Computer Oral History Collection, 1969-1973, 1977

Interviewee: Grace Murray Hopper (1906-1992)
Interviewers: Beth Luebbert and Henry Tropp
Date: July 5, 1972
Repository: Archives Center, National Museum of American History

LUEBERT:

I was interested in seeing you for one major reason and that was in finding out how you became the one who authored the articles for the journals with Aiken and were responsible, and he says (in a forward manual?).

HOPPER:

One day he walked up beside my desk and he said, you're going to write a book. And I said, I can't write a book, I've never written a book. And he said, you're in the Navy now, and I wrote a book. I wrote about five pages a day which I had to read to him at the end of the day. If he rejected them I had to start them over again. One section in there, on division, I've forgotten how much time I spent on it. No, that's how I came to do it.

TROPP:

But Aiken just said, you're going to write a book then?

HOPPER:

I think possibly in writing reports and things I had been a little more, I'd written a little better English. I had been brought up to write things and I'd had good training (in writing things?) and I'd always bugged all my students about writing things. When they came into my probability course, the first thing I did was give them a lecture on Sterling's formula and then asked them to write it up as a (?) and them I'd cover it up with ink and I would get a rebellion that they were taking a math course not an English course. Then I would explain, it was no use trying to learn math or learn anything about it unless they could communicate with other people and they should be able to write things clearly. So I have always been a little bit of a something or other about getting things written clearly even back when I was teaching, and I taught thirteen years before I went in the Navy.

TROPP:

Along with your (?) on geometry…

HOPPER:

So it was possible in writing up things he had noticed that my, that I had written a little more fluently and a little better English or something. But that's the way it was announced to me, he came up beside my desk and said you're going to write a book. And I did object and he did say, you're in the Navy now.

LUBERT:

And that's the same way for the articles, which were just a condensation essentially.

HOPPER:

Yes. When I wrote those, he didn't (?). because they were jointly authored (?).

LUBERT:

I was noticing when I wrote my paper on Babbage and Aiken that there was a lot more on Babbage and a greater perception on the analytical engine for what it was instead of the higher power difference engine as Aiken put in his '37 paper.

HOPPER:

I put that in.

LUBERT:

You put that in.

HOPPER:

I wrote all that. He did not write …(voice fades out).

TROPP:

I think I'd like to get on tape the comment you made at lunch about when Howard Aiken really discovered Babbage.

HOPPER:

Well that's the best of my understanding of reading of him and the way he talked. I can't be, I can't prove it. But I'm quite sure that he discovered Babbage well after he had the concept of the engine and that he used it as a selling thing that made it more legitimate. It was a part of a development of a sequence of developments, that made it more respectable and it would be easier to get money for it. But I'm quite sure it was his concept, independent of Babbage's. He could use the Babbage later …(voice fades out).

TROPP:

Let everything fit?

HOPPER:

Yes. Somebody probably said to him, have you ever seen Babbage's stuff? And knowing Aiken he'd go find out what it was all about and then he'd …(voice fades out). But I'M quite sure his concept was independent.

TROPP:

I'm also interested in repeating your comment about the Mark I as a communications instrument in terms of its overall structure.

HOPPER:

Well that's the way I always thought of it as a whole bunch of different engines which would (?). And I think it's a concept which we are coming around to again today and essentially it was. Those (?) were independent (?) and if you notice them in sign and co-function and cosign or whatever it was, in log and those functions, those were totally independent functions independently programmed by those step counters and you simply sent something over to it and they went to work and delivered it back again.

TROPP:

That's where I, of course, got the impression along with other things as I looked at the hand written programs of the duplicating, essentially I as a mathematician would do, is if I needed an expediential function I would go to the table. If I had to interpolate, then the next thing I would do would be to interpolate and then come back to my problem. And that's essentially what the machine did. It called the functions, did the interpolation, and then came back and…

HOPPER:

No, the functions were put in there particularly because of storing the constants, was the real reason they were built, in rather then. Of course, they were never used, after a very short space of time. Because they persisted, you see, inn delivering, for instance, with the cosign, it didn't care what angle you put in, it insisted that the angle must be somewhere between minus and (?) and reduced every angle. Well I had a problem which did that with the fire control on board ships, so I had to produce the roll of a ship and I could not tell that computer that I knew my angles didn't go beyond 90 degrees, but I tried, I knew that ship didn't (?). (LAUGHTER). It persisted in assuming that those angles could be anywhere between minus and

(?). Plus the fact, since that was built in it, it had to have complete generality (?), but it also had to meet the full generality of the machine, so (?) twenty three digits. You could, I only needed five, but there was no way of telling it to stop short of flat digits, it always gave full generality. As a matter of fact, I pulled the relays. I pulled the lower twelve position relays in the unit, of the constants. So it would only give eleven digits. (LAUGHTER). It got left out one day when somebody was doing something else and Aiken decided we couldn't pull relays any more. The reason those units were pulled out was that they always delivered complete generality and no individual problem ever required complete generality. So what happened was, we began to develop routines in our note books. And I had, let's say, a cosign routine for positive angles delivering ten decimal places. Bob Campbell might have one for angles less than (pi over two?) delivering eight decimal places and we'd yell at each other, can I have (your essential?). We had relative coding at that time. I think I turned over some of those sheets to what's her name which are relative coding essentially. And we copied each others routines which was one of things that was the basis for the concept of the (compilers?) you see. But those units were, we stopped using long before they were torn out of the machine. And they are the wrong kind of a thing to build into a machine. Now you can build in something like an index register. That's fine, for that's control of the program, not the numerical, but you build in something that's numeric and you're always restricted with complete generality but you never require that for an individual problem. Because that's what a problem is, it's something less than complete generality. You specify this…(voice fades out).

TROPP:

Of course that brings up I think, a philosophy that pervaded, at least as I see it, some of the early hardware machines in terms of Aiken's ideas about what the machine was going to be and at some point in time that became fixed and the machine was built. And even if you saw later that some of these things ought to be changed, it was too late to do it.

HOPPER:

I don't think it went, I think it went too fast for that. Those things were built under a very heavy wartime pressure.

TROPP:

I guess that's one of the problems, getting back to the, trying to recreate the atmosphere of the War.

HOPPER:

Don't forget that Mark II was built under wartime pressure. Get that thing built fast. Use existing components. Nothing new. Get it built. Get it running. It was critical. That was done awfully fast. The whole design and development.

TROPP:

I remember discussing with, I think it was Dick Bloch, the problem of getting the relay built and designed for that particular machine.

HOPPER:

You will find that Dick Bloch was the mathematician, he was the theory man whom you get much more of the practical building and everything. The realist was Bob Campbell. He was the one who really built it.

Bob was both theoretical and practical. He could design an adder and build it. But Dick used to change the instructions on the Mark I over night. If he thought up a nice instruction to make one of his problems easier, he'd put it in and none of our tapes would run the next morning. (LAUGHTER).

TROPP:

I'm sorry Beth, I'm getting away from your set of questions.

LUEBBERT:

I'm fine. I just wondered…

HOPPER:

I told her I was going to write a book. (LAUGHTER).

LUEBBERT:

Going back to Babbage for just a moment. Where did you find out about Babbage?

HOPPER:

Aiken gave me his book to read. He by then had a copy of "Lives of a Philosopher".

LUEBBERT:

And that's where you…

HOPPER:

Which he had written. I had never heard of him before that.

LUEBBERT:

And you went further then Aiken?

HOPPER:

?

LUEBBERT:

You went further in understanding?

HOPPER:

Well when I wrote the first chapter in this, I started to find out what had been in existence earlier. You notice I find some of the American machines and some were Babbage machines. I didn't have time enough to go as far as I wanted to, but I did round up and read most of that material. A good deal more than I wrote in my first chapter.

TROPP:

Had you spent much time looking at some of (Hollerith's?) developments?

HOPPER:

No I didn't. There was nothing available in the Harvard Library and I didn't travel in wartime.

You've got to remember all that was done in wartime.

TROPP:

That's right.

HOPPER:

We were limited by wartime restrictions.

LUEBBERT:

I was interested in how you got to Harvard in the first place?

HOPPER:

Ordered by the Navy.

LUEBBERT:

Ordered by the Navy. Just because you were a mathematician you could be used …(voice fades out).

HOPPER:

I presume that the punched card equipment over at the Bureau of Personnel turned me up because I had a course with Courant on mathematical solution of partial differential equations during my leave year from (?), I'd gone to NYU and had had Courant's course on solution of partial differential equations and that was a pretty good problem at this time. Was the solution of partial differential equations.

TROPP:

Because prior to the War, if you look at the development of differential allies, as a result, ordinary differential equations there was no pressure to solve problems that involved partial differential equations as far as…

HOPPER:

It came up during the War.

TROPP:

Right.

HOPPER:

(?) rocketry and missiles, atomic energy put terrific pressure on partial differential equations and I presume it was the fact that the punched cards turned up that I had had that course which was on solution, methods of solution from Courant.

TROPP:

So then Hollerith had an impact. (LAUGHTER).

HOPPER:

That's probably how I got ordered home. Because when I went in, I had assumed, I had had the course on cryptography and I had known (Lindstrum?) since the years when he had taught me at Yale and who was then in charge of the Navy Communications Annex which was building all the machines and doing all the crypto analysis and I had assumed I would be shipped there.

LUEBBERT:

What was your place in the hierarchy at Harvard after you got there?

HOPPER:

I was another programmer to begin with. Eventually I was in charge of the machine room …(voice fades out).

TROPP:

When you say another programmer, that's really a brand new idea…

HOPPER:

The program hadn't come over from England yet. We got problems run.

TROPP:

Who was the person who trained you in terms of coding or programming the machine?

HOPPER:

Whenever I got in trouble Blocker, I would yell at Blocker Campbell and he would tell me how to get out of it. Nobody trained us.

TROPP:

Just learned…

HOPPER:

We learned. We had a code book. I left a copy of it over here.

TROPP:

Yes.

LUEBBERT:

Who were the people that were at Harvard who you spent most time with? You all got together and worked on programming…

HOPPER:

No, we each had different problem that we worked on. Problems were assigned us to solve.

LUEBBERT:

Was there any…

HOPPER:

Blocker worked on his problems. Campbell worked on his, I worked on mine. Then later we got (?) and (?) to pick him later.

You see first of all there were only three of us.

TROPP:

I guess what maybe Beth is trying to get to is the intercommunication, the casual coffee conversations that you exchanged problems and ideas.

HOPPER:

There wasn't any time for that. I find it extremely difficult to explain to anybody today what a wartime environment was like.

It seems to be extremely difficult for the young people who are non-allied to realize that this whole nation could be operating on just one idea. That everybody saw it as an idea, the whole drive was on, just one thing, just win that war.

That we were all there because of it and we couldn't have been there otherwise. The one thing was to get your job done and make your contribution.

It seems to be impossible to recreate that atmosphere unless you were there, to explain it. People ask me, why did you joint the Navy? And I have only one answer, there was a war on.

For instance, one of my cousins is an architect and he has glasses that are about that thick and tried the Army, Navy and Marines, nobody would touch him because he had these very thick glasses. Well he finally got in the Sea Bees in Houston, he got in as a carpenter.

He finds he designed some of the finest (?) in the Pacific. (LAUGHTER).

You fought to get in. My brother couldn't pass the physicals on account of his eyes, so he finally volunteered under the Draft to get in and later he was sent to (?) and commissioned.

But to young people today, it's totally impossible to explain that.

TROPP:

I went through that same period and I know what you are talking about in terms of that kind of dedication. But in terms of your actual operating time at the Laboratory at Harvard, was the time pressure and the press to solve problems so great that there wasn't time for exchange of ideas and sort of a corridor kind of …(voice fades out).

HOPPER:

We didn't worry about the future at all. We didn't worry about mathematics except that it solved a particular problem.

Remember if we had a problem running we were in there twenty four hours a day, the number of days it was running. I can remember leaving there in '44 for instance. We had been there three days and three nights and there was a hurricane on. Three of us went home by holding hands. (Brendle?) and I and another girl, all three were Waves, we held hands and one would hold on to the lamp post or a tree while the other two would string out and get to the next one and hang on and we made our way up by laughing from tree to post because we had been there for three days we were going out even in a hurricane, we were going to get home and get washed.

But there was no theorizing, there was no higher mathematics. There was no future of computers, there was nothing but get those problems going, and what the computer was doing. The future in a sense, didn't exist.

TROPP:

Well if the War hadn't been won of course there was no future. That was part of the same time press.

HOPPER:

I stayed on three years after the War you see. I stayed there from '46 to '49 in the heart of the contract. I worked on the Mark III.

LUEBBERT:

You weren't in the Navy then?

HOPPER:

I got out in '46.

LUEBBERT:

You got out in '46?

HOPPER:

August of '46. I stayed on until June of '49. Then I joined UNIVAC.

LUEBBERT:

Were you a member of any of the conferences that were going on? There was the one at MIT on the differential analyzer. The one at Harvard.

HOPPER:

That one I edited the book for.

TROPP:

The '36?

HOPPER:

I edited that.

LUEBBERT:

And Aiken seems to have gone to one about every three months until '49.

HOPPER:

The rest of us didn't go.

TROPP:

How about communication with similar work that might have been going on near you, say at MIT? Was there much contact?

HOPPER:

There wasn't. Except some of the MIT from Radiation Lab people came up to see us. We didn't go down there.

What's his name, you know.

TROPP:

Gordon Brown?

HOPPER:

No. The famous guy…

TROPP:

Oh, Forrester?

HOPPER:

No, the…

TROPP:

Oh, I'm sorry, Robert Weiner?

HOPPER:

Robert Weiner used to come over in intervals and he and Aiken would scrap (?).

TROPP:

I wonder, the kinds of things that Weiner was interested in?

HOPPER:

Robert Weiner was very busy claiming he had all the ideas first which of course Aiken (?). (LAUGHTER).

TROPP:

Everybody apparently…

HOPPER:

Every seminar Weiner would go to sleep in the front row.

TROPP:

That was, I've even heard stories of Weiner not only sleeping in the front row but he was snoring so loud he almost drowned out the speaker. (LAUGHTER). Then asking the …

HOPPER:

(?). I thought he was obnoxious.

TROPP:

Well would you, as I look through some of the material, it's difficult to find out any role that Robert Weiner played in any of the development?

HOPPER:

He didn't. He claimed he did though.

TROPP:

What were some of the things that he and Aiken fought about other than priorities?

HOPPER:

He was a very good actor and a very good salesman and he collected everybody else's ideas and sold them, and then (?).

TROPP:

How about Von Neumann? Was he there when…

HOPPER:

Yes, he was there. Very, very seriously involved with (?) because that was the first computer he had his hands on.

TROPP:

As I remember…

HOPPER:

He didn't get to ENIAC until a year after he got to Mark I.

TROPP:

There was a problem, I think, that Bob Campbell showed me of his that was run on the Mark I in early '44.

HOPPER:

That's right.

TROPP:

And that, so far, seems to be the first direct connection I can find between Von Neumann and…

HOPPER:

Von Neumann was there quite often. All those problems were classified. The only way you can find them is to find out whether they have been declassified.

TROPP:

Well this one particular problem was declassified and I have seen it.

HOPPER:

I think the big one that Block ran, I think is still classified. I don't know.

TROPP:

That's the one, I think, on (?), the thermonuclear problem. Right, that's still classified.

HOPPER:

Yes, Bloch ran that one.

TROPP:

Yes. Do you remember Von Neumann being around before 1944?

HOPPER:

I didn't get there until 1944, I got there July 1st, 1944.

TROPP:

So Von Neumann had already been there. I think he showed up in about February of…

HOPPER:

I don't know. He was there when I was there.

TROPP:

Well that particular classified problem I think is a February or March problem of the same year.

HOPPER:

He was around when I came.

TROPP:

Apparently he was bothered by the slowness of the Mark I in terms of the crudity of the approximations it was giving him.

HOPPER:

I used to rush over to the typewriter and copy down some numbers and go out to the back room to a blackboard and write them all over and he'd wait (at the typewriter for something else?).

They were in an awful hurry. The pressure was terrific on all these problems. Because you see, we hadn't had rockets, we were just beginning to have rockets. We had no firing tables for them. We had new torpedoes. Nobody knew what they were going to do. All these things had to be computed.

For instance, (Brendle?) did one, no I, (Brendle?) did that one on the (D ?) towed behind a ship for the minesweeping techniques. They were right on our backs. There was one special phone. The Commander's desk was here and the Secretary's desk was here, and there was a table in between which had a ship's clock on it.

Right next to it was a telephone which was connected directly to the Bureau of Ordnance in Washington, it was a direct line to Washington. Well, we used to shake every time that darn thing rang. When are you going to have the numbers ready? The pressure was, it was normal wartime pressure which is totally impossible to convey today…(voice fades out).

TROPP:

Well that, the twenty four hour kind of thing that you talk about seems to have been common with all the wartime projects.

HOPPER:

It was.

TROPP:

The atmosphere varies from place to place and the feeling for the pressure seems to vary but the …

HOPPER:

And you didn't go out in the evening and drink beer and compare notes on problems. You were dead tired and you went home and you went to bed because you were going to be there at the crack of dawn the next morning.

TROPP:

I think one of the things that…

HOPPER:

There was no social life.

TROPP:

…Bob Campbell mentioned was that Aiken would think nothing of calling him up at say, two o'clock in the morning …

HOPPER:

No. He would call any of us up any time.

TROPP:

… and, you know, you get down to solve something or get something working.

HOPPER:

You were in the Navy. You were on duty twenty four hours a day. You were lucky if you went home to sleep.

TROPP:

Then if you didn't show up on time the next morning, you got hell from Aiken. (LAUGHTER).

HOPPER:

You were in the Navy. This wasn't just Aiken, this was the Navy.

TROPP:

When did Aiken, one of the questions Beth asked me was when Aiken formally became connected with (the Navy ?).

HOPPER:

He had been reserve as an engineer. He had been in the reserve before that.

TROPP:

This was before he even came back to Harvard as a graduate student?

HOPPER:

Oh yes. He'd been a reserve. That's why the computer went to (?). He was in the Naval Reserve.

TROPP:

Beth, I'm again stealing your question.

HOPPER:

He was in before World War II, before it began. You might, I don't know how much you can get of his record from the Navy Department. You might (?) his commission, but you should be able to get a biography from the Navy Department, the Bureau of Naval Personnel.

LUEBERT:

Could we get something the same on you, from the files?

HOPPER:

You mean the Navy files?

LUEBBERT:

Yes.

HOPPER:

I can give you copies of my fitness reports and my orders.

LUEBBERT:

That would be fine. Just to have.

HOPPER:

I would have to zerox them.

HOPPER:

Let me have a piece of your pad (?). I usually have a pack of cards with me and I forgot them today.

LUEBBERT:

I was interested in the role of computers in the military. I wrote a paper on it for a course at MIT last semester and was looking through the early developments both analogue and digital and filling out military applications, I found a lot more this summer and I could have written a better paper. That's one of the reasons I liked your writing.

TROPP:

Well, is it a more interesting avenue of research…

HOPPER:

Well up until the time as far as I know, before I got there, remember we were pretty much confined to the Bureau of Ordnance. So about all we heard about were the analogue fire control computers.

I did know that there was a certain amount of computing done at (?) but I knew very little about that, the military computer.

TROPP:

Now the military was…(voice fades out).

HOPPER:

They were very much concerned. You see, guided missiles were beginning in '44. The work was already on at Franklin Institute on the (Bat?) and those things. So we heard about those. Of course that involved a tremendous amount of contradiction.

LUEBBERT:

I was interested in the Franklin Institute. Going through, trying to figure out who was Aiken as a person? What he was like to work for? What were his ideas? The Franklin Institute wrote a paper on him when they gave him Harry Good Memorial?

TROPP:

No, the Harry Good is another one. No, the Franklin Institute has its own medal.

LUEBBERT:

Well, the Franklin Institute Medal, they wrote a paper for him. I've got a copy of that, and I was wondering what sources they would have consulted?

HOPPER:

They got most of it from me.

LUEBBERT:

They got most of it from you.

HOPPER:

You see, Captain, I can't think of his name, any how the guy that was in charge of the (Bat?) program, came from Franklin Institute and when the War was over went back to Franklin Institute and then was the Commanding Officer of my Navy Reserve Unit.

So when they were going to give the medal to Aiken, I was in Philadelphia and belonged to the Franklin Institute and he was the Commanding Officer of my Ordnance Unit and he asked me about Aiken.

TROPP:

This is probably the same gentleman who is now listed as a retired rear admiral.

HOPPER:

I can't think of his name.

TROPP:

Is it (Farnie?)

HOPPER:

No. No, he was a Captain. I can look it up though. I can probably find it.

LUEBBERT:

You've been talking about the war tactic for speed and getting things done quickly and on time. What do you see as Aiken's idea for the speed of his machines? Or was he just using what he could see at the time and he didn't think at all of the electronics?

HOPPER:

Things had to be built out of what we had. He was thinking electronics because he was going to move into it, you see, when he built Mark III. He was thinking of it. But he had to build things out of what worked at that time. He couldn't afford to fiddle around with circuits yet.

It wasn't until (Rubinoff?) came from Canada with the beginning of the building of the Mark III that they began to work on circuits.

TROPP:

When did he start talking to you about the electronic possibilities?

HOPPER:

He didn't talk to us about it. He said we are going to build Mark III and then he started to find the crew to build it. There wasn't time to talk. And it wasn't until (Rubinoff?) appeared that we even knew (Rubinoff?) was coming.

And (Rubinoff?) however was unique, he was the only engineer I ever knew, back there in the beginning, who said about building a computer, first we have a problem on one.

(Rubinoff?) got me to teach him how to program Mark II, Mark I. He ran a problem on Mark I before he started working on Mark III. It was unique.

TROPP:

It sounds like the thing that…

HOPPER:

He's a guy you must go and talk to (?), Morris (Rubinoff?).

TROPP:

That sounds like something Von Neumann …(voice fades out).

HOPPER:

He could tell you lots about him. He lived right next door to the Laboratory in one of those temporary housing units the Army built. He can tell you lots about all of this. Particularly about how the other machines, about how Mark III got started. Morris (Rubinoff?) was his name, a Professor at (Moore?) School.

TROPP:

That's somebody perhaps that you and I ought to see together.

HOPPER:

You must talk to him long and plenty. He was right in the thick of all of it. Particularly in the development of the early drums. We had disks that we worked with first, then the early circuits and building the drums down at the ship yard and so on.

I can remember when Aiken got the, well he had them, I knew about it, it wasn't practical yet for Mark III, he had four of the big square magnets which were the beginning of the core memories and they were shipped from Germany..

I don't know who, the Army, Navy or who had found them during the fall of Germany, but they were shipped over to the Laboratory, very special.

There were four, three of them in that box and they were being unpacked. They were squares about this big, the beginnings of all the core memories.

Other people claim them now, but I know personally they were the first cores to appear in this Country.

TROPP:

That would have been late '45 or early '46?

HOPPER:

'45. Some time in '45. No, wait a minute, early '46 I guess.

TROPP:

Early '46.

HOPPER:

They were shipped in a very special wooden box and they had been found in Germany, but we could not use them for Mark III because they didn't know enough about how to use them.

But I can remember having them downstairs in the Laboratory and building these (?) for them and everything and working on the concept of the magnetic core memory.

Now (Rubinoff?) can tell you more about that but I can remember being there when Aiken unpacked those cores, they were the first ones we ever saw. That's the size they were then.

TROPP:

I guess, you know one of the things that have become clear in talking to you, listening to you and talking to other people, is that you were working, as you indicate, with a long tunnel ahead of you with these problems to solve. Very little intercommunication and very little outside communication so that you were not involved in outside developments. You have these tremendous goals and…

HOPPER:

Our minds were full of what we were doing. You remember Mark I stopped very quickly when we couldn't find out what the bugs were. When you have to find the bugs in a machine, they used to borrow regularly.

I had a mirror, something like this one which came with my handbags. This is a later one, but I always had a small mirror about this big and one way to find the bugs in Mark I was that they were very often caused by the fraying of the brushes on the counters in which case they would spark.

So they would turn out all the lights and then they would borrow my mirror and they would go along and run it and they would look for the sparks in the counters and the mirror would pick up the sparks you see. Because otherwise you couldn't see down in to find the sparks. They used my mirror for it all the time. Because I always had it in my handbag, it came with the handbag.

TROPP:

Well Beth, it's really incredible when you look at the early developments as to how few people accomplished so much. Now you have teams twice that size working on one little biddy thing. (LAUGHTER).

HOPPER:

Well in the past five years, starting from the time I returned to active duty on 1 August '67, the most I've ever had in my group is seven people and will have completely coped with the standardization of cobalt and finally got the letters that went out from the National Bureau of Standards on the 29th June delegating it to the Navy. The whole development of the first pieces of (?) to insure that the compiler did in fact need a (stimulator?). We've never had more than seven people. Even when (?) that's all there has ever been. You can still get more (?). The more paper you put on the more communication lines you set up and (?).

TROPP:

In talking to John Backus about the development of FORTRAN, that was a group of about eight.

HOPPER:

That's right. And the first compiler that (?) I wrote myself by hand, every instruction.

TROPP:

Which is still the most efficient way when you can do it. (LAUGHTER).

Again, I seem to be getting away from your questions Beth.

LUEBBERT:

Perhaps really the last question I was looking at was how was Aiken like as a person to work for?

HOPPER:

You could make any mistake in the World once. If you made the same mistake twice, heaven help you.

TROPP:

That sounds exactly like Commander Hopper's spearing. (LAUGHTER).

HOPPER:

I adopted that line. I used to argue with Dick Bloch because he was always getting in trouble. And I would try to explain to Dick that he's just exactly like a computer, he's wired a certain way. And Dick would say, well its right to do this. And I'd say, I don't

care what's right or wrong, he's wired this way. If you are going to work with him you must realize how he is wired. Dick was, I suppose, was a little ahead of his game. He would be like the young people today, what he thought was right, was right with no concession to any individual. If you understood Aiken and understood how he was wired, he was excellent to work with. I never had any difficulty. But if you tried to tell him what was right, heaven help you. I mean he was wired another way. He was totally involved in getting a job done for the Navy and if one of the enlisted men made a mistake during the night on the computer or went to sleep or something, bawled the hell out of him. Well Dick would say you shouldn't treat a human being that way and as far as the Commander was concerned he was supposed to be on duty and doing a job. In fact (?) himself sometimes.

TROPP:

I think he still does. They still (?). (LAUGHTER).

HOPPER:

Aiken was doing a job for the Navy. He was a Commander in the Navy. I don't think he ever demanded any more of anybody, anything more of anyone then he would have aboard ship and it's true we were on dry land but we needed this and required this same discipline. Once you realized that and realized what was going on and understood it, there was no difficulty. But for instance, you couldn't get Bloch he was just too darn young. He couldn't understand it and I would try futilely to explain to him that the Commander was wired that way. Now up comes (Berkley?) from (Darwin?) and he's just a civilian computer. He doesn't know much about the Navy. He gets scared to death of Aiken so he starts sending me little notes. Stamps them, dates and stamps them and writes little memos and puts them on the Commander's desk. Well half the time the Commander would throw them away. (LAUGHTER). He come back and say, why didn't you have the guts to come and tell me. Because we used to plague the hell out of Berkley. I can remember the day when we sent one of those boys, we got one of the rolls of toilet paper, we date stamped all the pages and we sent it upstairs and sent Berkley up there, because he date stamped everything. (LAUGHTER). We started a tradition before he went to bed at night, he would date stamp the sheets so he'd know where he was the next morning. (LAUGHTER).

(Arnold?) was another one that was bracky. See the shore based jobs, they tucked all the bracky people in them.

(Arnold?) was a diet fanatic. He had one stage when he ate raw liver, cut into small pieces and you put it in a flask and break an egg in it and drink it. It nauseated Aiken.

And the next one he got was carrot juice. He stopped eating liver and eggs and started drinking carrot juice.

Well, he was then Senior Officer (?) and the Captain went off, I mean the Commander went off to Washington and somehow or other (Arnold's?) carrot juice got hidden behind the books in the Commander's bookcase.

Well when the Commander came back, (Arnold?) went crying to him and complained about how the crew had hidden his carrot juice. And Aiken went up to the ceiling and said, well if you can't run the crew you shouldn't be a Lieutenant Commander. He was then a Lieutenant Commander. You should be able to run, manage, your crew and discipline your crew, I'm not going to do anything about it for you. And then later Aiken finds the carrot juice in his book case and he carefully took out each can and threw it in the waste basket. (LAUGHTER).

Poor Arnold out behind the glass, looking and watching what happened and he didn't even dare protest.

Ask Bloch incidentally sometime when you are talking to him about the time he made a (m strip?).

TROPP:

Okay.

HOPPER:

Bloch had a tape all wound up, you know how fast the tapes spun around, (?) and I said, Dick, you can't do that. Oh yes, I can do that. And I said, Bloch you are going to make a (m strip?) and he did. (LAUGHTER). You couldn't tell Bloch anything either. He carefully took the two ends out and fastened it all together and he had a (m strip?).

He got it out the machine room. It was a long tape and he got one of the enlisted men to help him unwind it and he said it wasn't going to be a (m strip?). I told him it was going to be a (m strip?). He changed the ends.

TROPP:

Just one twist, that will do it.

HOPPER:

Well, it's the way you pull them out you see and put them on the thing. I said it was a…(voice fades out). (LAUGHTER).

One catch of course, was that I was older than any of them except the Commander you see. In fact, before I got there Bloch and Campbell had tried to bribe each other to sit next to me. Because one of them had to sit next to me.

I think it ended up that, I think Campbell paid Bloch five bucks to sit next to me. (LAUGHTER). They heard this darn old gray haired old school teacher was coming. (LAUGHTER).

As a matter of fact, the off time involved such things as, we were all quite used to getting kind of irked at Bloch and a Navy officer can't go out of doors without his cap. So when it came four o'clock and they knew Bloch wanted to go out on a date, he couldn't find his cap and nobody would tell him where his cap was.

As a matter of fact it was (?), it was up on the pipes in the machine room. (LAUGHTER).

And finally we discovered the backyard of the Army Store Room which was next to the area the computer was in and they had lots of nice paper and stuff. Very hard to get paper and stuff during wartime. And (Verdunk?) and I found a whole carton of nice graph paper and we were liberating it and the Commander came up and asked us what we were doing.

We said we were getting some graph paper. And I can remember what he said, he said, well you better leave one pack. The Army may not be able to count but they can tell the difference between none and some. (LAUGHTER).

So he made us leave one pack. (LAUGHTER). So that any time off was very brief and it was usually, it turned into pranks of one sort or another, I would say. A comic relief almost. Like the cap and the toilet paper and things like that.

TROPP:

In some of the cartoons I noted, you drew and the comic nurse…

HOPPER:

Did I give you the one of the machine unit chewing up the table?

TROPP:

No.

HOPPER:

I guess that' still …(voice fades out). I drew a whole set of things in which I had the, I had little cars traveling through the machine and each car was worried in why and why

not? People sitting in them and things like that. Explained how the machine worked. That was the Mark II.

TROPP:

I think on Monday we were sitting there laughing again over some of your definitions. Things that you wrote, some of the verse.

HOPPER:

I had a whole set of cartoons on the different parts of the computer. I had a lot of different kinds of bugs. The (?)mechanism was of course the dragon who chewed the holes …(voice fades out).

And I had one set of gremlins. Of course gremlins were (?), they came over on the planes that came back. And I had one gremlin that had a nose that picked up holes and put them back in the tape. (LAUGHTER).

You see if the tape got on the floor, if there were any hole on the floor and the tape got on the floor, those things would get back into position on the tape and stay there. And frequently we did find bugs that were nothing but the fact that a hole had gotten back into the hole. So this one gremlin had a snout that was just like the things you used to lift around coal or wood stoves and he put the holes back in the tape.

I had a whole bunch of gremlins. They used to live on a blackboard with some of my …(voice fades out).

But that was the relief if anything. It was very much affected by and aimed at the things that were going on. You see, getting food was a difficult proposition. There was a dead end street around from the Laboratory, there was a "greasy spoon" as I suppose you would call it. A cafeteria, most of the time we had to eat there.

We were all in rooming houses because the subway didn't run on account of, at night, on account of after midnight I guess, or eleven o'clock, on account of the wartime.

So we couldn't live over in Boston, we had to live in Cambridge and there was nothing but rental houses. I remember they were quite a way from the Supply School. We had no way of cooking anything or doing anything, so getting food was quite important and once a week we sent one of the enlisted men around to the (?) building to get us cigarettes and such things we could get.

But we didn't have ration stamps because we were supposed to eat at the main mess which we could never get to. We only got ration stamps when we were on leave, and it was rough rounding up food.

All of living was difficult. There wasn't any time to explore the future. There wasn't anything too important about it. Tomorrow was the nearest we thought about it then… (voice fades out).

TROPP:

I guess, then in terms…

HOPPER:

Day to day, very much.

TROPP:

…of the environment, when I talk to people, realizing that they were in the middle of a major revolution, this really doesn't happen until after the War. The realization…

HOPPER:

No. We were in the same revolution, if you will, as radar. Remember this was all starting, we knew about it.

TROPP:

All of them are related.

HOPPER:

All this tremendous wartime development, weapon development, as far as thinking beyond it to its civilian application, not yet. No, it was after the wartime development.

TROPP:

As you look back now from all your experience in and around computers, back to Mark I, what would you say it's most significant contributions were and what do you think are some of the main things that got lost?

HOPPER:

Before I go back to that, there was something (ahead?) because I went home on leave and I told my dad about what we were doing and what the computer was like.

Now dad had been in the insurance business since he got out of college in May of (94?). He was, his father was President of the Great American Insurance Company which was then (?), and then dad went in (?) here and then later became an

insurance broker with his brother. And he saw, he mentioned to me when I went home on leave, the concept of using the computers in insurance.

Now whether he had gone to New York and mentioned that to any of the insurance companies, I'll never know, but that was the first mention that I ever heard of using the computer in industry. It was from my own father.

TROPP:

Was he thinking in terms of record keeping, question answering, this kind of thing?

HOPPER:

Yes. Record keeping and computing premiums and getting premium notices out.

TROPP:

I think what you're talking about is also indicative of Aiken's…

HOPPER:

That was back in 1944.

TROPP:

…Right, of Aiken's thinking even during that same period, because somebody mentioned either Bloch or Campbell, talking to him about getting higher speed printers, and his reaction was…

HOPPER:

We did run that one problem eventually you know.

TROPP:

…Yes, but his reaction to higher speed printers was, why bother to have it printed any faster than somebody can read it. The idea that you might want to print something so that a million people might read it simultaneously had not occurred to him.

HOPPER:

That would not be part of record keeping. You still don't need it.

TROPP:

Right.

HOPPER:

You still don't need it in the insurance business. You don't need any higher speed printer.

TROPP:

Right.

HOPPER:

So that I don't think that would come in. But that is what my first encounter with any possible future application was from my own father.

TROPP:

It's interesting because that was the…

HOPPER:

He had been in the business for years.

TROPP:

…the industry that probably first made use of the …

HOPPER:

Now whether he had ever mentioned it in New York, whether he had talked to people about it or not, I'll never know, because he didn't tell me. But he could have. He could have talked about what his daughter was doing and then mentioned the computers and that he thought they could be us able. It's quite possible. Because he was a man of some standing in the insurance industry.

TROPP:

Of course with the War on, again nobody could think ahead because nobody was going to have this kind of equipment available to them.

HOPPER:

He had retired before the War started, but had gone back after the men had all left, the younger men had left. He went back to (?) until they came back. But he was a man of some standing in the industry and people would listen to him…(voice fades out).

And it's rather interesting that actually some of the most forward looking moves have always been made, and are being made today, by the New England insurance companies, which you expect to be the most (conservative?).

They are the most conserved in they pinch a dollar first, which also leads them into the most forward development. There's John Hancock, Etna Life and Casualty, Travelers was the first insurance company to go on line. It's the New England insurance companies that have taken some of the biggest steps forward for industry. And it's rather surprising, it's not exactly what you would have thought of as the most forward, research oriented industry at all. You would have thought it was just as conservative and immovable as anything, but it isn't, it's a very forward looking group, surprisingly so.

I also think some of the people in radar down at MIT, a large number of them were Bell Telephone engineers on military leave. And I think they talked very early in the game to Bell Labs and Bell Telephone. I think there was a very definite communication of the concepts of electronics and of the computers from Radiation Lab and from Radar Lab to Bell Telephone, very early in the game.

TROPP:

Of course Bell Lab had already been in the computer field. The complex calculator and then later the machines … (voice fades out).

HOPPER:

Yes, but I think the electronics may have well come via MIT. Very much so. Not the people like (Stibitz?) and so on, but from the engineering level. The engineers themselves went back with those concepts, which may have made the difference.

Now I know one in (Bell ?) Pennsylvania, for instance, that came back from the Pacific very definitely with the concepts of electronics. He had been in radar.

TROPP:

Who was this?

HOPPER:

(Helberstat?).

TROPP:

(Helberstat?)?

HOPPER:

Yes. He came back with many of those concepts into the Bell Telephone in Pennsylvania.

In fact, that whole group that was in my Navy unit, a very large percentage of them are Bell engineers that had been in radar and electronics during the War and brought it back to Bell in Pennsylvania.

And it wasn't alone that they did the work, but they brought back an acceptance of the concepts. So that when the things began to happen, there was an audience ready to accept those ideas. This is something that is missing today.

You see, during the War there were so many of us and so many new things, that we were conditioned to accepting new concepts. They didn't surprise us, we expected them.

Now today, you'll find you will find we're back to the old opposition, we've always done it this way.

And unwillingness to accept new concepts. They may think we are moving forward, technologically today, but I find far more resistance today, then there was during, and just after the War when we all realized that we were in a new world and a new world was coming.

And you will find more unwillingness now to accept new concepts then you would then. People have closed their minds, I don't know why, but they have. The hardest thing I have to do is not to make a new development, it's to get people to listen, and to change their minds.

Because they have gone back to the (inure sure?) of, doing in life, what do you call it, in ordinary life when they formed habits anything new, was going to mean learning something new, or adjusting to something new. Changing things, and they just don't want to do it. People will instinctively opposite it, anything that changes their habits.

TROPP:

It's interesting, because the generation we are talking about, is a generation that's grown up with constant change. Constant enervation, and it seems hard to recognize that they are like the medieval, as protecting their citadel.

HOPPER:

The roughest time I have is going on around, as I have this year, I've been to about 175 colleges and schools this year for DPMA and ACF. The young people are honest. They have just learned something. They have just gained command of it and I come along and tell them they are going to learn something different.

They fight it right from the word go. They have formed a habit and a way and it's comfortable and they aren't about to change. And some of the young people are worse than some of the people who survived the War years.

TROPP:

I say, I just find that hard to imagine. Because I've grown up and my life time has been one of constant change and the idea…

HOPPER:

Mine has been even greater than yours. I lived in the days when New York City's tallest building was the (Firing Building?) which was seven stories high. When in New York City every light fixture had one set of things which turned down this way which had a bulb in them with a glass globe over it and another set of things to turn this way and it had gas in it. Because the electricity was unreliable so you used the gas jets when the electricity wasn't working that day.

The telephone, (?) you could find out in the country, there were in New York City. In Philadelphia there were two telephone companies. You could call up one to get numbers for their half of the city, and so on. You would have to know which half of the city you were talking to.

The trolley cars on Broadway had overhead wires. It built the subway. I can remember reading stories in(St. Nichdas?)that they were building a subway and building the tunnels. None of that existed when I grew up.

My, I've got pictures taken from my grandfather's boat and New York City is flat, down like this. There were no telephones. It was a totally different world.

So I have had to go all the way from that you see. I know, far better than you do, the changes accelerate. The changes are coming faster.

TROPP:

It's an (expediential?) kind of growth.

HOPPER:

The people who don't accept change and grow with it, or who attempt to block it are (?) and aren't going to make it.

TROPP:

Are you having much luck in terms of getting people who have changed the paradigm within which they operate and look at problems?

HOPPER:

Oh yes, I'm getting quite, I always get two or three at every talk. I can always find someone. It's not always the youngsters. It's more apt to be the ones that were in World War II.

There's also among the young people today, this tendency to think technology can't do anything for them. Or, it's almost an anti-technology attitude. Whereas, if they would only realize it, it would be the finest tool. Particularly in relation to things like pollution and the environment and everything else. What we need is a great many more facts in the (?) can handle and we can be very (?). It's when we plan on only a few facts that we go wrong.

TROPP:

Right. Well one of the dangers of predicting the future in terms of some of the dooms day attitudes, is our lack of realization that we are probably going to have more major technological break-through that are going to change the whole way in which we view the problem.

HOPPER:

I don't go along with Forrester at all because if I used Forrester's methods and went back to the buggy whips, I would have the whole world full with buggy whips. Because they would not realize what was going to be …(voice fades out).

TROPP:

We know those changes are going to come, we just don't know what they are going to be. (LAUGHTER).

HOPPER:

Well, also I find it a complete failure that we would go out in space. It was just a complete failure to realize that the human race would ultimately go out into space.

One reason of course, is that we have to. Because the Sun will lean over and incinerate all the planets. So that my that time the human race must get off the Earth. I fully expect that when that happens and we have the last space ships ready to leave, there will still be some people who will refuse to leave because they won't believe the Earth is going to be incinerated.

This is what people are like. But we will go into space, we will have to go into space and we will have to travel in space. I'm not going to see it, but it will come.

If anything, I can have the satisfaction of being a part of how we got there because it will take computers to do it. One trouble with my accepting any of the doom sayers, like Forrester and everybody is that there have always been doom sayers.

I suspect that when the first couple of men agreed that they would say good morning to their wives by saying, "um", that there were doom sayers in the tribe who said that everything is going to go to pieces now. And they could have said everything is going to go to pieces if you develop language.

TROPP:

I'm not sure that I would classify Forrester as a doom sayer. I think what Forrester is saying is that given no new technological break through, we are going to have to change…

HOPPER:

That's not what they said when they published the darn book.

TROPP:

…Yes, that may be true. I'm just talking about conversations with him. I think he too…

HOPPER:

Besides which I put holes in his dynamic anyway.

TROPP:

…but he too is trying to create a new way of looking at things. Whether his is the right way or the correct way is open to debate.

HOPPER:

He's got too much computer in it and not enough imagination. I mean, you can go dead wrong if you use computers wrong. Computers never have a new idea. They have no imagination. They do only what they are told to do. They are a tool. Any time you take them beyond being a tool, you are in trouble.

You give them a problem and they will do only that problem as you give it to them. They will not add one atom of imagination to it. This is the thing that's missing in many of our concepts, and that's imagination.

And we aren't encouraging imagination. If somebody has imagination and thinks up new concepts and new ideas, we are very apt to put a committee around them and cut them down to size. We don't tend to grow any giants any more we try to cut them back to the average to make them like everybody else. We are afraid of giants, so we are not growing any. We need a few giants.

TROPP:

Well, in talking about giants, we have to look at the Mark I as one of the early giant steps forward.

HOPPER:

Right. You could not sell it…

TROPP:

Howard Aiken saw that idea.

HOPPER:

Right. You could not grow an Aiken, or a Mauchly or an Eckert or a Forrester today. Because he would be immediately surrounded by a committee that would cut him down to size.

TROPP:

Well how did Aiken originally sell the idea for something as revolutionary?

HOPPER:

He sold it. He showed logically that it would work.

TROPP:

Well lots of people are able to do that and still not sell ideas. What did Aiken have going for him?

HOPPER:

It was wartime. It was wartime and there was a war coming. All new ideas were being implemented. Anything that might help and might be useful (they were grabbing for everything?).

TROPP:

Well one of the things as I look back through the literature of the…

HOPPER:

And he was a very convincing salesman.

TROPP:

…you know, the wartime development of computers is that there was a lot of thinking within the American military during the War, that this was going to be a fairly short War and they wanted things only that would help immediately.

HOPPER:

Not in the Navy.

TROPP:

Maybe the Navy was different then but the computer looked like a long range assist.

HOPPER:

They had to have it to get those rocket tables. They had to have it. They had to have for the radar equipment. They Navy was building them for crypto analysis. They had to have it. It was the Navy that helped find the money that set up the RA Office in St. Paul after the War was over when they took the whole of Communications Annex and moved them to St. Paul. It was the Navy that helped them find the money. I was there when they had them go ahead.

TROPP:

You have looked at some of those documents haven't you Beth?

LUEBBERT:

Yes.

TROPP:

The ones that Dr. (Waitland?) gave me.

LUEBBERT:

Yes.

TROPP:

Or help me get. He was part of that group.

HOPPER:

No. I think in most cases the Services, the people who should have been looking into it, were looking into it. The rest of them were like just the rest of the people today. They weren't looking into the future and they weren't going to change their minds.

TROPP:

Well I'm thinking in terms of the first resistance that Eckert and Mauchly had a year before they submitted a proposal and finally got ENIAC going. It was resisted on the grounds that it was for some time in the future.

HOPPER:

For the last three years, over in the Department of the Navy, there have been a group of people that have been saying that we ought to put a mini computer on board ship for administrative purposes, an on-line computer console, for administrative work.

But there's another group of people who have been saying you can't do this. So for three years they have been writing each other memos. One saying you want to do this, you want to do that. We can do this, we can do that. The other saying you can't do it won't be any use to us, don't spend the money on it.

I told the Admiral one day, I finally said, look, add up the amount of money you are spending having those people writing each other memos. For each of those men who are writing memos, for their secretaries and the stuff going back and forth. I said, it would be much cheaper if you bought a computer and put in on board ship and found out. And he said, that's an idea. (LAUGHTER). And so they are going to do it. So this is what you get in any bureaucracy, even in wartime. One group of people says let's go this way and the other group of people who aren't going to benefit by it or won't be able to cut their budget or something, are going to oppose it. And it takes somebody to say, let's stop it and do it. It still happens.

TROPP:

I guess the reason, one of the reasons I asked you that question was that again look back and retrospect is always dangerous, Harvard just seems to be an unlikely place for something as revolutionary as the Mark I to have occurred.

And that's why I wondered about…(voice fades out).

HOPPER:

It is from that point of view. It was solely Aiken not (Harvey?). Aiken sold the concept to IBM who built it and then he told them to give it to (Harvey?). And he gave them all his rights and patents in order to get it.

TROPP:

You may not want to talk about this, but this was a question that you raised. Maybe you can phrase it better Beth about the role and the clash and the whole difficulties that later developed between Aiken and IBM.

HOPPER:

IBM never gave the credit they should have to Aiken. They gave credit to their own engineers but they did not give it to Aiken.

LUEBBERT:

We were reading IBM's…(voice fades out).

HOPPER:

When they came down to take the pictures when Watson visited us, they took the picture of Watson and the IBM enlisted men, but not the officers that ran the machine. Not the, just the pictures of the ex-IBMers.

TROPP:

Had that kind of clash occurred earlier or was it…?

HOPPER:

It had certain begun to occur by the time I got there. IBM was about to grab the whole credit for it because their engineers had built it.

LUEBBERT:

Was that because Aiken was down at (Dalvin ?). I guess it was. While it was being built, that they wanted credit for it?

HOPPER:

They wanted credit for all the ideas and it was true that the multiplier had been invented ahead of time by some of the IBM engineers. They built the multiplier which was later incorporated, the concept was incorporated in the Mark I.

The overall concept and in particular the secrets mechanism and the interpolator, were purely Aiken's. And IBM tried to take prime credit for all of it. They couldn't conceive of anybody but IBM building it. They built that horrible mess known as the selector sequence control (calculator ?), which is one of the worst (?) that anybody has built.

TROPP:

One of the other things that…

HOPPER:

Watson did not give the credit to Aiken that he merited.

TROPP:

That's the…

HOPPER:

That's the scoop.

TROPP:

Of course, there's another view that I…

HOPPER:

Plus the fact that Aiken wouldn't cow tail to Watson when Watson …(voice fades out). I've had my own experience with IBM in '49 when I started job hunting. When I, when my three year contract with Harvard terminated. When I was job hunting, I went to him for an interview in New York at IBM. They gave me a three or four paged thing about this long on yellow paper to fill out.

And I had gotten to one and a half pages when they started singing songs to Watson in the next room and I handed them back the blank pages and said, this is no place for me. (LAUGHTER).

I have a record of those IBM songs if you want to hear it sometime. (Which I?) liked to give them away a few years ago.

TROPP:

We just got a copy of that. Yes, in fact…

HOPPER:

And they really did sing them. That's the thing that soured me and I never went near IBM again.

TROPP:

We also have a copy of the 1934 song book.

HOPPER:

I couldn't live in that kind of an environment.

TROPP:

Well one of the things that struck me was another point of view in the opposite direction, when I look at the dedication records for the Mark I. It's essentially a Harvard announcement which tends to exclude everybody else.

HOPPER:

Well that was Harvard and typically so and that annoyed Watson too. But that's Harvard.

TROPP:

Yes, I was going to say a Harvard inauguration of the Mark I. Well going back to the Mark I, I want to go back to the question I asked you earlier in terms of its major contributions and its ultimate impact in the subsequent developments and some of the ideas that got lost.

HOPPER:

Its major impact was through the people who worked with it. We carried it away with us.

TROPP:

That's one of the things that struck me, that was the…

HOPPER:

The basic concept you see, for compilers, stems from Harvard which I took with me. The ideas which I was generating on how to write programs easier at Harvard I finally brought to a fruition (?).

It was the people that, who were here and went somewhere else who took it. Because we were all scattered. (?) and everything was scattered and we took them with us and they grew everywhere. So that the impact is far greater than people realize.

TROPP:

Well that was the…

HOPPER:

That we took them with us.

TROPP:

…the conclusion that I had come to sort of tentatively that Harvard was the training ground for the future. It performed a major function.

HOPPER:

Very much so. And the next big one was the UNIVAC I believe it or not.

TROPP:

Oh yes.

HOPPER:

The UNIVAC people are all over the industry far more than IBM. If you look at that history of software outline that I made of the development of software, you will find the origin of most of those concepts came from UNIVAC. And that's Betty Holberton and so…(voice fades out).

And you see, for instance, Joe Harrison, you know came to UNIVAC before he vanished with APL.

TROPP:

There are two interesting parallel developments going on …

HOPPER:

Both of them came to UNIVAC. Katz came to UNIVAC. Many of those Harvard people came to UNIVAC from what I heard.

TROPP:

At the same time Beth, there's a parallel development going on in the West Coast of a similar kind of thing.

HOPPER:

It spread through people. Very much so. Not through the colleges.

TROPP:

So, in looking at the developments historically, we really have to look at people and what they took with them and where they went.

HOPPER:

And who worked with whom.

TROPP:

Right.

HOPPER:

Now you, for instance, you'll find in those early days at UNIVAC that a number of people came and took those early courses and then went out from there. The whole prudential group (?). The John Hancock group, those groups that came into UNIVAC for training and then went out to spread it in other places.

I go around the Country and then someone will come to me and say, you don't remember me, but I got my, you taught me about computers in 1950. You don't remember me, but I heard your lecture in 1950. This is the way it spreads you see, from those early things. And it spread through people. Not the colleges until much later.

And there was no publication… (voice fades out). I can walk in to any manufacturer today and point to the people I trained originally. That's why I said when I (got the (?) award ?) that the most important thing I could do was all the young people I trained, not the development of the compiler.

TROPP:

When you say you took the ideas from Harvard that led to the compiler, what were the kinds of pressures that you were feeling, while you were programming at Harvard that ultimately led you?

HOPPER:

Well, for instance, it was the development of all the pieces of coding that were written in relative code. And it was pretty quickly obvious that you could process those and piece them together into one program and that's all the first compiler did.

Plus my own laziness and natural refusal to do anything over again that I had already done. And the fact that when I got down to UNIVAC they were building BINAC then and I had to learn how to program it. So I learned how, I still thought I was a mathematician.

I learned how to add, subtract, multiply and divide. I was real good at it, the only trouble was, at the end of the month my check book didn't balance.

And I had to realize, my brother, after three days of hard work, said, the rumor was not to subtract in octal. (LAUGHTER).

I had to realize that I couldn't work eight hours a day in octal and then live the rest of the time in the normal decimal world. And my answer was not that I learned better octal, as the damn computer could learn decimal. I would instruct it in my own language. They could do the dirty work. The transformation because it was built to do that. So I …(voice fades out).

And in my own case, very great deal of practicality and common sense. I had no great development abilities or creativeness or anything. I had a very large amount of common sense and a very great deal of (Von Neumann's views and a lot of them?) that I had already done.

TROPP:

There are some of the characteristics of Mark I that I'm not sure why they were there. For example, you mentioned the twenty three digits and I wondered if this isn't because some of the early impetus for Aiken back in the '30s wasn't from people in astronomy who saw needs to do computation.

Because otherwise I don't know why he had so many digits in the …(voice fades out).

HOPPER:

Any engineer had to cope with vessel functions. The only way to compute them was by recursion. And you've got to have a lot of digits for any of the recursive formulas and he eventually did the vessel function.

TROPP:

So that you're speaking of the set of tables that he, (in reliance?)?

HOPPER:

Recursion. The phenomenon of … The only …

TROPP:

And that's why the machine was built so that you could get thirty six digits if you needed them?

HOPPER:

Well no. That was added later. That wasn't in the original machine. The double precision was added later. Much of the computation was done by recursion. These were the only formulas we had and if you were going to use any kind of a reverse formula, you've got to start off with a heck of a lot of digits.

TROPP:

I guess that's right because that, Aiken says that in his '37 paper, that this has got to be the …

HOPPER:

And if you look at the early matrix work and the early partial differential equation work, you had to start with twenty three digits or you weren't going to come up with anything. We had to have it. Or we wouldn't have had the answer, we would have blown it.

If you remember Babbage had forty some digits in his differential (calculator?).

TROPP:

I guess the reason I asked the question was because in the, early in the late '30s when the machine was not yet designed or off to IBM for building, two of the people at Harvard, that were pushing hardest were members of the Astronomy Department.

But I don't know of any incident, or problems that were later solved.

HOPPER:

No. I think it was largely the matter of the recursive formulas. And not much investigative work had been yet done on how much accuracy lost in computation and there was a tendency to put in plenty, so you would be safe.

TROPP:

So your round off error (?).

HOPPER:

Yes, in truncation error. They didn't know what was going to happen on truncation errors. They had no idea. And a function like the sign can roll off the machine awful easy. So that, I think that was there for safety.

I know, on the first early problems, when we were computing how much accuracy we were having, it was an appalling rough computation. We didn't know much about it yet. And I was unusual because most mathematicians didn't know anything about round-off errors and truncation errors and the reason I did was because I had taken a course on chemistry, that was where I learned it.

TROPP:

That's interesting.

HOPPER:

And that was where I had learned about round-off errors and computational errors, not in mathematics.

TROPP:

How did you work in (?) and statistics?

HOPPER:

Not in graduate school or anything, I took a course in chemistry… Mathematicians didn't worry about digits anyway, they used symbols. Probability wasn't that far along. Statistics wasn't that far along. Extremely elementary at that time.

TROPP:

I wish we had the time to get off into the later work with UNIVAC and BINAC. We probably ought to save that for another time. (LAUGHTER).

HOPPER:

I'll come again. Incidentally, feel perfectly free to call me up if you've got a question at some time. Just give me a ring.

TROPP:

Let me turn this off.

HOPPER:

Because I'll be in my office the whole of July.

LUEBBERT:

You were in charge of Mark I?

HOPPER:

Later.

LUEBBERT:

When Mark II and Mark III were being developed?

HOPPER:

After everybody else began to go play with Mark II then they left me in charge of Mark I. Which was a victory on my side because when I walked in there he had not wanted a woman officer and I had said he was going to want a woman officer.

You see, in 1946 for instance, the Navy turned me down for regular navy. I was two years too old. It took me twenty years to win that one. (LAUGHTER).

I kind of make a habit of winning. It's taken five years with this triple standard.

TROPP:

Well you know, it says something then for Navy discipline in regard to Howard Aiken, he accepted the fact.

HOPPER:

He had to. He was in the Navy too. I think probably the greatest disappointment of Howard Aiken that he ever faced was that he didn't make Captain and that was due to one

very bad fitness report which had been written by an officer (?) and he never made Captain and he should have.

But he didn't, and I suppose quite accurately from that officer's point of view, an insubordinate and the fitness report was in his file and …(voice fades out). He should have made Captain.