Computer Oral History Collection, 1969-1973, 1977

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HOPPER:

Yesterday, John Solerno, over at Federal Reserve, called me up and he had a question about some programming. But, then, he said, "I want to know — somebody asked me — what do you consider your greatest achievement? And, without thinking (and it's curious how you do these things), I said, "Well I guess it was realizing we had to make it easier for people to use computers, and underline the people." And he said, "I thought it was the compiler." I said, "Well that comes out of that." I said, "The greater thing was to realize that it needed to be done; then, of course, comes the first compiler and the first English language compiler, and so on. But, I think, that the real achievement was to realize that this type and class of thing had to be done, and what could be done — not the actual doing of it." And, then, he said, "Well -" He thought that over and said he'd thing about it. Then, he said, "Well, what else?" And, I said, "Well, I think probably the second one is the large number of young men and women that I've trained who have gone out all over the computer industry to lead developments themselves." And then, he went off — he said, "Well, I'll have to think that over."

I think he would have put the A-0 compiler first, you see. But I still think that the realization of what was needed and what could be done was more important than the actual doing of it.

MERZBACH:

Well, that is a telling difference.

HOPPER:

I hadn't thought of that before that way either, because I had always said this — well, where do you start — well, A-0 compiler. And yet, there was a knowledge back of that, and a thinking, and a work, and everything else, of what can be done to make these things so that people can use them, and I still think that job is not finished. And there again, you see, the training of the young people is (because I won't be around that long is) part of that same principle — to make it easier for people to use computers, because that's the only way they'll ever come into their own or be properly used, or we'll find out all the things we can do with them. We can't keep professionals alone, so we've got to bring it more and more, so more and more people can make use of them, and can use them. So then, it all ties together if you go in from that point of view.

MERZBACH:

We were talking about Harvard — I think we had gone over some of the people, and your experiences during the early days. You had made some remark that you wanted to come back and say something about Mr. Berkeley, I think it was.

HOPPER:

Oh yes. Ed was sent up from - When we started to begin to think about Mark II (and I'll have the specs, the early specs, on Mark II for you eventually — I'll give you a copy of them — they were produced there at Harvard), and Dahlgren assigned Ed Berkeley (he was then a lieutenant commander in the Navy to Harvard) to monitor the development of that project. Well, Ed was a riot to all of, because Ed was very systematic and every-time he held a conversation with the commander he'd take little notes. Well, this drove Aiken crazy, so Aiken wouldn't let him take notes, and so he'd go out to his desk and make notes as soon as he finished talking to the commander. And everything he did - He had a date stamp, and he stamped every single thing that happened with a date stamp. Well, this just thoroughly amused the rest of the crew, and as a matter of fact, one day they very carefully stole his date stamp, and went up and date-stamped the whole roll of toilet paper up in the men's room. Berkeley threw a fit when he found that — his precious date stamp. And one day somebody asked him (somebody in the crew asked him) if when he went to bed if he date-stamped himself in his sheets so he'd know he'd been there. He never lived down that date stamp business. He should have (if you get in touch with him), a tremendous amount of notes, because I don't think he ever threw anything away, and he should have some of this material.

MERZBACH:

Yes. I haven't been in touch with him, and it occurred to me also, because particularly in the early days of Computers and Automation (and that has continued to some extent), I think he devoted quite a bit of time to keeping track of -

HOPPER:

Yes, he did. And he was the one, of course, that started ACM. And in all of those early days, he kept (very much) track of what was going on all around (of what people were doing). He would know of people that contributed and then disappeared, because so many did in those early days contribute one thing and then vanish like Laning and Zieler, and he would know many of those things, and many of those people. But poor Ed — that date stamp — he never lived that down; the whole crew — that was all they thought of was Ed (the date stamp), and his little slips of paper with the date stamp on them. And he was always losing them, but he always found them again. But he would have a very good record of much that went on, and I have a feeling he kept a good deal of that. Of course, he was bound to take a ribbing from those enlisted men — this was inevitable.

MERZBACH:

He was the one person (I know) you indicated you wanted to come back to. I believe we had been talking about Mark II development -

HOPPER:

Well that was when he came, you see.

MERZBACH:

Yes, and we were going to (perhaps) go into a little more detail on some of the technical aspects of it.

HOPPER:

Well, the Mark II - We weren't sure the war was going to end — let's see, this was '44, '45 — nobody knew how soon it would end and there was need for more computation, desperate need for it, and there was only Mark I then, you see, and ENIAC. And so, the answer was to build one in a great hurry out of existing components, which meant build a relay computer. The electronics at ENIAC were highly experimental; they were still really getting it going when the idea of Mark II — before (Mark II wasn't really proposed almost, before -) ENIAC was really running, and consequently it was really necessary to build it out of existing components and it was designed as a relay calculator. And it's for that reason that history has forgotten it, because it was built out of relays, but that was very essential at that time. It was the only thing that could've been done to get something going that fast. And the thing that - Where people should go back and read about it and look at it is, that it was a dual processor. It did have two complete computers (now they could), and it had four sequence controls. The sequence controls were exactly like those of Mark I in theory, and that is that they were external (paper tape). But they were different in the fact that one could control the other three; one could say to three take off and do something, and they could run simultaneously. You did have simultaneous sequencing on the four sequence controls. Now, they could be divided into two with a master and slave in each half of the computer, and the whole computer could be divided in half by programming. They were what was called bus-tie relays which connected the two halves of the computer together, and under program control you could open the bus-tie relays (and you had two independent computers each having two sequence controls), and each of those could be of master and slave combination. Then, you could close the bus-tie relays and you had everything in one computer. You could have one master and three slaves; or, a master and a sub master and two slaves. And a great deal was learned in how to handle multiple sequencing units which got forgotten. Because, you see, we don't have another true multiprocessor until we get to Lark, and there it's a master and slave — and now to 1108, where we do have actual independent processors that can talk to each other. Now even when you had opened the bus-tie relays, and had two completely independent computers, there were some transfer registers. And Computer "A" could

throw a number up in a transfer register and send a signal to "B", I've sent a number for you, who could then pick it up and similarly "B" could send quantities over to "A", even when they were operating as independent systems. So, you see, there was a great deal of work done there in the logic of independent sequencing and simultaneous computing. Unfortunately, much of it got lost because that was a relay computer, and nobody was looking at it, because everybody was busy building electronic computers. And it's about time that somebody reread those manuals and things, on some of the programs that were written, because a lot of work was done on the question of the independent sequencing of more than one computer able to exchange information, even though they were operating independently, and — this business of signaling. And if "B", for instance, looked for some information, and "A" hadn't sent it there yet, they'd have to wait until they got the signal that it had arrived and things like that. It was also interesting from another point of view, in that it was the only one that had what I'd call a semi-fixed programming. In other words, what you had was a background program that was always operative — it was built in. And on each of the intervals of the cycle (there were 60 intervals of the cycle), you could, for instance, on the first line — you could read into the addend, and then you could do two transfers, I think. And then you read in the addend and there was another pair of — no, then you read in the multiplier, and then, finally, the sum came out, and down further the multiplication came out, and in each of these cycles you could perform four additions and two multiplications and, I think, six or eight transfers. In other words, of the addresses - It became a single address machine, in the sense that it was really a two address machine, but one address was always fixed and the pattern was fixed and it was one way of achieving speed with those relays. And it meant, also, that on every multiplication you were overlapped two additions and four transfers (they happened simultaneously); it was the first of really parallel programming. I think we'll have to come to it, because we're pushing speed of light now. I think we're going to have to come to something like that again, but it does mean you have to have an independent adder and multiplier, of course. And it is a way, though, of overlapping and it's pretty effective. And again, I think that should be looked at — that technique of programming, and I think we can make very good use of it, maybe. And maybe with these large-scale integrated circuits, it may come back again. It was a good concept; it was the only one of its kind. What it amounted to, you had a lot of slots coming by, and you could stick certain things in when those slots came by, and certain things came out when those time slots came by, and again tremendously upped the speed of that relay machine, because of the overlaying.

MERZBACH:

How much was this emphasized, at the time?

HOPPER:

They didn't realize what they'd done.

MERZBACH:

It really wasn't an explicit -

HOPPER:

Also, it was completely buffered. When you wanted to print something, you sent it to the print transfer register, and you'd go on and work and then it trickled out from the print transfer register to the printer. When you wanted to punch tape, you sent it to the tape register and then you went on doing things, and it trickled out of the tape register. All the input-output was buffered again to obtain speed which, you see, wasn't done again until you got — well Univac I was buffered, but then the buffering was lost. All of the early IBM machines, you remember, had no buffering. When you had to write tape, you sat and wrote tape and nothing else happened. Whereas, in both Mark II and UNIVAC I, you had the buffering which is, of course, one of the critical things now. But Mark II had that long before anything else, you see. And I think everybody has completely forgotten that that computer had in it major developments, way above Mark I, and way above anything until Univac I which is much later, of course, and didn't get into the general run of things until quite a bit after that. So, I think it would be worth someone's while just to go back and see what were the concepts in Mark II which we might make use of today, which have been neglected — just to review it — it would be worth it, I think. I'd like to take some of the Mark II concepts, someday, and see what I could do — start from that as a base and design a multiple processor — particularly with that programming technique. I think we may have to come to something like those time slots, to get the speed we want. And with the LSI's we ought to be able to have two or three adders and two multipliers, both going at the same time. On the other hand, it practically took a computer to schedule it; studies would be made on Mark I on how to program on Mark II.

MERZBACH:

Yes, you mentioned that — well, of course, this would -

HOPPER:

This was done BINAC, on how to program on UNIVAC I; all the exploratory work Betty Holberton did. On BINAC, for instance, all the questions of how to sort — the sort timing and when to switch tapes and all those things were done by Betty Holberton on BINAC before it was released to Northrop. Those were all done on BINAC, in order to design all the sorting (the tape sorting) for Univac I. So all the basic research for tape sorting was done on BINAC, and again Mark I was used to do the research on this timing and scheduling and everything else, for Mark II.

MERZBACH:

There's one of the major events of the period that we just touched on — I understand we were going to come back with a meeting of the 1949 symposium.

HOPPER:

That was - Aiken's concept was that it was time to get everybody together and talk about what was going to happen next. Nobody realized it was an industry — it was a branch of research of some kind. There were beginning to be more people; it was time to pull them together. Berkeley wanted to form an association, of course. Aiken didn't; he didn't think it was time for it, yet. In fact, he was dead against ACM for quite a while, but he did feel that they should get together, and everybody should bring everybody else up to this state of the art. And that's how that symposium came to be held. They were invited to Harvard, and that was an outstanding group of people — all the beginners were there — the starters. And that was published later as a volume of the series, and that was really tremendous. I don't suppose, ever again, we'll have that group of people all together at once. But that was because Aiken felt it was time — there was enough development to get together. And we'd all been isolated during the war, you see, classified contracts and everything under the sun. It was time to get together and exchange information on the state of the art, so that we could all go on from there.

MERZBACH:

Was it possible at that time (already) to discuss a number of things that had been classified?

HOPPER:

Yes, it was. We talked about Whirlwind and some of those things, you see. There was nothing on software, yet, though — nothing on programming. You'll find it was all on hardware and engineering, and specific problems — not on the programming techniques yet — software doesn't exist, yet. It doesn't begin to exist really until '51.

MERZBACH:

Would you say that that meeting did represent existing activities fairly well?

HOPPER:

Yes, I think it did. Even the people that Aiken argued with were there.

MERZBACH:

Was there much discussion at the - This one thing that doesn't quite appear.

HOPPER:

Yes, in the halls and around at the meals and everything, it was a steady run of discussion. People that hadn't seen each other in years, because one had been at Oak

Ridge, and one had been at Harvard, and one had been out on the Coast, got together. England was there — the people from Europe, for the first time. But, of course, some of the English had come over during the war, but the others, from the rest of Europe, were there for the first time — the first real interchange. I don't think that any of them ever stopped talking the whole time, and everybody stayed up all night talking about things — it was just a steady run of conversation. Of course, that's all lost, because all this is, is published papers. But, I dare say, that it gave quite an impetus to the industry because everybody began getting ideas from everybody else; they'd been living in isolation, and this brought them all together. We'd had a greater advantage at Mark I because it had always been open, whereas Whirlwind had been classified, ENIAC had been classified, and so this was the first time many of those people got out talking to other people, working in the same field. And I think — I can't pinpoint any particular thing that occurred, as a result of it, but I think a great deal that happened in the next few years were a result of it, because we began to get cross fertilization and communication. And, of course, Berkeley did find enough people who were interested in forming a group, and did start ACM.

MERZBACH:

One other thing, that we've only touched on, is the physical situation, the location; I just read an article in which reference was made to the fact that the work was being done in the basement of Mem. Hall.

HOPPER:

Cruft Hall.

MERZBACH:

Well I was wondering, because - Was there ever anything in Mem. Hall?

HOPPER:

No, it was in Cruft Laboratory.

MERZBACH:

That struck me, I thought -

HOPPER:

And they had to take down part of the wall to bring the computer in. When I got there, in July of '44, it was there; it did not have a case on it. The case — beautiful case you see — was designed by Norman Bel Geddes. I don't know whether that's been recorded; it was designed by Norman Bel Geddes. IBM gave it — Thomas Watson gave it, and the case

was a Bel Geddes design. And it gave poor Howard Aiken an awful pain, because it was fifty or a hundred thousand bucks for the case, and he could've used it for a computer, and that irked him.

MERZBACH:

This was at the time it was dedicated, or did -

HOPPER:

No. Yes, the case got on (the front of the case got on) just in time for the dedication, but it was designed by Norman Bel Geddes. I think that got lost, too, I don't think that's down anywhere.

MERZBACH:

Yes, I don't think it is.

HOPPER:

But he did, and that was put on, and that cut down the noise. And it was in a large room; you did go down in the - You went by the guards up at the end of Cruft Laboratory; the Law School was then Radar School, and Cruft was over here and the new Computation Laboratory is over here, and normally you went in here and a guard's desk was here. There was, however, a back door we could sneak in and out of, at times, and you went down a hallway, and then you went down a little stairs, and the computer was down in here. And there was (an entrance way) an entrance and a platform here and steps went down either side, and what was an office here and (an office and) a little room here, and the computer was out along here, and there's the computer. The tape racks were in back of it. And in this office was where Dick Bloch, and Bob Campbell and I, and the other programmers were — the secretary was here. This platform and these steps went down — this was all one room — you could look out through the glass at the computer, and then there was a table below that, and the secretary was over here, and the commander's desk was here — Commander Aiken's desk was here. When you went through this doorway, there was a little tiny room here that was used for putting the tapes together. We had an iron, you know (plain ordinary iron), and you put this little white masking tape almost on the tape, and then you ironed it and sealed it, so that they made the loops. And, in fact, one day Dick Bloch took a tape which had been coiled up this way, and he proceeded to pull the two ends out and put them together, and I told him that he'd made a moebius strip, and it wouldn't run. And that argument has been going on for years; it was a moebius strip. And then you went through this little room — you came out thru here into the machine room, and there was some space around the machine. Over here was the punch machine, and there was a desk along here, and along there for the maintenance people. Then, later, we got a door open and got another big room out here, (I'll have to continue it over on this end — we got another room out here), and the coffee pot was

moved out and around the corner, into a little corner here which had the coffee, and then there were work benches out here, and that's where they started the experimental work on Mark II. You know they did quite a lot of work on phosphor as a storage medium. And that was all done there, before we had the auxiliary place over in the other buildings. Then there was another room off here which had a blackboard, and became a conference room; that was where von Neumann spent all of his time. Then there was a door here which proved to be very interesting, because (we finally got it unlocked) being Navy, and it turned out that here was the Army storeroom. And so, one day Aiken came out and he found me and Verdonck out there (he was the yeoman), and we were liberating a case of graph paper because we had no way of getting anything — we didn't belong to anybody. And the commander looked and said, "What are you doing?" And we said, we were borrowing some graph paper, and he said, "You're going to take the whole case?" And we said, yes, we were, and he said, "oh no, don't do that," he said, "leave one pack," he said, "The Army may not be able to count, but they can tell the difference between some and none." So he made us leave one pack of paper in the case, and we took the rest. The Army never did find out, because that was a back door — they always went in another door, and we used to liberate stuff from the Army storeroom all the time. Don't tell them. Well you can tell them now, this doesn't matter — they'll never catch up with us now. That was the physical layout, and you came in Cruft and down that long hallway and then in a door, and down steps either side to get to the level of the computer. It was really down in the basement.

MERZBACH:

How much time did von Neumann spend there?

HOPPER:

When we were - When his problem was being run, he was up there about — at least every two weeks, over a period of, maybe, three or four months. Dick Bloch did the programming on that problem.

MERZBACH:

Did he - While he was there, was there much -

HOPPER:

They'd go in this back room and compute all over this blackboard and, then all of a sudden, they'd come rushing out (and the typewriter was on this end of — the typewriters were down this end of the computer), and they'd come and lean on the big level thing here and look at the numbers, and copy down numbers and they'd all go rushing back through this door, and back in this room, and then they'd go all over the blackboard again and then they'd come back and, maybe, have Dick change a switch or something, and this went on and on. I'll just never forget that surge out of the backroom (to see if some

numbers), and then surge back again and put them all over the blackboard, and von Neumann predicting what the numbers would turn out to be and, ninety-nine percent of the time, with the greatest of accuracy—fantastic. He just seemed to know how the computation was going, or to feel how it was going. I don't remember all of the names of the people that were with him. There was one little round man who was funny as he could be, because he just lived on — hung on those typewriters. I'd swear he read every number that came out of the computer — he was completely entranced by it. And when we weren't running his problem, we were running a job for BuShips and Gene Smith (A.E. Smith of BuShips) used to be up there a great deal, because you see, we were still under BuShips until the 1st of January of '46. We were working for BuShips and Gene Smith used to come up a great deal as liaison. Of course, now he's the one who's got all the computers in all the shipyards, and he was the one that backed us when we moved into COBOL. He has really sensed where software was going from the very beginning. His name has never gotten as attached to it as it should have, because what he did was to provide the support, the encouragement, the use, the trying out, and the testing. He was one of the first one's that got somebody to try out the A-2 and supported it way back in the very beginning of software and, of course, he was first to move to use COBOL all out. And he initiated those Bureau of Ships symposiums on software which were the earliest symposiums on software. In fact, there's a lot that wouldn't have happened had it not been for Gene Smith's support.

MERZBACH:

How did he get into this, do you know?

HOPPER:

He was liaison officer to the laboratory from BuShips. He was in uniform then — he was a lieutenant commander, then. And of course, he's retired as a commander in the reserves, but he was on active duty then, and he is one of the people you should talk to.

MERZBACH:

Yes.

HOPPER:

The next thing was the design of the Computation Laboratory.

MERZBACH:

That's interesting — we did talk about that last time.

HOPPER:

We had this other building which, again, was temporary from World War I where Mark II was built, and the Mark II people went over there and, in the meantime, the money was available to build the laboratory. We had a wonderful time designing that laboratory, because I was the one that insisted it should have a galley and a refrigerator, which it has to this day. And that at least one of the ladies rooms should have a shower, and so should one of the men's rooms so that you could freshen up before you went out for the evening or something like that — and we had a great time designing that. And one of the things we made the greatest effort to do, and if you go look at the lab today you'll find out that it happened, was not to waste any space on hallways. And there's only one hallway down the side of the offices, the rest of it is all either machine room or is useful space, and I think a rather unusual job was done in getting no hallways. Of course that big central thing downstairs was where Mark III was to (yeah, Mark III was to) be started, and then the surrounding laboratories where the work was done on them. I can remember the first time they had one of those discs that took off down there when they were testing to build the drums (see nobody knew you could build the drums) and they had discs. They were about — not more than a half an inch thick, and they looked just like a record. And the first time one of those things took off at high speed, you'd have thought a whole gigantic four-motored aircraft had taken off in the basement. And they had shields on them for fear they'd run loose, because they could've killed somebody. But that's where the Mark III development took place was downstairs there. And by then, part of the Dahlgren crew had joined us permanently, in Harvard. That's where Dick Woltman came into the picture. He came up from Dahlgren and, then later, joined the Harvard crew. He's now with Univac also. And the war was over by then. It was '46 and we began to — the place was more open — we began to do more teaching — we had the little lecture room — we began to have more and more, and more and more visitors. We spent more and more time taking people around and doing things like that. And I can remember that shortly after the dedication of the laboratory, Mark I of course was along the long mall, Mark III was starting out in the middle of the room. The — what is the name of that group — the Board of Governors (or whatever it is) of Harvard University, Overseers of Harvard came to visit, and that was the day that the computer decided to become totally recalcitrant. And no matter what happened, it was stopping all the time. And of course the red light would go on it would stop. We didn't know what was doing it, but it was something in the check circuit was failing. So it was stopping on every check instead of going through most of them when it was working perfectly well. And I stood in front of that unit and kept my (right) my back, more or less, and shoulder across the trouble light so that nobody could see it. And then every time it stopped I'd hit the start key and they didn't notice it; they thought it was running because we kept a clock-up, but I can remember my shoulder against that red light so they couldn't see, and pushing that start key every time it stopped. Later, we found that through vibration the check relay had fallen out. It was on the floor, and that was what was causing all the trouble. Of course it stopped on every check because the relay didn't pick up. I can remember that visit — it was one of the earliest in this beautiful new building, beautiful computer and everything else, and we'd just built the subsequence mechanism which Dick Bloch had designed, and everything was so beautiful and then that was the day the computer wouldn't work. It was also while we were there (in the early days there) that somebody finally put on a tape inside out.

Now the tape, you know, had the "in", "out" and "operation" on the right, so that when you reversed the tape (put it on inside-out) all those "in's" became "operations" and the interpolators tried to step forward and back at the same time and stripped the gears — everything tried to take off at once and you never heard such a crash — you'd have thought an airplane had crashed in the bldg. and it came to one screeching halt. Everything tried to happen at once and it went just absolutely dead. That was the worse anybody ever boggled up that computer — that's when they got a tape on inside out and it's a good example of Murphy's law, though, that anything that can happen will happen eventually — then finally, a tape did get on inside. Then I can remember one of the operators — his wife put him in charge of their small daughter (around two-years old, I guess, she could walk but she was tiny) and he had her in the machine room and she was getting all over the place, and he picked her up and put her in one of those round waste baskets and she happily sat there and waved at the computer for about an hour, and we decided it was a very good babysitter — it amused her. And I can remember telling one of the boys or somebody telling somebody, that this was one of the bad moments. We used to — Nobody understood about computers, and they showed him how that they put the cards in the card reader and then they told this poor guy that those cards traveled down in that big round thing, and went up in the counter, and the poor guy believed it. They used to tell people the most horrible things, and I'm afraid we were at least partially responsible for some of the mythology that grew up around computers. And of course, we had called her — they don't do it anymore—she was she. Mark I was always "she" because she behaved like a female; she ran when she felt like it and didn't — she was stubborn and so on and so forth. And besides which a Navy crew should have a ship and a ship would be a "she", so the computer was a "she" and she was always called "she". I think she was last — the only computer that ever was given a female — very definitely a female aspect. And I can remember hunting bugs on it in those counters, remember there were little brushes that go around — and one of the things that could happen was one of those little brushes could twist out of place and make a contact. There was absolutely no way of finding a bad, brush except the fact that it would spark. And so with great regularity, I used to have to produce — I had a little rectangular mirror in my Wave's purse and it was just the right length to hold (it) over the top — to slide it and be over the top of those counters and they could see if there were any sparks —

[Part II]

HOPPER:

…over the top of the counter and they could find the bad brush that way. I forgot to mention by that time Joe Harrison had joined us. He was then… later lieutenant commander; he is now a commander in the reserves and he joined us and started programming and then he went on to DPL and disappeared behind the classified curtains and he's come out again since. He is now the second in command out at NBS. Kind of working for Dr. Roche and Dr. Harrison. He joined us then in uniform and he can remember some of those early days around the computer. Rex, oh dear, can't remember his name right now, but I'll think of it because I just got a Christmas card and I'll have to

send him one. He is now with IBM but we've begun to increase the crew and get more people from different areas doing more different things. I should go over some of them and what they were doing at various times at some point. The Mark II was the first one that had a real bug in it—did I ever tell you about that?

MERZBACH:

You mentioned it, but let's get it on tape. Because that was just a …

HOPPER:

The building that we built Mark II in was a leftover from World War I and there were no screens in the windows and they were all working nights in there and it was loaded with bugs and mosquitoes and one night_____went down to track the bug and found beaten to death by one of the relays about a three-inch moth. So they took it and put it in a log book and covered it over with cellophane tape and as far as I know it's still in the log book up at Harvard. And that was one computer that had a real, honest-to-goodness bug in it—that was the biggest one anyway. It was also the day that I went down I happened to be down town and saw in one of these shops on the street some of these fake bed bugs and I bought a box of them and I put them in the back part Mark I and it caused utter panic. They tried to track down where they were living in that back wiring and they brought in all kinds of you know spray stuff and powders and everything to get the bugs out and I didn't have the guts to admit that they were fake bugs. I never mentioned them but finally somebody discovered that they were fake bugs, but I don't think that they ever did find out who put them there. But that caused a two-day uproar, trying to get the bugs out of the machine. I thought it was quite obvious that if it had bugs, it should have bugs, but…

MERZBACH:

It's interesting it took that time until somebody inspected it.

HOPPER:

Well, it took two days they were scared to death that they found bugs in the machine and there was a good deal of accumulation of dust and dirt around those big cables back there around the motor generator set. It was plausible_____.

MERZBACH:

How much of a real problem was the dust?

HOPPER:

After we got the case not a great deal. We did have a hand electric it wasn't battery operated it was electric so you could carry it around on a long cord vacuum cleaner which they went over the relays with at intervals. Because one thing that did happen was if we had been for a long time on one problem and for instance if it had only eight decimal places and you suddenly tried to run them with twelve decimal places you were in trouble because there was dust on the contacts would accumulate and when you started using contacts which had been sitting idle they wouldn't work. So that when you changed decimal point and went from a small decimal and started using higher parts of the registers quite frequently there were a very large number of bugs. And, when Dick Bloch? started work on the Bessel functions which took the full extent of all the registers, I think there was a two- or three-day period of cleaning that machine up to be able to use just because of the dust problem and because I guess metal sitting over time a relay contact would get sticky and not operate—the metal would get stiff or something and wouldn't pull. And so that you could make the remark which they did make that she had gotten use to this problem and wasn't going to do another one. Seemingly, but actually it was the dust and so on. But, the case kept it pretty clear of it but there was a dust problem very definitely. And, they did go through it with a vacuum cleaner at intervals. But, on the other hand if you cleaned it up too much then you'd sometimes get some other bugs because you'd move the dust instead of getting it out and you created bugs sometimes.

MERZBACH:

I just opened this up because you began to mention some people I thought _____.

HOPPER:

This one is by the time we're getting on to Mark II you see. Mark II crew is in here too. Orton Gadd, John Harr were civilians, this is after the war is over, you see. They had been in the service and come and joined us as mathematicians. Bob Hawkins, of course was always in charge of the maintenance. He'd been with IBM and took over maintenance when it was given to Harvard. He's still there, as a matter of fact, Arliss and Kincaid were mathematicians. Herb Mitchell, of course, went on to be with Collins Radio. He is now with NASA. Ben Moore was the designer of Mark III. Now, Herb is out at NASA, Goddard. And Herb was the first one that ran… he ran the _____matrices on Mark I—did the first job on matrix algebra. Now then when he came to UNIVAC he built the first matrix algebra system for UNIVAC I which everybody said couldn't be done because it only had 1,000 words a core but he used those tapes very cleverly and he built a tremendous matrix algebra system and for a time was head of the computation analysis laboratory at UNIVAC.

Ben Moore was the overall designer in charge of the Mark II. And, Bill Porter was the chief. He came back from the pacific and was with both Mark I and Mark II. Connie Rossen was a Vassar graduate that I brought over there, a mathematician and did some beautiful programming and began to convince people that women made good programmers. Charlie Richards was an engineer. Clarence Ross was then a commander at

Dalgren and he took charge of Computer I and went to Dalgren was later out at Wright Air Development with the development of ARDVAC. Ted Singerstaden was for a while in charge of the laboratory. I've forgotten where he is now. Bob Wilkins eventually went with Dick _____ of Honeywell and worked on RADAK. Dick _____ is still with UNIVAC. _____ was of course on the development of drums and later formed his own company up on Route 128. Now of these many of these were technicians so I wouldn't know them so well. Tom Miller did a great deal of reproduction from my drawings of the drawings for the manuals. He drew them all. Betty Jennings became eventually the Commander's secretary up in the front office and did much of the typing on the final manuals and everything. Frank _____ was a yeoman during the war period and eventually went to MIT and is now in the purchasing department at MIT. The enlisted personnel are _____, yes, we had them before—they're gone.

MERZBACH:

_____ and then we can come back after you've had a chance to go over your material. Well, what happened next as far as you are concerned?

HOPPER:

Well we went on to Mark III and to a design of that coding machine which again is a concept which we will see come again. The concept of the coding machine was that you plugged in your sines and cosines and whatever as you wrote your program in other words you wrote in a higher level language really. And then the relays of the machine put out the exact coding. I think we will see this happen but not in quite the same way. We will program that way because we have the large-scale integrated circuits that will carry out those operations. We will be able to go back to that kind of coding. I think that is one of the things we'll see come again. And when we… I got out of the Navy in August of 1946, I stayed on as a Harvard employee under the Dalgren contract to build Mark III. Now when you have a contract with Harvard—I was on the faculty you see.—I was in research trial of engineering sciences and applied physics. If you have a faculty contract at Harvard, at the end of three years if you're not promoted your contracts terminated. And this is automatic and nothing can be done about. On the other hand, they didn't promote women at Harvard at that point, so at the end of three years my time was up. So, I started looking around for a job. Well, there were loads of job offers, quite an assortment of them for any of us who had come from Harvard of course. I even went down to the ACM meeting at Oak Ridge. I remember talking with lots of different groups of people. They wanted me to come down to what's his name… begins with an "H", my good friend wanted me to come down there but I decided I didn't want to live in Oak Ridge and I did decide that what I wanted was the place that looked as if it was next going to have an interesting computer that was going to be running. And eventually I did go for one interview at IBM and decided I couldn't take it 'cause that was back in the days

when they still had flags, an IBM flag and sang songs about it. And that was too much for me. I finally narrowed it down to two places both of which looked as though they would very soon have computers. When I was at Yale, one of the instructors in the graduate school had been Howard Engstrom. When I set about joining the Navy, I had thought I was going to be assigned to then Capt. Engstrom's group at the Communications Annex in crypt analysis and I was very much surprised when instead I was shipped to the computation laboratory but I did keep in touch with him all the way along and when I got out there was an offer because he'd gone out, Engstrom and Norris and that group had left Communications Annex and Parker had found money for them and they had formed Engineering Research Associates in St. Paul and the government, the Navy had been quite interested in keeping that group together and having them continue to build computers and so Engineering Research Associates was operating in St. Paul and Howard Engstrom wanted me to come out there and the other choice was the ENIAC group, Eckert & Mauchly who by then were starting to design and build BINAC and UNIVAC I for a commercial development in Philadelphia and I talked to both groups because Betty Holberton was in that Eckert Mauchly and she talked to me quite a bit and somewhat influenced my choice of going to Eckert Mauchly. Of course, the interesting thing is that no matter which way I'd gone, I'd have landed up in the same place, because both those companies were bought by Remington Rand and merged with Sperry. So I did go—made the choice—finally on two bases, one I kind of liked Philadelphia better than I did St. Paul, but the overriding thing was that they had a running computer. BINAC was running and UNIVAC I was within a year away and I wanted to be where there was a computer that was working and that was what finally tipped my decision to go with Eckert Mauchly, plus the fact that John Mauchly looked like a wonderful person to work for and I would be working for him.

MERZBACH:

When did you first meet him?

HOPPER:

Oh way back when I was still in uniform in '46 I guess. I went down to see ENIAC; I was sent down from Harvard to visit ENIAC and find out all about it and see what the problems they were doing, the type of class and so on. That's when I had met the ENIAC people. Then, of course, they had been up various times in between. So, 1 January '49 was when I started with the Eckert Mauchly group and we were out at that old factory on Ridge Avenue and on one side of us was an automobile junk yard and on the other side was a cemetery and we always said that if UNIVAC I didn't run we'd throw the computer out into the junk yard and we'd jump out the other side into the cemetery and finish the whole thing up. That was an amazing crew; because there were only about 300 people total, the whole outfit including the janitors who were part of the outfit in those days and everybody did everything and there was no money. That's one of the places I learned to get things done and manage to do without cash dollars but to get things done anyway. But that was the shift that was primarily caused… I would have stayed at Harvard and gladly

except that I couldn't be reappointed and the Navy contract was due to end. Nobody knew quite what the Computation Laboratory was going to do next. Whereas by going down to Eckert Mauchly I would get to a new… and they had the new internal computers and BINAC was running and it all looked very forward going and like fun.

MERZBACH:

Before we go into the… just one question that has to do with your continuing contact with the people at Harvard during this period. Did you…

HOPPER:

Well, I have always kept on and as a matter of fact Christmas cards every year has been the primary communication with some of them who have disappeared from the public scene. I have managed to keep track of most of them, what they are doing and where they have gone, the ones that I worked with closely like Delo Calvin is still up with IBM and ? Whiz White is up there, and so on. I do know what became of them and where they are and as we have gone on in the industry I see them. Every once in a while they turn up at that ACM Anniversary her in Washington. For instance there is a lot of that original MARK I crew did turn up that one time and so I do see them, do hear what they are doing. It's amazing how many of them have gone on and become very successful in the computer field. Some fell by the wayside and we never heard of them again but many did keep on with it and did go on with it. And where they have been the least willing to write Christmas cards why I have kept up with them and for instance during the time I was at Harvard my roommate was married while we were up there down at the chapel in the shipyard and I've kept in touch with her and my other roommate from midshipman's school, now a school teacher out in Gold beach, Washington, Oregon I mean and I've kept in touch with them mainly through the Christmas cards each year we've kept track. Of course, they are now flabbergasted that I am now back in the Navy at long last, when they are getting ready to retire.

MERZBACH:

What about Aiken…well, on the one hand your association with Aiken and then also his own keeping in touch with the people who worked with him every day?

HOPPER:

I don't think that Aiken has done very much on keeping in touch except with a very few. While I was at Harvard, to some extent, yes, but not a great deal. I don't think he made a real effort in that direction. He has been difficult to keep track of himself; he is not a letter writer and he is hard to catch up with and he can get very recalcitrant and as he gets older he has become more recalcitrant. When they wanted to give him the award he couldn't make up his mind whether or not he could come to California or not or wherever it was but he finally got there. But he can be quite uppity at times. He is still a consultant

for the Air Force and of course he has the Aiken Associates down in Florida. He doesn't want to leave Florida; he doesn't need to bother now. Aiken was very possessive and I think the thing was that while you were his property and his employees and his crew he was interested in you but when you ceased to become a member of his crew he lost it; it was his next crew that he was concerned about. He was very possessive of his crew and I think when you ceased to be a member of his crew he had gone on to the next "his" crew. I don't think its criticism at all because he primarily concerned with building and welding a crew and doesn't really have time to worry about the people that have gone by though he will remember you if he sees you and talk to you gladly and so on and so forth. I've stumbled over him twice on airplanes in the intervening years; we've landed on the same plane which is bound to happen now days. He is probably one of the toughest bosses and also one of the best. You could always make the mistake the first time and nothing happened to you. You might get bawled out and you got told not to make it again but nothing happened to you until you did the same dumb thing over again. And he was very fair. Many of the kids didn't realize how fair he was. He was extremely fair. He was a good leader. He did weld a crew; he did pull people together to work together. He was tough; he was rough at times and he had a driving to get things done and he drove the people around him so that while he may have been rough to work for he gave you training that was invaluable. I know when I was writing that first manual my quota was three or five pages a day I've forgotten which, of finished manuscript, and I was in the doghouse when I didn't finish them and I'd never written a book before. And then, he taught me another thing for instance which was the minute you've written something go read it aloud and if you find yourself stumbling, if you can't read the sentence easily, it's bad sentence; write it over again. That's been invaluable to me in attempting to write and in learning to write and he's the one that taught me to write clear short sentences and to leave out all those goopy words like very and much and so on and so forth, be clear in my writing. He gave me a marvelous course in writing plain English… really very good. But the trick of reading aloud after you've written something is wonderful, but if you find yourself stumbling you know you have written a sentence that is not smooth. It's really good. So he is a rough boss but a very fair one and a very good one. And, he formed very, very loyal crews.