head of this task force, and Ralph Slutz was involved with the overall machine--with the technical progress--after Senf and Lubkin left, and this was quite early in the game--so that didn't happen very long. I don't think Mr. Lubkin was there even a year, as far as I can recall, probably less than that. I think Mr. Senf was there about a year. But Slutz was there a considerable amount of time, and he was--I gave you his position. Now, in charge of the detail logic was a man by the name of Al Leiner,

MERTZ:

L-E-I-N-E-R?

GREENWALD:

L-E-I-N-E-R. And he got out the basic logic on the machine, the arithmetic, how these things were to be controlled and so on. Now it was up to me to take this general thing and then change it into these building blocks. I had to decide the precise--how these things were going to be timed, precisely how this was going to be changed into hardware. Then I would develop a real electrical diagram for this device, just how it was going to be done.

MERTZ:

The wiring.

GREENWALD:

Then I would give it to a technician. The technician then would get down to the wire-by-wire, the exact layout, what clusters were to be used, just what the arrangement was to be on this flat panel. So, that was the—

MERTZ:

That was your procedure.

GREENWALD:

In other words, the logic was given in sort of rougher form, and it was up to me to make sure that everything worked out correctly with the timing and phase, and—

MERTZ:

Was this done in particular--for instance, was the arithmetic unit done, control, --

GREENWALD:

Yes, that is correct. I first worked on the control unit for SEAC, that was my first job, to get that all done and working correctly. And then I worked on the arithmetic unit, which involved addition, subtraction, multiplication, division, and some of the other features.

MERTZ:

Now, in connection again with the machine environment: for those things which did have not such strong signals as the input devices, you mentioned magnetic tape. Did this impose--

GREENWALD:

To preface that, in those days, I mean, actually, I guess if you could get something to work, you felt you had achieved something, and speed was not necessarily of the essence. The thing was to be able to get something that would function a lot better than, you know, relay machines and these fixed programs, because this was a--We felt this was the first really completely variable program in a digital, all electronic machine that was built. You see, this was finished in, I think, in May of 1950, and was already doing problems at that time. Which gets to input and output. ... Now the input for this machine originally was punched paper tape. In other words, that was the way we got into the machine that was how we got data into the machine, that's how we got instructions into the machine. And, of course, this was extremely slow--and fairly complicated, as I recall. There was a man by the name of James Pike, who was primarily responsible for designing this punched paper tape mechanism that had multiple timing to make it--

MERTZ:

An asynchronous mechanism?

GREENWALD:

He was primarily electromechanical, that was--not logic, electromechanical was his forte. And our original input was teletype, extremely slow. Now this was all right for a while, but it became very evident that we had to do something faster than this. There had been a group, while I had been working on the logic and control and arithmetic circuits, there was a group that was working--there were three people who were working on the tape unit for this machine. We were not thinking in terms, as we do today, of multiple-channel type of things. This was strictly quarter-inch tape, single-channel type of thing. But I don't know what happened. The group did not work well. They came out with virtually nothing, so Sam said to me, "OK, you're in charge. Give me something." And so I took one of the men of this team, formed a team of two--myself and this one other chap that had worked on this--and started from zero, because from what I could tell I didn't have much faith in what had been done. Started from scratch and built up a single-channel tape unit which served as the mass memory, if you will, of the machine.

MERTZ:

External memory.

GREENWALD:

Again, by today's standards, it's very, very primitive. But there is where we started to get problems.

MERTZ:

Who was this other man?

GREENWALD:

A man by the name of Ainsworth. He still works for the Bureau of Standards. Well, that was kind of a problem because here you had a thing where you were dealing with extremely small signals coming off the tape, and you had to bring these signals up to respectable levels, and you had to, then, time these things very carefully with the logic of the computer. Because the things coming off the tape unit are slow and they're asynchronous, whereas the machine is going ahead at its own rate, and it's going extremely fast. And so, you have to have a means of meshing these two. And so it was a part of my job to design the logic and the circuits and the control for writing on the tape, and then reading off the tape. This was quite a formidable job. This, again, with nothing to go by is--what commercial work was going on, of course, was--we didn't know about, and it was under commercial wraps anyway, so a group of two of us were trying to do this. One of the problems, as I recall, was, above our laboratory was a tube lab, which was involved in designing vacuum tubes of various types, fundamental research in cathodes, and so on. And among the instruments they had, as I recall, was an RF heater which pulsed at 60 cycles and gave out something in the vicinity of several hundred kilocycles of a very peculiarly damped wave, which was so disastrous as far as the--It didn't bother our digital circuits any; they didn't mind this at all. But when you came to this, when it came to the tape circuits, this became a problem. So we had to learn how to shield, with a great deal of skill, in order to keep this out. And I remember this as being quite a feat before we were able to overcome this sort of thing.

MERTZ:

What was roughly the order at which Al Leiner produced his detailed logic? We talked about the arithmetic unit. Was the control unit the first thing that was worked on, or was the arithmetic unit?

GREENWALD:

As I recall, I think the control unit was the first unit that was worked on. It was my job to produce this control unit.

MERTZ:

I see. And then the arithmetic?

GREENWALD:

Then the arithmetic unit.

MERTZ:

Right. And then what came after that?

GREENWALD:

Well, there were some other parts. There was a large shift register in the machine which was involved in input and output; and that was another thing. There was another man who'd worked on that part of the machine.

MERTZ:

Do you recall who? Who this man was?

GREENWALD:

He was a man who was not there for too long. I think maybe he stayed there about a year or two and then left for California. I can't recall what his name was.

MERTZ:

Then after the shift register--I'm trying to get some sequence of how the machine was developed.

GREENWALD:

Well, OK. There was the--the magnetic tape, you see, came later, and that tended to replace all this teletype equipment eventually.

MERTZ:

We haven't touched on the internal storage of the machine. What was the--well, perhaps you don't recall the capacity capability of the machine.

GREENWALD:

Yes, I do, roughly. There were 512 words in this machine, and we used a mercury acoustic memory for this. This was a type of memory that had been developed for radar use during World War II.

MERTZ:

That was an acoustic delay line memory.

GREENWALD:

Acoustic delay line, mercury type, yes.

MERTZ:

When you say 'words,' now what was the 51-

GREENWALD:

Yes. There were 512. The capacity of this machine, believe it or not, was all of 512 words, each 'word' being forty-eight bits in length.

MERTZ:

512 forty-eight bit words.

GREENWALD:

That's correct.

MERTZ:

Using solely the mercury, acoustic—

GREENWALD:

Using the mercury delay lines. Each line contained eight words, so that you had--The number of bits stored was then eight times forty-eight.

MERTZ:

I see, yes.

GREENWALD:

The machine was capable of accessing the--If you divide eight into 512, you have the number of mercury lines there were.

MERTZ:

Sixty-four.

GREENWALD:

There were 64 mercury lines. This doesn't seem like much memory, but it was quite a

large box at the time, to store this. Each mercury line was about twenty inches long, and then we had to have the electronics that could pick up this very delicate--first, to drive one end of the line and then, to pick it up at the other end where it was a very weak signal--you see, by the time it got to the other end it was a very weak signal--to build it up to our logical levels; and then to be able to write, to synchronize it with the rest of the machine, and be able to write externally, let's say, from the arithmetic unit. In other words, to put things in and take things out, to erase, and so on.

MERTZ:

Making these acoustic delay lines synchronous may have been a problem anyway, because they're not synchronous.

GREENWALD:

Oh, absolutely. This was absolutely synchronous.

MERTZ:

Not the storage itself, was not?

GREENWALD:

Yes, this was synchronous. The key to the synchronism here was the fact; again, there was this one-megacycle clock. Plus one other thing. You see, a mercury line has a specific delay. And with this delay and at this repetition thing, you see, we were able then to put in--is it 384 bits? It's eight times forty-eight.

MERTZ:

Right. So 8 times 48 make

GREENWALD:

Is that 384?

MERTZ:

Yeah.

GREENWALD:

OK. So you have these 384 bits. But, you see--And this delay line is a very specific length, so that you can get this 384 bits. But the problem there is the length of the line is very dependent upon the temperature, the temperature of the mercury. And as the

temperature changes, this length changes. And, if the temperature changed too much, you see, this thing can get out of synchronism. You see, in other words, this has to be very close to a delay of 384, and very, very small differences--if we talk on the order of a microsecond, if you're talking about a fraction of a microsecond, then the clock can bring this back into synchronism, because there is always that clock that is not only synchronizing the logic but also synchronizing the memory, coming in there and keeping everything in beat. That clock is the heartbeat of the machine. So we have that if there are small differences. But, due to this temperature problem, it meant that we have to keep the temperature of that cabinet, which was a separate entity--in other words that was housed separately from the rest of the machine--that had to be kept to, I believe, something like a quarter of a degree Centigrade, plus or minus a quarter of a degree Centigrade.

MERTZ:

Was there an infinite of the tolerances [?] ?

GREENWALD:

Yes. Which meant that you had to--These mercury lines came encased in a heavy aluminum channel, and this channel was then bolted to a very heavy plate, and this heavy plate in turn had a number of heaters on them. And these heaters were cycled on and off, so that that temperature could be controlled extremely closely. Now, you never turned the memory off. The memory heaters were always on. The machine could be turned off at night, or you could turn it on and off, but the heaters always stayed on. In fact, if they went off, if there was an emergency--let's say, if there was an emergency in the power coming off the line, or something like that, and that cabinet got cool--it might take, I don't know exactly, but it might take a whole day or maybe more than a day for that temperature to come up and stabilize throughout that cabinet.

MERTZ:

Which raises one question about turning the machine on and off. Were there any peculiar problems associated with beginning the machine? Did you have any problems in terms of ...turning it on?

GREENWALD:

Did one have to wait several minutes for a warm-up, and so on, is that what you mean?

MERTZ:

Also in terms of power supply. Could you turn on parts of it and phase it on when you put it on, or?

GREENWALD:

I think there was a certain amount of phasing there. I think this is true. But this was a, really, not terribly important thing. You see, for example, you would not want to turn on the machine so that all the tubes would come on and stay on and not be cycled such that you might exceed their dissipation. So certain parts would probably have to go on before others, and there were, you know, lock-outs for that kind of thing. But this was a matter of seconds. There was no--

MERTZ:

and shut down?

GREENWALD:

And the machine would shut down if it--

MERTZ:

When the machine wasn't running, did you shut it down, or did you operate fairly continuously?

GREENWALD:

No. We would operate fairly continuously, yes.

MERTZ:

Well, was any thought given--well, you mentioned that the heart of the internal memory was the mercury acoustic delay line. Was any thought given, do you know, to electrostatic storage tubes, like the Williams tube, or any of this?

GREENWALD:

Oh, yes, by all means. If you want me to say any more about the mercury lines, I'll just mention one fact that I remember in passing, that in order to use the line you had to make contact with the mercury, and we spent a good deal of time trying to figure out what kinds of metals you could put in mercury that would not be corroded that would work for a long, long time. This was quite a problem that had to be solved, too.

MERTZ:

So, part of finding the answer, did you all work on that yourselves?

GREENWALD:

We worked on that ourselves. ... And we had to use tung--I did not work on the memory, I just remember that this was a problem, and things like tungsten and stainless steel were tried, and so on. We had this problem of corrosion.

MERTZ:

Do you recall off-hand who some of the people were?

GREENWALD:

I think Jim Pike, who was working on the teletype unit had this--I think he had a little part in working on the memory, and I think this was one of the things he was sort of personally involved in.

MERTZ:

In the, the question, what were, in your judgment--Oh, one question was: In terms of arithmetic, floating versus fixed point, which was in some respects a matter of making more complicated the circuitry. Do you recall, were there any questions about the pros and cons of the—

MERTZ:

I don't know. My own recollection is that floating point arithmetic never came up. I think this was--I don't know whether it was thought of at the time. I think this is a later development. Certainly, a more sophisticated kind of thing that we did not put in. Ours was fixed point arithmetic. I might point out that, kind of jumping to something else, that the machine was, I say it was certainly unique in this dynamic logic. You hardly find this kind of thing anywhere. So the unique development that ... worked out, again, very fortunate, I think, in so short a time developing a complete new technique that worked as well as this. I want to point out something I thought was rather unique in the design of the machine in that it was a four-address machine, which you just don't find anywhere. It was four addresses, which we called alpha, beta, gamma, and delta. Alpha and beta were the two operands, and gamma was the result of the operation, you see, and then delta was where you would go for the next instruction. You just don't find that anywhere. And furthermore, it was made such that at some time in the future we could convert to a three-address machine merely by turning a switch on the control panel. And the three-address feature, the guts of it were there. It wasn't put into effect until quite a bit of time after the machine had been put into practical operation. And so with a single switch you could turn a three-address system, so that no longer was delta specifically put in by the programmer, but rather there was a program counter to which you went: which is the way most modern machines work. So, you have a choice. It was rather unique to have this as early, the three or four address. And the programmer, after this was put in, could say, "Well, this is going to be a three-address program," and turn the switch and that was

it.

MERTZ:

I see. Well, you have already anticipated one of the two questions I would like you to address yourself to. One is, some of the principal bottlenecks, the really serious problems that were encountered in putting the machine together, if any, and perhaps you've already touched on some of the problems of the incident of the lines upstairs for this RF heater; but with regard to the machine itself, its design and construction. And the other, which you have already touched on, are the things that you consider significant and unique about the machine. You've touched on some of those.

GREENWALD:

Well, I guess if we look at the sort of the hardware, I don't know, it's so far...down it's a little hard to say what was--I know that we were plagued by solder joints. This was for quite a long time, we found, you know, cold solder joints that eventually were not making good contact. Month after month we kept finding these things in the machine. Another thing that we found that started to plague us from the hardware point of view, perhaps, maybe a year or so after the machine had been put together was the--we found out something about the delay lines. The delay lines, as I said, were made from a standard coaxial--I think that was developed for radar, for radar work--I don't recall the exact number. But anyway, it--what it amounts to is that you have a very, very fine wire which is a very tight spiral instead of just a single wire. It is a very, very thin wire that is in a tight spiral which acts as the inner conductor, and the outer conductor is a conventional shield of this thing. Well, by virtue of the distributive inductance and the capacitance of this thing there is quite an appreciable delay in this line, which we could then use for timing. Well, in order to get all these delays right and to keep our tolerances as best we could, we used to make these lines in various standard lengths that would work out with our clock phases. And putting these lines together, they had to take this very thin wire, and we would dip this into a--we're talking about extremely thin wire, now--we'd dip this into a chemical liquid that would take off the outer tough layer, and you were left with this very fine hair of copper wire. And then this would be then attached to a conventional wire, and then this in turn would be connected to a socket, and the socket then was plugged in. You see. Well, it turned out sometimes that if this extremely fine wire had not--if this chemical had not been completely flushed, there would be corrosion of the wire. Because you're talking about a little, a tiny filament. And so maybe a year later you would find that some of these things were beginning to give you trouble. And it was traced to improper cleaning of this thing. It was that kind of thing that I recall. Sometimes, I recall--the whole computer was on a wooden floor, and when--it might be in the middle of the night, we worked virtually twenty-four hours. This was, as I say, quite an eager beaver crew, because there was something at stake here, you know.

MERTZ:

Was that part of that esprit de corps?

GREENWALD:

Absolutely. A marvelous crew with tremendous motivation. The kind of thing that if you're lucky you hit once in a lifetime.

MERTZ:

You can always look back on with satisfaction.

GREENWALD:

That's right. Sometimes we'd be so frustrated, because something would not be working, just sporadically. The machine had something working at a megacycle rate, but if something goes wrong--say once in a million times, you know, maybe it goes wrong once every fifteen minutes or something like that--how do you find things like this? This trouble-shooting problem. Maybe someone was on this wooden floor jumping up and down if there was a bad connection trying to see if he couldn't accentuate this thing; someone looking at the oscilloscope seeing if something happened at that time. It was a tremendous experience.

MERTZ:

In connection with your own work on the machine, what--in your own view looking back on the experience with SEAC--what were the things that you derived the most satisfaction from doing, as your contribution to the SEAC?

GREENWALD:

I guess being part of a team that sort of brought a--helped to bring a sort of a new kind of mechanism into the world--that just has such a tremendous impact that at the time I just could not--I really didn't have any realization of--I had no ideas what it was going to bring. Absolutely none. I can recall how, you know, maybe, say, six or seven years later, after the machine was built and we were--I was still working at the lab on other problems and components, we were no longer working on the machine, because it was now in use and it was a working device. At least, as far as I was concerned, I was just working on other components and so forth. And I still had no idea of what the ultimate impact--I remember talking with a salesman about a particular machine--he happened to be working for IBM, and I said, "How many machines have you made of this particular type?" He said, "Well, how many do you think?" I said, "I really don't have any idea; maybe twenty?" He says, "Something like 700"; and I about fell down. When you begin to realize that at the time we were working on this that this thing was unique, you know, in '48, '49. What was there? There was virtually nothing, as far as I know, except some relay computers chugging along in a very, very primitive way, and this was such a

tremendous step over that. It was such a tremendous step over ENIAC!

MERTZ:

To get back, and can you be more specific than your feeling of satisfaction of being part of the team that produced the machine in terms of your own work on the machine, or, to rephrase that in more general terms, the specific things in terms of the technology of computing that you think this machine contributed to in a significant way.

GREENWALD:

Well, I don't know quite how to--It was--of course, everything grows out of prior art, but I think this was--as far as I can see, it was a leap forward in technology in the digital art, in logical design. Of course, there are other things that it led to. For example, it was--again, I'm kind of proud to be involved in--I can recall, you see, I was given the job of putting a tape unit on this machine. You could do very little, of course, with a teletype. And I recall the first problem that we worked using the tape, I believe, was one of the first times that a linear programming problem was actually tried on a machine. And I remember there was a man by the name of George Dantzig--who I think was also somewhat involved in funding some of this work--but he was also a mathematician, and I think he was deeply involved in this new method of algebra which didn't make much sense until you could get a good programmable computer. And I was proud that that tape unit that I was personally involved in was there when that machine was chugging away for seven hours at a stretch using the arithmetic unit, using the tape unit seven hours before they got an answer, and it worked. And, if anything had happened for one fraction of a second anywhere, it would have destroyed it--and it worked. And we just about hit the ceiling, you know?

MERTZ:

Seven hours of error-free performance.

GREENWALD:

Performance on a kind of problem that had never been tried before on a machine. This gives you a good feeling.

MERTZ:

Of confidence in the machine and your own contribution. Well, could you very briefly comment on your own career after your involvement with SEAC?

GREENWALD:

Well, I didn't get uninvolved with SEAC right away. I got to be known--you see, when

you start doing some of these things, and if you are lucky enough, you become a trouble-shooter. And then, if problems come up, you're it. So, somewhere along the line, why, this was going on. See, in May of 1950, the machine was dedicated and turned over for actual work. But it was a very peculiar kind of thing. It wasn't like you turned this thing over to a customer and said, "Here's a finished machine, now go ahead and we'll maintain it, or somebody will maintain it, and you can work your problems, and that's it. Now we can go on to something else." Now this was kept as an experimental and expanding machine while it was doing problems. So you had a very, very peculiar situation, where, for eight hours during the day, usually it was that way after the machine was dedicated, the engineering staff had, in other words, people like myself and other people would have the machine to work on, to make modifications to--and I'll tell you one modification—

MERTZ:

Play with the machine in an engineering way.

GREENWALD:

In an engineering way, to maybe get a bug out of the machine or maybe improve it in some way or another, expand some part of it, add a feature, and that kind of thing. And during the other sixteen hours it was in use by programs. So, you had to be--take, more or less--taking some things apart, but make sure at the end of your eight-hour stint that that machine was ready to go, and this was no fooling, because at the time--at one time while this was happening the AEC had the machine for the other sixteen hours, and, by golly, that machine had to be operating and going, and this was no fooling. So this was a very unique kind of situation.

MERTZ:

It was both an opportunity and a challenge.

GREENWALD:

That's right. To both have an experimental and a working machine

MERTZ & GREENWALD:

at one and the same time.

MERTZ:

What kinds of improvements--?

GREENWALD:

Well, OK, one of the things that was going on--as I say, there were a number of things going on sort of simultaneously. One thing was in the external memory. It is surprising how much the programmers of those days could do with 512 words. Today a programmer would look down his nose and say "you just can't do anything," that kind of thing. Today, people deal with 16000, and thirty-two, and sixty-four, and so on. Then, there were 512 words of internal memory, and that was it. Now this memory was relatively slow, because an acoustic memory of this kind is serial, and you have to wait for the bits to come around before you can pick them up again. They are not--it is not a random access memory. And this is what we wanted desperately. Well, the machine was made for this serial memory, but we did fix it up so it would be possible to put on an external, another memory, which was parallel and random access. So this machine was built originally with this in mind although it didn't have it at the beginning. And so, while some of this work was going on in building this machine and using this machine, there was a small group that was working on a Williams's storage memory, and they experimented with various types of cathode ray tubes.

MERTZ:

Do you recall who was involved in that?

GREENWALD:

Yes. I'm trying to think of who the principal man was. I can't remember his name. Anyway, there was this group of--there was a few people working on this Williams memory, because if we could get something like this going, of course, we could have random access and that would mean you could speed up the machine by sort of a factor here. So anyway, this work was going on, and, of course, Williams's memories were also being worked with at other places like the Princeton machine; I think, IBM was doing some work in this. I think some of the original work was done in England. So our people were trying to learn about the basic technique. And there were quite a [number] of different ways that one can operate such a memory and it had all kinds of problems. The phosphor has blemishes and you have to avoid the blemishes. The phosphor decays as you use it. All kinds of problems. You're dealing with very low-level signals, and at the same time you're dealing with extremely high-level signals in deflecting beams. And you've got to do this in very, very short time. There's a whole, a whole ramification here. It turned out, anyway, a lot of basic work was done on it, and finally it was installed in the machine, and sort of, sort of worked, but not very dependably. And the people that were responsible for the whole design could run the machine, left. But they still wanted it. I had finished the magnetic memory, so they said, "OK, you're it. See what you can do about this," because they wanted to use it. It wasn't any good to say, "Well, you know, it's possible." Because it had worked. They had it on the machine in its design, but it would work for a while and then,

MERTZ:

It was far from error-free.

GREENWALD:

Then it would conk out, and then do something, and then it would conk out again, and it was nothing but a problem, and the people who had designed it had left. And so they said, "You're it. Go ahead." "I don't know anything about this. I had nothing to do with it. I don't know what the technique is." "Ah, don't worry about it, go ahead." So they gave me another engineer, a junior, and me and a technician and said, "OK, we'll back you up, and don't worry about it. You'll get all the help you need." And you know what happens. You're it. And so, for a year, I fretted and worried and changed and did all kinds of things. I'm happy to say at the end of that they ended up with another factor towards the memory; [laughing] because that's all it was. In other words,

MERTZ:

You increased its memory.

GREENWALD:

Increased its memory by--still by a factor of two. At the same time, it was random access, so that you could immediately go to—

MERTZ:

About when was this, '53 or so? '52 or '53?

GREENWALD:

I would say this was probably '53-'54.

MERTZ:

Which was just the threshold of the introduction of the magnetic core memory.

GREENWALD:

Yes. Which never got on the machine. And after that, I was really no longer associated. After we had--we changed quite a few things, and we found out what to do to avoid some of the noise. We changed some amplifiers. We learned quite a bit about what you have to do to make it work. And, after that period was over, that about ended my association with the machine, but not the laboratory.

MERTZ:

Right. That just about ends this tape. Since it's about to go off, thank you very much, Mr. Greenwald.

[End of Tape 2, Side 2]