Computer Oral History Collection, 1969-1973, 1977

Interviewee: Heinz Zemanek
Interviewer: Henry Tropp
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TROPP:

This is a discussion with Dr. Zemanek in the Smithsonian Institution on the 12th of December 1972.

ZEMANEK:

OK.

TROPP:

I was pretty much going to give you freedom. Let's start with the Austrian environment as you came into it. How you got involved and what your background and interests were?

ZEMANEK:

That means I have to tell you about my early history, because this is how it started.

TROPP:

Sure, that's a good place to start.

ZEMANEK:

When I was a young student of telecommunication and that was '38, approximately, I looked around to see something which would be, in a way, unique for me. So that I really could develop. And I got interested in Laplace transform, we would call that today, at that moment it was still more Fourier transform. What I found was that the pulse was a real counterpart to the sine wave, but everything in electrical power engineering, any telecommunication at that time was mainly oriented towards sine waves. So I felt the pulse would be the thing which could carry me on. Now, that had a lot of consequences. For instance, I got interested in the spectrum of pulses and then one of my friends had a summer stage in the Vienna small, well for Austria it's a big industry, one of the telecommunication enterprises. And they had to deal with pulses and had problems with the bandwidth of a pulse. So I did, when I returned for a, you call it permission of

the army? A vacancy, a stay in Vienna from the army. I just, for fun and to go back to what I had known, I calculated around rectangular pulses and gave them the necessary information. How much bandwidth they would need.

TROPP:

When you are talking about rectangular pulses, you are talking about, what we call, I guess, square wave pulses.

ZEMANEK:

...Yes, right. So I was kept interested in this, and then when, well, there's the other story, how did I escape from the Army? I laid two lines out to get me out and they came to operation at one and the same day. I got a call of the army in October 1943, and I had a choice where to go. And, as frequently in my life there was a question "do I go into high frequency technology or do I remain with the pulses?" And again and again, I decided then to remain with the pulses. So I did there and this brought me into the Ernst Lecher Institute, which was an army radar research institute they set up when they discovered they were so much backward in that field. So from fall '43 to spring '44 I was there, and there was an interesting project. A German engineer and air force officer had the idea of designing a communications system with so short pulses that the enemy can't hear it.

TROPP:

By short pulses you mean low frequency?

ZEMANEK:

Microsecond. No, no. Well, shorter time.

TROPP:

Shorter time, okay.

ZEMANEK:

Yeah. Now, his idea was, if you make it short enough they will not hear it, because they are not equipped to pick up such short pulses. Now from my knowledge of the spectra, I knew, if you had a narrow band receiver, you would still get them. So I assured him "your invention is wrong." But, of course, he didn't believe me, but he was smart enough to put me on. He said, "Okay, show me. Calculate it." And at the same time, he put somebody to produce short pulses, milliseconds; it was at that time, to check whether one could hear them. I said, with the ear you can be even safer, it's a nonlinear device, and therefore you will perfectly hear the thousand hertz sound as short as ever you get your pulses. And, in parallel, I came out with all my calculations and that man had his short pulses, tenth of a millisecond and still you could definitely hear it. So he was very

positive to me and helped me later on to continue when I was thrown out of that institute.

TROPP:

I should get the name of this institute properly. ...

ZEMANEK:

Ernest--Ernst Lecher. That's the man who invented the double wire to measure short waves, you know that system? Two parallel wires and the lamp, you go and find the nodes and the maxima of the standing waves. ...

TROPP:

And the institute was—

ZEMANEK:

The institute was named after him. And it was on the Semmering, south of Vienna. I did a number of things there in parallel which have little to do with computers.

TROPP:

Well, it's interesting though because so many of the early workers, like you, came out of the radar environment.

ZEMANEK:

Yea, definitely.

TROPP:

Maurice Wilkes, for example, spent his whole wartime experience in the radar technology.

ZEMANEK:

Of course, the Germans didn't have very much, and we were really beginning from scratch there. Then they found out it was too Austrian, so they moved out all the Austrians from that institute and I had to go somewhere else. And I convinced them to send me to Berlin, because I wanted to finish my studies; what I did primarily was finishing, I had all the lectures and exercises but what I had to do were the examinations. So I did them one after the other. And I really made it, to go to Berlin, to have everything except the diploma work.

TROPP:

Now when did you spend this period in Greece?

ZEMANEK:

That was before. Between April 1941 and August 1943.

TROPP:

And there you were an instructor, you mentioned.

ZEMANEK:

Yes, I was ... a kind of instructor.

TROPP:

In communications?

ZEMANEK:

In communications.

TROPP:

But this was primarily telegraphy or radio communications?

ZEMANEK:

Well, the following happened. I was sent down to a telephone company. Telephone and telex, they had. I was educated, in the early days of my army service, in telex. But they used me on the phone. I didn't like just being a[n operator], I wanted to be on the technical side. So when we came into Salonika, when the Germans had taken Salonika, a couple of days before the l5th of April, I went in. I just got hold of one of the soldering irons and went up and helped the man who was in charge of soldering the lines, in his work. At the beginning they were very suspicious about the guy who mixes in here without any charge.

TROPP:

[Laugh].

ZEMANEK:

When they saw they could make use of me they kept me there and that made me an engineer ... in that company. It was the telephone company, in fact, of the German

highest command for the Balkans.

TROPP:

And then after you left there you went to the institute?

ZEMANEK:

Right, right. From there I went to Berlin and I was in a very interesting place there. It was the Academy of the Air Force, but it was also called Institute for Telecommunications. But he had a particular task. It was the "Reichsbeschleunigungsstelle", the ...German Acceleration Institute. Or Acceleration Office, if you so want. And the idea was to check electronic equipment against accelerations which would occur in ... V1s, V2s, etc. But the physicist there, Dozent Klumb, was much more interested in physics than in the war. ... He was a professor in, he was at least for a while, a professor in--he was in Eastern Germany, then he returned to West and was in Frankfurt, I think. He was a specialist for high frequency tubes, magnetrons, and he had established a system where he could produce them. But since he was so unwilling to support the war he didn't believe in, he slowed down everything.

TROPP:

Well, in that particular period, or era, you weren't concerned with guidance at all?

ZEMANEK:

No. I'll tell you the first task. I said, I want to finish my diploma work. Give me a subject where I can make a thesis about it. And so he proposed to me to investigate the system, well, a particular parameter of a system where he produced 100 000 g, [(g is the] earth acceleration, and he did so by firing two anti-aircraft guns at one and the same moment against each other. He had a big tube, and it's easy to calculate ...the [necessary] thickness of [the] tube. He had fixed the guns [on the tube; they were fixed at the same moment. The air was incredibly compressed and on the return, the two bullets developed [an acceleration of 100 000g]. Now what he wanted me to investigate was [the dielectricity] and [the] distance when they were closest. I said, "Sir, these are two unknowns and one equation, can you tell me any second?" And we couldn't agree on the way to proceed, so I said, "no I'm going to do something else." I [joined a project] on a [light-sensitive anti-aircraft shell equipment. ... It should have a bridge and two of the four elements of the bridge would be light sensitive elements. So when the shell comes in the neighborhood of an aircraft, and it would sense that there's a difference in light, left and right, then it would explode. And therefore, it would improve the chance of hitting the aircraft.

TROPP:

So it was kind of a proximity fuse?

ZEMANEK:

Yes. ... My task was to just investigate light propagation. So I had a beam between Gatow and the other side of the Havel River and I made [camera-recorded] measurements. ... I was in the wrong environment [for diploma work] and I had myself moved in the Summer of 1944 to Ulm. There was the "Zentralversuchsstelle fuer Hochfrequenzforschung" (Central Experimental Institute for High Frequency Research). There I was closer to radar technologies, and there I got finally a good [theme]. I had to produce a microsecond pulse. And that was really unique at that time. [The idea was to have Richard] Feldkeller, the famous German telecommunication professor [to supervise my thesis. When I first visited him, he remembered about milliseconds [only an experiment] using a candle, a piece of metal [hanging on a thread] over a wheel; they would burn through the thread and when it fell down it made a pulse. [Laughter]. That was [, of course, not a reasonable] way of making short pulses. [The first proposal was] starting off from a sweep signal, like in a cathode ray oscilloscope, and then making the edge steeper. We both didn't realize what a difficult network problem that was. [It is easy to make the edge less steep, but to get it steeper is very difficult].

TROPP:

[Drawing] You were going from this kind of a configuration to this kind of a configuration. Is that right?

ZEMANEK:

No.

TROPP:

Or was it down at this end?

ZEMANEK:

You can differentiate this [Fig. 1]. And the [steeper] the incline here is, the shorter is the [produced] pulse. That explains to you how I came to the [final] solution. I [over amplified a sine wave so that its] upper and lower [parts were cut off]. By this, of course, [the transition becomes shorter and shorter].

TROPP:

You're working at that... you're working...

ZEMANEK:

That's ... right. The more you amplify, the steeper the side becomes. And then a

differentiating element, ... a capacitor and a resistor [yield the pulses. (Fig. 2)]. And my first [device made] twenty microseconds; [it used] a RV l2P2000, a very famous German all-purpose tube. [With] the [RV 12P]3000, which was an improved version and went [up] to even higher frequencies. ... I made then a real one microsecond pulse. __That was the subject of my diploma thesis.* *Zemanek, H. 1944. "Ueber die Erzeugung von sehr kurzen Impulsen aus einer Sinuslinie." Staatspruefungsarbeit an der T. H. Wien.

TROPP:

Your thesis dissertation?

ZEMANEK:

I returned to Vienna and passed the examination at Christmas 1944. I made a real technical report about this, which was captured 1945 ... by the American Army. Then I went back to Vienna, I was again inclined to go into high frequency because radar didn't seem of any importance after the War. I could tell you a lot about how I finally came back and, but this is rather personal.

TROPP:

Well, when--I'm going to ask you one question in terms of the Americans who captured, you know, all the wartime documents, and then they became part of the Archive: Were you one of the groups of people that were visited at the end of the War by various scientists from the U.S. and England who were—

ZEMANEK:

Yes. They had a full membership list of the institute when they came to find us. We were dislocated. We withdrew from the Ulm area into upper Bavaria. And there they found us. They didn't have me on the list because I had too recently been transferred ... , but most of the people in the institute they had on the list.

TROPP:

Upper Bavaria, that would be the English group then that was operating primarily?

ZEMANEK:

It was a combined Commission, if I remember it well. There was an English colonel and an American.

TROPP:

Well, I guess, the only reason I asked you the question was, we only hear the other version, and I was curious as to which American scientists or English scientists you

remember meeting at that point in time. If they had, you had any conversations with any of them?

ZEMANEK:

...[Bavaria] was in the American Zone, by the way. Bavaria was American. [I do not remember the names of the military scientists, but, I believe, one had] a very general name like Johnson or so. They were absolutely aware of [the German] developments in radar technology, and the invention they were after was propeller modulation. You know, in order to distinguish an aircraft from the little strips they were throwing, you could search for the kind of modulation which the reflection of an aircraft would give due to the movement of the propeller. It wouldn't work for jets, but for propellers, it worked.

TROPP:

In that time period?

ZEMANEK:

And that was almost worked out in our group and that was the main point they were interested [in] when they heard about all the work.

TROPP:

Okay. Well, we can skip over any of the details of that period and—

ZEMANEK:

Okay. I returned to Vienna as early as I felt it was safe, namely when I heard that two ... two Austrian scientists which had been taken away by the Russians, had already returned. That turned out to be February 1946. For one year, we did two things. My friend Ernst Steinbrecher who is now here with COMSAT--by the way, a member of the ... Ernst Lecher Institute, I mentioned to you, was Mr. Reiger, the founder of the COMSAT Laboratory. You know him?

TROPP:

No. ...

ZEMANEK:

...He died two years ago. [He had been director], not of COMSAT itself, but [of] the Laboratory. [An auditorium is named after him].

TROPP:

And do I have Steinbrecher's name spelled, with a C-H?

ZEMANEK:

Spelled C-H. Otherwise it's alright. He is there at COMSAT. We intended to write a book on high frequency technology as far as we knew it at that time. [We] never did the book. And secondly, we intended to begin a company. Because we said we don't see why it's always the lawyers and the economists who earn the money, and the poor engineer has only a small fraction. After a year I'd learned my lesson. I knew why it was alright that the lawyers and the economists earned more. He had not so fast understood his lecture. So I went out of the company and, because there was an opening at the University of Technology, and I became assistant. That was [in October 1947].

TROPP:

Now an assistant at the University required what kinds of duties?

ZEMANEK:

In our case, we had a very old professor who had been called back by the principle that everything which the Nazis had distorted should be corrected as good as possible. So, since he was a holder of the chair before and was expelled by the Nazis, he was called back. But he was very old and so we did the lecturing. We did practically [his job], we were a part of his professorship, so to say.

TROPP:

I see.

ZEMANEK:

That gave me, of course, a lot of chances. I lectured on television. I lectured on all parts of, of—

TROPP:

He essentially had a chair in what we would call electrical engineering.

ZEMANEK:

Of telecommunications.

TROPP:

Of telecommunications.

ZEMANEK:

It was the Institute for Telecommunications and there was only one professor at that time. Later on it was divided into two institutes, and now it's already three, and the fourth one would be the one they have offered to me. But at that time it was only one. And I would take over telegraphy as my particular interest and again, the pulse technology. Now, I had a scholarship of the French Government for the scholar year 1948-1949. And that I spent in Paris with three Institutes, namely the Ecole Normale Superieure--*

TROPP:

Yeah, I know that.

ZEMANEK:

There was Professor Rocard, a kind of French authority on short waves. ___ *[the other institutes were the Sorbonne and the Ecole Superieure des Telecommunications (PTT). HZ]

TROPP:

Well, could you spell his name for me?

ZEMANEK:

R-O-C-A-R-D. First name was Yves, Y-V-E-S. Yves Rocard. And when I told him I wanted to work on pulses, he said, "there is nothing to invent there. You better do twenty centimeter waves." So that was another attempt to get me in high frequency.

TROPP:

[Laugh].

ZEMANEK:

I said strictly no. And then we had no working basis to do anything, so I started a study on the physical units, dimensions and units, and I ... read all the basic literature; the original publications of Gauss and so on, when the different units were created. Which was a very fascinating study. It was only later, [in April 1949], that I found ... access to pulse technology, because I discovered that at the PTT Laboratory they were working on pulse code modulation. And so I joined that group. What I achieved there, essentially, were two things. I contributed to their work. I'm not sure they were applying it, but I had a circuit for a division by seven. You had a train of pulses and, you know, you had the seven bit code in PCM in the early days. So you needed, down from the [received pulse sequence], a division by seven. And the invention I had made was a very simple one. I had a feedback line, a delay line, with six contact points and each of them fed back a

negative pulse to the grid. So that the original pulse could not pass six times, and only every seventh ... would come through and go into the feedback line.

TROPP:

So it was kind of a modulo seven system. Like Gauss had done his arithmetic. [Laugh].

ZEMANEK:

Right. Yes, exactly. That I have published in England in the Wireless Engineer; I was very proud of my first English language paper.*

TROPP:

Then again, you were involved in the development from radar technology?

ZEMANEK:

In a way, certainly. Well, it was, at the same time it was my beginning

TROPP:

Pulse and delay line—

ZEMANEK:

...of digital communications. And also there I had my first contacts with the computer. I'd heard, of course, about the computer. I saw it was the application of my pulse ideas of the earlier years. So I tried to get as much information as I could get, and in particular I had a hope I would see what the French were doing. And at that time, computers were still practically unknown. It took me several months to find out that there was a Mr. Couffignal, that he was working on a computer and where he was. All of that was a big research work. It was through certain friends in the PTT who knew him or had heard--they didn't even know him. They said, "Couffignal, with a very funny *[Zemanek, Heinz. 1954. "Pulse Frequency Multiplication and Division by Delay Lines." Wireless Engineer 31: 10, 264-265. HZ] spelling of the name"; so they even weren't sure how the name was to be spelled. And so finally, I visited him in the Institut Blaise Pascal, where he was working. And that was in the Institut Optique, [boulevard] Grenelle. ... [A description of his planned computer can] be found in [a Harvard] conference volume.* And he showed me every[thing]--he [said, but actually] he showed me nothing. He told me long stories about how excellent his machine would be, much better than anything the Americans had. When I said I would like to see something, he said, "Oh, that far I am not yet, come again in two months." For some reason, I came only three months later and he told me exactly the same story. Only he changed the parameter, he said, come back in three quarters of a year, and I can show you something. From that I concluded that [his] development was [not con]verging and [that] I would

have no chance whatsoever to start such [a] development in Austria. So therefore, when I returned back from that scholarship, I started digital communications; that I had seen with PCM, and I built up a tradition within the institute that students first use more than three or four tubes, which, until that time, was the maximum. So I had one diploma work with several hundred ___ *Couffignal, Louis. 1951. "Traits caracteristiques de la calculation de la machine a calculer universelle de l'Institut Blaise Pascal." In: Proceedings of a Second Symposium on Large-Scale Digital Calculating Machinery. Harvard Computation Laboratory, Sept. 1949. Cambridge, MA: Harvard University Press. Pp. 374-386. …tubes and that was a sensation. And the second thing is, since I saw I would have to use even more, I built up teamwork. And that was also very unusual at that time. The diploma work was something done by one man. And I had to invent very sophisticated ways of sub-dividing a task to different people, lay out what part they would have to describe, and then I usually [had] made an n+1st ... thesis, which would be the integrating one, describing the system. So I came on a kind of system thinking already at that time.

TROPP:

That's right. You had n people and then a—

ZEMANEK:

And we started all kinds of almost computers. I did, for instance, an analog computer for the resolution of polynomials, which had however, a step-switching to run the variable through from zero to one. You can have papers on all of that. Most of that was published in German.* ___ * [Zemanek, H. 1944 (see p.).; Newald, K. 1950. "Der Sperrschwinger als Impulsgenerator." Staatsprufungsarbeit an der T. H. Wien; Zemanek, H. 1951. "Zeitteilverfahren in der Vielfachtelegraphie." Dissertation an der T. H. Wien. 54pp. Stampff, R. 1952. Impuls-Phasen-Modulation." Oesterr. TF 6: 113-119. Harmuth, H. 1952. "Eine elektronische Rechenmaschine fuer statistische Berechnungen." EuM 69: 23, 24, 501, 552. Stampff, R. 1954. "Bemerkungen zur Impuls-Delta-Modulation." OTF 8: 58-63, 92-97. Wipoltshammer, J. 1954. "Die logistische Relais-Rechenmaschine LRR1." Staatspruefunfsarbeit an der T. H. Wien. Holzer, J. 1954. "Ein Versuchsmodell fur Impuls-Zahl-Modulation. OTF 8: 125-132. Horner, J. 1954. "Eine Analogie-Rechenmaschine mit Schrittschaltantrieb zur Losung von algebraischen Gleichungen bis zum 6. Grad." OTF 8: 153-158.

TROPP:

Yes. Let me ask you a question about this period. Because we know that there are developments going on in the United States and we know there are developments going on in England. These are far beyond most other developments at that point. But there aren't very many publications. There aren't very many things to read. Did you have in Austria, or in Paris, any verbal or other knowledge of what was going on at the Moore School or at Harvard or at Bell Laboratories, or other places? In that time period?

ZEMANEK:

The answer is, I picked up a fairly reasonable knowledge in the years between 1949 and 1954.

TROPP:

Yes, but this is, we are talking about before '49.

ZEMANEK:

No, no, no, no. I had only very general news before I went to Paris. In Paris I had the hope, now here is the man who can explain to you what a computer is like and how much work it would be to get to one. I saw there was no hope. So I had to step back and--what I did in France, of course, I collected publications. I found one way or the other the early descriptions of the ENIAC, I had very probably already at that time in my hand. I would have to look back what--see, at that time for instance, the Proceedings IRE. Proceedings—

TROPP:

Beginning, they were beginning to publish things.

ZEMANEK:

I would have looked them through regularly and there were already publications. You get--I, of course, got into information theory. I saw the articles of Shannon, I was intrigued by that. Switching algebra, I'm not sure, I might have seen, I might have heard about it. I have not seen very much before 1950, but that was then around 1950, one of the subjects I took up. And then I did the following. We had [until 1955 the four-fold] occupation in Vienna. So since I knew that [the computer] was essentially an American and English development, I would contact science officers or those who were looking for the scientific developments in Austria and ask them questions about computers. And I got, step by step, more and more material. Of course I didn't trace the date when I got one or the other.

TROPP:

No. But for example, Mathematical Tables and other Aids to Computation was publishing.

ZEMANEK:

Yes, but this was one of the typical journals which were very difficult to get hold of. So sometimes I asked my friends, "couldn't you try to get me a publication"; I think [I got] one of the ENIAC descriptions [in this way]. Then I encouraged several libraries to get

the proper journals. I was running my own library at the University Institute so I could get hold of journals. I got the Bell Laboratory Record. That was—

TROPP:

Yes. The articles that E. G. Andrews was publishing then.

ZEMANEK:

I don't remember the names, but I was clearly aware of the relay things they had done. That is hard to tell without looking at my early [notes].

TROPP:

Oh yeah.

ZEMANEK:

But you could see that from the article I had written in 1954* and what I have talked previously about it. I started to write a lot, because I got encouraged by a number of people to write on information theory and on automata, and all the things that were coming down: control and Wiener's theory, and cybernetics. So I wrote altogether some twenty or twenty-two articles for a, well, a radio engineering journal of not too high a scientific level. But that gave me an introduction into scientific writing. The series was very good; if I had been more business and also actuality minded, I would have made a book out of that. What happened was that the Hungarians translated it** and the translator was a man whom you might know. Because meanwhile he has made a big career in the Bell Telephone Laboratories, Mr. Julesz.

TROPP:

No I don't.

ZEMANEK:

He's a specialist on perception, and he published recently a book on his theory of perception, very interesting. And at that time he had not yet escaped. That was before 1956 and he translated all these articles of mine and made two little small size books out of them.** ... ___ *Zemanek, H. 1954. "Grosse elektronische Rechenanlagen." OTF 8: 7-13, 37-45, 73-85. **Zemanek, H. 1956-57. Informacioelmelet. Transl. by B. Julesz. Budapest: Muszaki Konyvkiado. Vol. I, 124pp, vol. II 108 pp.

TROPP:

That's interesting that you immediately got into the Hungarian environment.

ZEMANEK:

Yes. Well, I got also into the Russian environment by--I was interested in cybernetics. I ...got Wiener's Cybernetics; the old professor gave it as a present to me. I have the signature in and the date, so I know when it was: [15th January 1952]. When I had read that book I didn't know what cybernetics was, so I looked further on and I found that there were three real machines in existence, namely ...Walters' Turtle, Ashby's Homeostat, and Shannon's mouse in the maze. And I started to do th[em] with my students. And I guess I'm the only man on earth who had copied all the three.

TROPP:

[Laugh].

ZEMANEK:

[Our] Homeostat ... [is] a nice version, I happened to fall into a student who was in a plastic factory. So he could ... shape everything very nicely. With the two others we did quite a development. Shannon's Mouse in the Maze we extended to have not only the information in what direction the mouse had left the field, but we added an algorithm concerning Ariadne's thread. Which is another two bit information. And with that the algorithm became complete, [avoiding looping and able to go back from the found goal to the start.] In the other case you would not know if--well, you would have to go into detail of that thing. So that was very nice. The other development was the artificial turtle. That, as you know, was the idea of just realizing as a little moving around circuitry an algorithm written down by Pavlov. Now I had, for some reason, the chance in 1959 to have [in Vienna] all that year a Hungarian specialist in conditioned reflex behavior, [A. J. Angyan]. And he would tell us all the stories and we would translate them, the student and I, into a circuitry, in an extended artificial turtle. On this there exists a paper in 1960 at the Fourth Conference on Information Theory in London.* ... Now this was a very remarkable automaton because it had six state variables. So, in principle, it could react to the outside stimuli in sixty-four different ways. Now it didn't have all the sixty-four states. It had some forty states, but parts of them were not stable in time. They would jump back into more stable states. But still then the pattern of behavior was very complicated. But it really gave a model of the complete knowledge of the East and West school of behavioral sciences in the conditioned reflex field.

TROPP:

That's fascinating.

ZEMANEK:

Now, this was--I may make here a remark which relates to much later work, it was my first experience with the problem of translating from natural language descriptions into formal ___ *Angyan, A. et al. 1961. "A Model for Neurophysical Functions." In: Fourth

London Symposium on Informatyion Theory (C. Cherry, ed.). London: Butterworth. Pp. 270-284. descriptions. Medical people, of course, don't have very much of an algebra to describe what they are doing. So the usual situation was we should say "we have understood what you have told us, we have formalized it." Then we gave examples. "If, if, if that happens on the outside, then, then, then the following would be the direction of the machine." And it happened very frequently that he would say, "yes, yes, yes--no, I haven't said that." We had said, "you didn't say it, but it's the clear logical conclusion of what we have derived from our talks." He said, "No, that's not at all so." So we had to re-phrase the early description and step by step we came then to something which was satisfying to him. We also became aware of the remainder which is always there if you go from informal speaking to formal. In the informal way you are not very precise. You have contradictions. But you cover a wider field, because you always can operate with a part of the knowledge, which is the active working of the brain. Doesn't need that much specification but has items in it which are larger, they are not worked out, but they are contents which the formal definition then would miss. So it was from that time on that I was very sensitive to any tension between formal and informal description, which was very helpful for my later language development. Now let us return, how does it come I moved into computers? As I say, I was interested and we did a number, we did at least two bigger relay machines. One was an analysis machine for logical functions. You will certainly remember the work done in England by [McCallum and Smith of] Ferranti.* ... And we did the same. ... We had telephone equipment and [on this machine LRR1,** one] could program any Boolean expression, like on a telephone switchboard. And then the machine would run through...--up to seven variables, 128 combinations--and it would [indicate and store] "yes" or "no" [for each combination].

TROPP:

Okay. Let me back off for one moment here, and ask you where your background on Boolean algebra goes back to?

ZEMANEK:

That, I would assume I got already from the intensive amount of literature I'd gathered. I was a big reader at that time and I would look through all the American journals I could get hold of and see whether there was anything related to pulses. And of course, switching algebra was related. From my study of Shannon's works I soon heard that he had written on this. He was quoting it somewhere and I found it out. And then in these days, around, well, really around 1950, there were already articles appearing. I would have to use my notes to tell you.

TROPP:

Yes. Well, I'm just curious, you know when these things come into an individual's environment, because Boole's work had been lost for so long. Nobody paid any attention to it. ___ *McCallum, D. M. and J. B. Smith. 1951. "Mechanized Reasoning." Logical Computers and their Design." Electronic Engineering 23: 126-133. **Weipoltshammer,

J. 1954. "Die logistische Relais-Rechenmaschine LRR1." Staatsprufungsarbeit an der T. H. Wien 1954. Zemanek, H. 1956. "Logistische Rechenmaschinen." NTF 4: 207-212.

ZEMANEK:

It was in fact not switching algebra what he did, because he tried to describe the logical derivations by arithmetic. ...

TROPP:

Right. But it was through the ideas of Boolean arithmetic that, for example, Stibitz built the first relay computers as opposed to Shannon's work. He became knowledgeable about Shannon's work only later. So he got into the ideas in the early, the very first relay machines, through the Boolean arithmetic as opposed to the other approach in switching theory.

ZEMANEK:

My first article on Boolean algebra is within the [mentioned] twenty articles, [the last of them].* ...

TROPP:

You mentioned two machines. What was the second machine?

ZEMANEK:

The second one was a computer. At that time I knew already about Zuse [and his] special circuit for relay parallel addition of binary numbers, [e.g., out of Rutishauser et al 1951**]. And I did a machine, of which you can again get easily the description,*** having [a word-width of] 18 bits and ... 16 cells of memory. [It had] multiplication, division and square rooting device [carried out by means] of rotating switches.

TROPP:

Let me turn this off for a minute.

[RECORDER OFF]

___ *Zemanek, H. 1955. "Schaltalgebra." Radiotechnik 31 no. 5/6: 210-209 [?] **Rutishauser, H., A. Speiser and Eduard Stiefel. 1951. Programmgesteuerte digitale Rechengerate (elektronische Rechenmaschinen). Separatdruck aus der ZAMP. Mitt. aus dem Institut fur angewandte Mathematik an der ETH Zurich. Vol. 2. Basel: Birkhauserverlag. 102 pp. ***Zemanek, H. 1955. "Die Universal-Relais-Rechenmaschine URR1. EuM 72:6-12.

TROPP:

The point that I made when I turned off the machine was that essentially you were repeating the American experience, as different from the English who started with the electronic period and didn't go through the relay and electronic development. You were going through this all over again at this later period.

ZEMANEK:

The main reason was not that I thought I had to go through the American development. The main reason was relays were the component I could get hold of in [sufficient] quantities simply by going to the PTT friends high up in the hierarchy, and they would give me access to the place where they were destroying all old equipment. And before doing so I could point to kinds of relays I wanted to have and I got them by hundreds. There was no hope to do that at this moment by tubes, but the worst thing with tubes was the power [unit]. The power supply for a couple of hundred tubes was quite a problem. And when I looked on this I was sure I would not do it with tubes. For the relays I could really go step by step. I had a lot of soldering work to do, but the students were really [excited] to go along. I moved one diploma work after the other on that machine. It never really worked; for instance, the multiplication. I don't remember we have ever multiplied with it. But we have added. ...The program would [come from] a punched tape, and very primitive programs we had in fact carried out. But then, the following happened [in 1954]. My boss came and said, "Heinz, we are going to build a computer." I said: "What happened?" "[We have got a Koerner Prize. ... And we] got an extremely big one." I said: "How much is it?" And he said: "Thirty thousand shillings." That's about one thousand dollars.

TROPP:

[Laughter].

ZEMANEK:

And I said, "that's a lot of money, [I agree, compared to the usual amounts,] but for a computer?" I said. He said, "[Well], it comes from the [Trade-]Unions." "...If it comes from the Trade-Unions, then let them put up their," how do you say?

TROPP:

"Roll up their sleeves."

ZEMANEK:

"And shift the decimal point." [Laughter].

TROPP:

A couple of decimal points really.

ZEMANEK:

Well, I would have been satisfied with one. Because I was sure I could get a lot of material from the industry. And that was the basis on which we operated. He said, "but, you know, I got that amount, you have to do something about it." "Well," I said, "this is a basic decision. If you want me to go ahead I'm willing to do, I was always dreaming of doing it. But in this case, it's a big operation and you will really have to support me, because in that case I would have to leave everything aside and do only this computer." "Okay," he said, "I will support you." So then my concept was I would use the 30,000 shillings like the British Fleet, you know, just by the fact of existence. [Laughter]. So I ran around and the main problem was, of course, first to find out what kind of machine should we do? And secondly, where do I finally really get all the components, in particular the tubes, or since I was very convinced tubes wouldn't do it, the transistors? And that was really an advanced step in [those years]. Now, I tell you the result. I had myself invited to Philips Naturkundig Laboratories in [Eindhoven], ... in Holland. And I talked Mr. Rinia, who is a man who is known in this country because he had been for one year the [Vice] President of IRE, into really giving me the necessary (we thought at that moment) [around] thousand transistors. We didn't fix the number and, in fact, I got altogether some 3,000 transistors and 5,000 diodes from Philips free of charge. [Now, as the necessary money:] I had been a big Boy Scout leader, I was the International Commissioner of Austria [from 1949 to 1954]. And via my Boy Scout friends [I got] a channel [to] see the biggest banker of Austria at that time. He said, he was not going to promise me anything, but he would probably talk to the Bankers' Association. And in fact, I got the promise, if I can get the transistors, I would get from them 100,000 shillings. In fact, they made it three times as much, so I had much more than 10,000 dollars capital altogether. And with that I managed to make a [machine worth] ten times that amount.

TROPP:

Let me ask you something because of the--I look at the early development of transistors and they were very erratic. Nobody knew much about their characteristics.

ZEMANEK:

Yes.

TROPP:

They had imperfections, they were difficult to work with. Much more difficult than tubes. How far had the state of the art of both production in terms of quality control and knowledge about their characteristics grown by 1954? That you felt confident about going into a brand new technology and skipping tubes altogether? That's an interesting

jump, you know. I just talked to you about not skipping the mechanical and relay stage and then you end up skipping the tube stage. [Chuckle].

ZEMANEK:

... I just had no chance of trying it with tubes. I could get tubes, but it was always difficult. Companies would not like to give away non-fitting tubes. You know, they have certain margins which the different parameters should have. Now it happens all the time in tube production, that you get a full series which in some detail doesn't meet the requirements. So they had many of them. The trouble was to get them out. Because they said, "even if we don't stamp them, people would recognize it's a tube of our make and if it doesn't fit, we get problems. Therefore, we don't like to give them to you." So I had really to convince them they had to stamp them "Not within the conditions" or something. [And they made such a stamp]. Still, to get in [the size of a real computer], would have been very difficult and mainly I feared the power requirements I would have and that would never have made this. The additional question was, with the given manpower ...(I had no industry behind me) I could do it essentially with the students. ... I just could make it for the relative low energy and low tension power equipment for the transistors. And they were a problem.

TROPP:

You say, in 1954, they were still a problem, in terms of uniformity, weren't they?

ZEMANEK:

Yes. So we had to have measuring equipment. We developed a cathode ray tube curve tracers, to check them. We would not allow any transistor to go in without being checked back by us.

TROPP:

Where did your background come into transistor technology? It was different to anything you had worked in up until then?

ZEMANEK:

Well I felt, we just have to do it. So I got a student of physics, who is now my second man in my laboratory, [K. Walk] to work on the circuit technology and [E.] Rothauser was looking into measuring problems. I just told them, we are going the transistorized way. And they said, okay, let's try it.

TROPP:

[Laughter].

TROPP:

And this was in 1954?

ZEMANEK:

Well, it started in '54. The real [development began] in 1955, ... the year of the Darmstadt Conference. At the Darmstadt Conference I could publicly announce that I was planning to construct a machine in Vienna. Now since we knew the transistors we were going to have were hearing aid transistors, we feared we would have to go down quite low with the clock frequency. At that time [tube computers] were somewhere between 100,000 and 1,000,000 bits per second. And I couldn't dream to do that. So I said, and this is where the name comes from, I said in Darmstadt, "we are not going to produce a Whirlwind or a Typhoon or any of those big American storms, but we will [have] a very nice little Viennese Mailuefterl," which is a spring time breeze.*

TROPP:

[Laugh].

ZEMANEK:

And I meant it just as a joke. [But] the German professors ... said, "That's a wonderful name, you should keep it."

TROPP:

[Laughter].

ZEMANEK:

So I did. My own collaborators were very unhappy, they said, "you make an earnest enterprise and you give it such a funny name."

TROPP:

[Laugh].

ZEMANEK:

[A number of people felt like that. For example, the Prime Minister of Austria, the last, had been a "student" of mine--he came three times a week in the morning at a quarter to eight, and for one hour, he [learned] programming, computers and cybernetics and whatever he wanted to know. And he then devoted in his memoirs ([written after] he was voted out as Prime Minister) one chapter to me. And there he ... remarks, "in a typical Austrian way he misnamed his computer."** ___ *Zemanek, H. 1956. "Die Arbeiten an

elektronischen Rechenmaschinen und Informationsbearbeitungsmaschinen am Institut fur Niederfrequenztechnik der Technischen Hochschule Wien. Nachrichtentechnische Fachberichte 4: 56-59.

**Klaus, Josef. 1971. Macht und Ohnmacht in Osterreich. Konfrontationen und Versuche. Wien: Molden. Pp. 195-196.

TROPP:

Well, I think it's a charming name and I'm glad you did it that way. [Laughter].

ZEMANEK:

Yes. I feel until now. And we got the significance of that name and [we] kept it.

TROPP:

So much nicer then an I-A-C ending machine. [Laughter].

ZEMANEK:

Yes. I didn't like, you know from NSDAP, I didn't like the abbreviations.

TROPP:

Was, to your knowledge, at that point in time, was there anybody else working on a transistorized computer? Did you know of any other work going on?

ZEMANEK:

No. I knew, of course, of all the German [University] enterprises. But they were all tube. But I was clear, it would take me a couple of years, and I felt: It's now the moment; it's the chance to go. I talked a lot with the Philips people in order to see what I, as far as one could see, what I was doing. The Philips people assured me about certain properties of the transistors and we checked them out and we found soon out that we could go much higher [in the speed]. We [found] with that hearing aid transistors, in the digital case, [and with some ideas*] we could go up to 250,000 bits per second, which we did not dare to do in the machine, but the __machine had then 133,000 steps per second. *Walk, K. 1960. "Die Ausnutzung spezifischer Halbleitereigenschaften beim Entwurf der Volltransistor-Rechenmaschine "Mailufterl." Solid State Physics in Electronics and Communications. London: Academic Press. Pp. 924-938. Walk, K. and H. Zemanek. 1959. Schaltungsanordnung zur Verzogerung und gleichzeitigen Verstarkung oder zur Verstarkung allein von einzelnen Impulsen oder Reihen von Impulsen." Patentschrift 202 192, Kl. 21 A1, 8, Wien, 10 Feb 1959.

TROPP:

How about memory?

ZEMANEK:

Oh, the memory story is a particular one. Well, I was absolutely clear: the drum was the first thing we started. Immediately, [when] we got the 30,000 shillings, I started the drum development. And it was clear for me; I would [spray] the liquid on the magnetic tapes. You know, Germany was very good, BASF.

[RECORDER OFF]

Well, I just was saying that the drum was the first thing we did and ... we knew there was a liquid to be sprayed on the surface.

TROPP:

The magnetic coating, yes.

ZEMANEK:

Yes. And we found out that it was a safe way to go. We had already the experience of the German groups which were ahead of us. So, and that worked out very nicely. And then, I needed, of course, some kind of fast memory. And again, I went to Philips and asked them for cores. And we got cores. We got even selected cores. Unfortunately others had selected the cores and we got the tails of the distribution.

TROPP:

Almost the rejects. [Laugh].

ZEMANEK:

So we had to make an invention and we made one. You remember, usually the reading was done by throwing the core back into the zero position. We did it the other way round. We threw the remainder on to one and got quite an improvement in the distortion situation and that was a patent. * Well, here I have to tell you now, who supported me further. That was Zuse. The agreement was Zuse would pay one of my people the salary. So I was, in that respect, independent of the bankers, and the agreement was, that man would do the logics, the layout of the structure, and when that was finished and confirmed by the development of the circuitry, he would change from my group to become a member of the Zuse Company.

TROPP:

I see.

ZEMANEK:

And that was really carried through. The man made a very good career in the Zuse Company. His name is [R.] Bodo and he became the first engineer ... until the Company was absorbed by Siemens; he is now at Siemens. ...

TROPP:

Bodo. Another area, that we [should cover], in our short time available, should be your input/output.

ZEMANEK:

Yes, you are right. Well, one thing was clear from the beginning. From my telegraphy practicing in teaching and in also having it in the laboratory, teletype equipment was the clear answer. Siemens [and ITT] would help me in that respect and the main input/output was teletype. But that was only 50 bits per second, as you know, and that was not fast enough. ___ *Bandat, K. 1960. "Zur Storreduktion in Ferritkern-Matrizen-Speichern, eR 2: 177-182. Bandat, K. and H. Zemanek 1962. "Anordnung zur Speicherung digitaler Informationen." Patentschrift 222 921, Kl. 42 m6/10, Wien, 27 August 1962. So we went on and we designed a construction, which we called Octavio, which was a fast punched tape reader. Which did not work to our satisfaction. The man who did it was too fast in his work and forgot about temperature compensation. But otherwise it was an interesting construction. We found out that if you remove the black cover of the transistor, you can use it as a light sensitive device. But the transistors at that time were still three, four millimeter thick, so putting them together would not fit to the tape. So, we took glass rods, a strong lamp above, and then at the end we glued a scratched off transistor.

TROPP:

Yes.

ZEMANEK:

And that was the reading device. And that worked very well. What did not work was the amplification afterwards, the interconnection. So we got an ITT punch, which didn't work either very well.

TROPP:

[Laugh].

ZEMANEK:

So, I/O always remained a kind of problem.

TROPP:

One other question about your machine. In terms of its architectural structure. You said, you had the man who later went to Zuse do to the layout. From a philosophical point of view, do you feel that there were any innovations in that machine, where you did things that were different from the machines that were then currently becoming available. Most of them, tube type. In terms of the logical structure and the overall architecture of the machine?

ZEMANEK:

Yes, there was. It was not really our own invention, but looking into the different structures, we came across of the work of Van der Poel. And he had coined the term and the idea of the functional bit. So we had a very flexible instruction word which had four bits for sixteen (or rather fifteen, because one was empty) main operations. Three other bits for [seven] additional operations. One could combine each of them with each of them. And then there were nine single bits, which were functional. They would do, for instance, the necessary addition and subtraction of one, required for the multiplication and division, to work up the word and do the counting and so. So we had a very flexible code; it had, if you wish, two million [different] instruction words. We also extended the idea of a flag big. We had a sixteen, a four bit flag. One was just a real flag bit which one instruction could set and remove. No, the flag bit was only one. The four bit part was the conditional part. You could construct any kind of condition, code it somehow, and code it into one of the fifteen combinations. We never made use of all the fifteen we had.

TROPP:

Let me back up to one other question that I think is relevant there. When your professor came to you and said, "you're going to build a computer, we have to have a computer here." What was the motivation? What were what kinds of pressures were there?"

ZEMANEK:

[Professor Skudrzyk] was a very young man. He was acoustician [by] origin. And he remained interested mainly in acoustics. And he left me over in the telecommunications side. And he was a very encouraging man. He just saw I was interested, and he came in and he thought he had given me a chance to go. So he said, "Go ahead, I will back you up." And I didn't continue that story. He left one year later for the United States. And he still is in the same place, namely, [in] State College, [PA]. And I was there alone, but that was a big chance also. Because I was my own boss. I had a horrible overcharge because I had to do all the teaching, all the things connected with the chair. I practically ran the chair and in parallel ran the computer development.

TROPP:

But there were no particular pressures to get computational ability. There were no problems of this sort?

ZEMANEK:

Well, no. The University was [between indifferent and] absolutely against me. [One of] the mathematicians once said to me, "I ... esteem you as a very intelligent young man, but your computer is a crazy idea. It will never work."

TROPP:

[Laughter].

ZEMANEK:

And just to terminate with a nice story. ... Professor [Skudrzyk] was, as I said, very encouraging. And so he had encouraged, at that Institute, a number of research projects. And then one blew up for some reason. It had a political accent. It was [the care for the acoustics of a new Viennese hall] and they made a big case out of it. And suddenly, the [official holder] of the chair who was, of course, a full professor, got very nervous and he came to me and said, "now give me a full list of the projects you are running at the moment." So I gave him a list of four major projects and I'm not going to tell you about the others. Each of them was a problem. I will just tell you the story of the computer. ... He said, "your computer is also absolutely impossible, you are an assistant, you are running such a project? That's crazy, you can't do that. That must be done by a full one, by one, by three full professors. And they have to be in the field." I said, "but there is nobody in the field." "Well," he said, "I know. I am here and therefore the other two should be mathematicians." "Okay," I said, "that's clear, there are three mathematic professors. One you cannot talk to, so there remain two. Should I go?" "No," he says, "I am going to." A couple of days later he came in and said, "I have talked to the two mathematicians and asked them whether they want to take share in the funeral of your computer."

TROPP:

[Laughter].

ZEMANEK:

"And they said, no." I [asked], "so what?" And he [answered], "well, we are going to stop the project." I said: "Look here. I have got a lot of money from the banks. I have collected ten times as much in material. I am in a relationship with a number of industrial companies who are looking at what I am doing, and they would either like to see the results, or if you stop me, they must receive letters telling them that the project has been

stopped. And clearly, I don't stop the project, you do, and therefore you sign the letters."

TROPP:

[Laugh].

ZEMANEK:

So he said, "Okay, let me think over that." And he didn't come back. And I finished the computer and the triumph was, the first program we ran was in music, theoretical music, namely the question "how many all sound twelve tone series are there?"

TROPP:

[Laughter].

ZEMANEK:

It's two times 1928.

TROPP:

[Laughter]. And the second one was for exactly that professor, who had run into difficulty. They had [a research project] on the question "how do you feed [high frequency signals on a] high tension power transmission line and thereby [cause] minimum disturbance for the air traffic which is in the same frequency range?" They had thought they could solve that in the classical way, you know, electrical field analysis with vector [expressions. But] they found out [they could do it] only in America. And they had to come back to me and I ran a thirty hours program and I had the solutions for them.* ...The real triumph moment was when I handed over to him a ___ *Kiniger, J. and W. Riedler 1959. "Probleme der Tragerfrequenz-Nachrichten-Ubertragung auf Hochspannungsleitungen." Jahresbericht fur das Bundesministerium fur Verkehr und El. Wissenschaft Wien. Dezember. 150 pp. symbolic bill.

TROPP:

[Laughter].

ZEMANEK:

A reduced rate, but still [a lot]. You know at that time, it was a horrible amount of money, [and not foreseen in the budget; of course,] I requested it only symbolically. We did not ... [mention the funeral story but I am sure he thought of it and he knows that I thought of it. We are great friends now].

TROPP:

[Laughter]. That's a marvelous story.

[End of Interview]