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Interviewee: John Mauchly (Talk - NBS Colloquium, Ambler, PA)
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"Mathematical Machines and Myths Concerning Their Makers or Babbage vs. Gutenberg"

INTRODUCTION:

Today it's a great pleasure for me to bring here someone who can talk to us about a problem area that's not peculiar to the Bureau, although I think he's going to bring to it his own peculiar and well-known talents. I don't know, John, whether I should say it's peculiar but certainly they're different. Our speaker is an old acquaintance - and I see in the audience people who have known him for a very long time - he has many things for which he is known but I think I'd like to mention one bit of distinction. First of all, John Mauchly is a native of this area. I think that's rather unusual. He was also educated at that neighboring institution of which I'm an alumnus, Johns Hopkins University, and he has the peculiar distinction of having received his doctorate without ever having bothered to get anything in between his high school diploma and the doctorate. John has his own explanation for this, but I think I'll leave that to him. There are other little bits of lore that I think he might want to tell you about. I could reveal my own side of some of these things but I think in deference to our speaker I'll let him do that.

Now so far as the title of the talk was concerned, Dr. Mauchly gave me several choices and I picked that one which I thought was least harmless and would probably cause least difficulty with people downtown who censor what goes into the calendar, as you know. So, John, I think I've taken up the usual two or three minutes it takes for the speaker to collect his thoughts about whatever he's going to talk about, so why not just turn it over to you. Dr. John Mauchly.

We have a question here as to what's the title and since it might be other from the one that was printed, I'll leave it to you to tell what it is.

MAUCHLY:

Tell me, is this my glass of water?

ANSWER:

That's your glass of water.

MAUCHLY:

First I'll toast, to Babbage of course.

COMMENT:

There is one thing I might say. Regardless of what Dr. Mauchly says, the real reason we invited him here is, as you really know, what he's famous for is, he is the co-inventor of the modern computer as we know it. So whatever you say, John, keep that in mind.

MAUCHLY:

I don't know whether I can keep that in mind, but I am very reminded this morning of the fact that I have another quirk, idiosyncrasy or peculiarity, for which some people blame me and which many of you probably have never heard, and that is, I bring snow. This is established not by a single observation, but by as many at least as three, I believe now, four I can remember. At one time I worked for the Sperry Rand Corporation, the UNIVAC Division. It's now the Sperry UNIVAC, but at that time I was sent roving around on various missions through the country to speak to assembled minitudes - or sometimes multitudes - and I discovered through that experience just what is being demonstrated again today. I went to places where snow is most unlikely and when I arrived, there was the snow. One of those, for instance, was Fort (Watshuka?) and I must say that we've done better here today than we did down there. There I stayed overnight at Phoenix (was it?) and drove through 6 inches of slush to Fort Watshuka to find that the people who were to listen to me had all slipped off the crowned roads over the mountains from Tombstone where they lived and only a few people who lived on the base were able to get there.

Well, I thought nothing of that as one instance does not prove a swallow, or one swallow does not insure a summer, or whatever the saying is. So shortly thereafter I went down in Mardi Gras season to Baton Rouge to a computer conference and they had one of the very rare snowfalls there which enabled the - I think they had something like almost an inch of snow and they had to call off the racing at the race tracks. The horses in that area were not used to that kind of weather.

Later on - of course snow is not too unusual in places like Toronto, but it's somewhat light sometimes, but I remember flying in that area - I guess I was flying to Buffalo and the pilot told us that the weather was clear and everything was fine, with ten minutes to landing in Buffalo. As we landed it was snowing hard and we took our vehicles through about three inches of snow, I think, and that happened to be late in April, which is what made it unusual.

Well, I haven't had a chance to try this out till today and it works. So it's unnecessary for me to explain to you, probably, that I am interested in weather prediction and like so

many people, I can't do much about it. It was never my intent to bring snow here; it's just one of those things that happens.

Now I have a lot of things here which are supposed to help me tell you about Babbage and what went wrong; and if nothing goes wrong we may get to the bottom of this. Since you have probably read the announcement as to one title or another, I should say, I'll tell you that one of the titles I submitted and I don't know whether it was used or not, was "Babbage Began the Beguine". But I was asked to submit catchy titles and I always thought that the beguine was a catchy tune. The reason, however, that I even thought of that title was a very simple one. There are some words in the song which say, "Oh, the chance that was wasted." I don't think Cole Porter was thinking of computers when he wrote that, but anyone who dwells much on the history of Babbage I think comes to that feeling, "Oh, the chance that was wasted."

It was just a hundred and fifty years ago that the Astronomical Society gave Babbage the Gold Medal, not for having constructed a difference engine, but for having had the idea. It may be just coincidental of course that only three years before he had had to found that Astronomical Society of London and they may have been looking around for ways to honor their founders. But at any rate he did collect a Gold Medal 150 years ago in 1823 and received quite a talk in honor of this, all praising the noble and far-reaching ideas he had and with great expectations as to what might come of this, primarily of course for the benefit of the astronomers.

A second title that I submitted is "Babbage versus Gutenberg" and this again has a kind of a very small interconnection with the main topic of Babbage, but the point here is that Gutenberg not only invented the printing machine but its great virtue is supposed to be, it had movable type so that you could use the same letters over and over again without having to re-carve them into the printing material. As I read it, one of the main reasons why Babbage got onto his computer kick was because he was so irked (and that's a very mild word) - he was so irked and vexed, put out, and so on, because of errors which occurred in tables of functions which he and astronomers and other mathematicians were using. So there's one story at least in which he is supposed to have said after a couple curse words or what not over the errors that they were finding in some tables, while he was working with Herschel the astronomer or someone. He said, "Well, I just wish that we could compute these tables by steam." To which Herschel is supposed to have replied to him that, "Well, that's quite possible."

This is one of the stories, true or not, which explains how he might have been encouraged to start on further write-ups of his equipment, his plans for equipment. At any rate, the steam which was going to do the computation represents of course in his day some kind of power. He wouldn't have said by electric power at that time because that was just about the days in which we were beginning to invent telegraphs. As a matter of fact, the electrical relay which later turned out to be useful to Bell Labs and others, Aiken and MARK II, for computing machines - the electrical relay was, as I gathered from some of my reading - the invention of one Joseph Henry and he didn't do that till about 1835. So

here was Babbage in the 1820's, naturally pretty well constrained to thinking about computation in terms of mechanical devices and even a simple thing like a relay not having yet been invented, it's a little too much to ask that Babbage turn around and invent that just because he wanted to make a relay calculator, say.

The essence of his times was the mechanical power revolution and let's get on with hooking up a steam engine to some kind of an automatic device, but - and this to me is the very interesting part which seems sometimes to be ignored in today's references to Babbage - he wanted that device not to depend on man and movable type to produce the tables, but rather to itself do the printing, so that those tables once printed were bound to be as correct as that computing machine could make them. There would be no human error - nothing touched by human hands or monkey hands or any other kind of hands once the tables were computed, whether they were going to go down on the paper or whatever recording medium, just as correctly as the computer could make them. Of course as he pursued this idea he had further the fact that the computer if automatic, properly put together and properly programmed, as we would say nowadays, could be relied on not to make errors.

So the only relation that we have between Babbage and Gutenberg, as far as I'm concerned, is the fact that from the table printing idea Gutenberg was just a man of mischief. He allowed the type to be movable and Babbage wanted to go exactly the other way. Let's have flexibility of course but never let us have any chance that the type can move around during the printing process. In fact he did invent ways in which even if you used movable type you could lock it in place, run little holes through wires after the type had been set so it couldn't fall out and be misplaced. In that sense he was really venturing in the area of the Linotype machine. In other words, he thought one way of getting the printing done was to have soft material pressed against plates which carried the numbers (number wheels) and this soft material would become the cast or mold for a printing process which was already known and in use, stereotype. That was one way of doing it.

But he also envisaged the other possibility - of having a machine which would automatically pull from the type boxes the proper type, set it up in line and then once it was set up, lock it in place with this extra wire through an extra hole or channel so that nothing thereafter could interrupt or change the accuracy of what had already been done. He was no fool either. He knew that if you put a lot of bins of type for this machine to pull, that a human being who might be loading these boxes or bins, they might make mistakes and so he wanted other channels and coding grooves on the type such that if the wrong type was in the box the machine would complain. There's a lot in here that just says Linotype to me. He wasn't trying to cast slugs out of hot metal and things of that sort but the idea of letting the computer set the type and lock it up in such a way that once set it couldn't change, that was his. I don't know how many printers feel that they owe a debt to Babbage on that account, but that is part of the history.

The place where we come against the myth which seems to get around quite frequently is, why didn't all this happen? Well, pretty obvious, pretty clear to all of us sitting here 150

years later. I just explained there weren't any electrical means of doing this, no relays, nothing of that sort. You had to do it mechanically and, gee, who knows much about the mechanics of that era? Probably pretty poor so how would you expect him to do it mechanically? What we now think of as computers do so much that we know we would never want to do mechanically that it's just hard for us to put us back in that frame of time and evaluate what might have been the case then. The easiest thing to do is to say, well, technology was not up to it. The more you read the more you may encounter just that kind of an explanation. You almost just shrug him off at that point, you know. Gee, what wonderful ideas but the technology just couldn't cope with how to put this together in a mechanical (era?).

But if you read Babbage himself of course you don't get that idea. That's one way of going back to the source. Babbage wrote a lot of things. However, you don't have to depend on Babbage himself; he might be prejudiced about this and think you could do more than you really could do.

A second kind of myth which is related to this, of course, is that Babbage was a mathematician. In fact in the history of mathematics, one or two that I looked at, it didn't even mention the fact that he had anything to do with devising computers, computing means. They mention him because he was one of those who, with the Analytical Society which he founded or helped to found, drove mathematics toward what is now called an abstract field, an abstract ology and things of that sort; and that some people feel that before that mathematics was really all more or less tied to the real world and nobody wanted to venture out in this area. I'm not a mathematician; I won't venture to comment on that, but the myth that goes with that point of view is that Babbage really couldn't have built a computing machine because he was a mathematician! What did he know about mechanics and how to construct these things?

Well, you don't get that point of view with that kind of a myth if you go to some of the people who have looked at the sources pretty carefully and considered the pros and cons themselves and given us their opinion. One of those whom I respect is Dr. Douglas Hartrey whose book, I think it was "Calculating Instruments and Machines", was published around 1949. That includes a summary of earlier calculating equipment, both analog and digital, and goes through a discussion of the first electronic computer, the ENIAC, which Dr. Hartrey was invited over to use and was privileged to try. It was he who made some of the best published descriptions of the ENIAC in the early days. When he evaluates Babbage he doesn't say, "Well, he was a mathematician." After all, Dr. Hartrey was a mathematical physicist and probably a little more prejudiced toward mathematics than some of the commentators who felt that only engineers can build computers. So Dr. Hartrey's feelings are not that he couldn't have done it, but rather that here is the first man who realized that while the big problems in the construction of such a calculator which would have many registers and many adding cycles, that in such a thing the problem of carry-over had to be coped with; and that in most machines you're up against something called a successive carry-over. If you're working in the tens notation, as most mechanical calculators did and many still do, then after adding from

nine and going to zero on one wheel or one register or one element of this thing, you've got to carry into the next column, but that may again have a carry and that may again have a carry, and consequently you may be up against the problem of providing for as many carries from one column to another as there are columns, or as there are decimal digits in the numbers you intend to handle.

Now most people with mechanical computing devices of that time were content to try something more like 8 or so decimal digits because that was adequate for trade and commerce. But Babbage wanted to make tables for his accumulation of differences which would be extremely accurate and he was prepared to go a large number of differences and a large number of figures to try to maintain and insure that accuracy. So he actually wound up with plans for 50 decimal digits and he wanted to run those things so carry neither took all of the energy of the drive nor did it take out of the time of the operation. Another machine before that used what was called successive carry. You first carry from the units column and then you would find out, well, does that generate another carry which goes into the tens - into the hundreds column from the tens, and so on. That method was adequate for the people that were just building little adding machines, you might say. He wanted something faster, better, and capable of mechanical realization in his time.

So he spent a lot of thought on this and he came up with a simultaneous carry. As Dr. Hartrey points out in this history there, this seems to be the first time when somebody had solved this problem and, just to jump ahead a little bit, with this first electronic computer, the ENIAC, we solved the same problem. It happens that the men who were building the ENIAC didn't know about Babbage. I can tell you that on a personal basis because I knew Mr. Eckert and my name is Mauchly and it just so happened that - yes, I'd heard of Babbage but of course I'd also heard at the same time that he was interested in some kind of mechanical calculators back in the previous century, so it never occurred to me that we should even look up a single reference on Babbage at that time. We knew how we were going to build an electronic calculator. What in the world profit could we get from looking up these old references on the last century? So we went busily ahead getting an ENIAC, only to find out when we got through that Babbage wasn't exactly out of touch with what we were trying to do next - namely, an EDSAC. But that's the kind of history that has a chance of repeating too, and the same thing happened to Aiken, despite some references, some myths that I've picked up in the literature that Aiken was building Babbage's machine according to the plan of Babbage very deliberately because presumably he knew all about Babbage. But I believe the story is correct, although I haven't heard it from Dr. Aiken's own mouth, that he designed what he wanted to build in the way of a computing device, which became the MARK I, and it was only after he was well embarked on that, that somebody brought to him a description of what a computing machine should do and he was somewhat aghast because it looked like there was somebody else working at this and laid out exactly the same plans. So they said, "Relax, Howard, this was written by a guy named Babbage in the last century." And he said, "Well, if he had just lived 75 years later he would have scooped me!"

So Aiken had nothing to fear from a dead man and we in Philadelphia didn't even consult what Babbage had written at the time because we had nothing to fear from a mechanical conception of the previous century, so we thought, and it's probable that other people are in the same boat. I note, for instance, and since Dr. Von Neumann is now dead I cannot ask him, but I note that so far as I've ever heard or anything I've read, I don't believe that Dr. Von Neumann ever referred to Babbage, but then that was his way. In talking about computing machines - and he did a lot of that - and that's one of the things which helped to launch the new era of automatic computing machines at first - was the immense propulsion to the idea which was given by Von Neumann lecturing at all professional societies and many cases of lectures where he was advocating the power and the capability of these new devices that became possible in the 1950's, but in most of those cases that I know of Von Neumann always referred to all these ideas right down the line without ever making any attribution or reference to Babbage or anyone else down the line. What he was interested in were the ideas themselves and not the history. I'll confess that this was the way I looked at it when I was working on computing machines back in the forties. I was interested in getting our machines done and using them. I wasn't really interested in the history and so I didn't really pay much attention to either what Babbage or others had done before nor did I pay much attention to making adequate records of what we were then doing or what we were thinking about.

Now of course that I've reached that grand old age when one can go on Medicare I'm beginning to get a little more history oriented and finding out how the records of history are sometimes not preserved and also that even when history exists, records do exist, myths somehow propagate. So as I say, the biggest myth concerning Babbage is that the technology of his time did not permit his carrying out the computing devices which he had planned and which he talked about and which he spent most of his life in trying to realize. That really was wrong. Well, first you've got to knock down the one about the technology - that is, if that's an adequate explanation we don't have to look for any other. I think first of all the best simple refutation, of course, is the fact, as many of you know, that a difference engine - in fact some of them - were built (not by Babbage) and were operated (not by Babbage). Shikes, a printer among other things, built one of these things. It took him a while. The Swedish government had to help him and his son had to help him, but they persevered and had one in an International World's Fair on exhibition in Paris, I believe, around 1855. It worked!

It was later sold to an astronomical observatory in this country, in Albany I believe. The Shikes machine, so-called, actually accumulated differences. Now one of the things that we have to distinguish, of course, is that what was built and what worked was a difference engine. What Babbage ultimately wanted to do was called an analytical engine, which would essentially do a lot more and accept a program for a lot more complicated calculations and therefore was not limited to just building up any function from successive summation of differences. Actually as soon as you realize that, you are ready to connect in with the reason why Babbage failed. The fact that the difference engine could be built, as I say was demonstrated because they were built and they were operated, not immediately in 1823 but within 20 years or so, and built by other people

who had less technical advantage, you might say, than he. This printer, Mr. Shikes, apparently knew nothing about engineering. He didn't know anything about physics either. He just happened to be a printer who thought that it would be nice to construct one of these difference engines and see if he could make it work and maybe do more with it. So Mr. Shikes's machine I think went off with the number one prize at the Exposition in Paris when Babbage's machines couldn't get any prize in Paris. He had nothing on exhibit.

The second thing which has to do with that myth is, some people say, well, he wasn't an engineer - he was a mathematician. How could he build such a thing? Actually the building of a machine after he designed it was up to, first, for many years there it was up to a man named Clement who was supposed to be one of the best toolmakers and instrument makers, and who could design and develop new tool-making machines so that he could make tools to make tools to make tools to do something he wanted to do. He was not just the ordinary artisan but rather someone who could invent new ways of fabricating things. As a matter of fact there were in later years professional societies who were attesting to the fact that, due to the attempts at construction of a Babbage difference machine and due to the innovations which Clement and his people had embarked on in order to construct what Babbage was starting out to do, that the whole industry of making calculating - not calculating but fine instruments we'll say - the whole industry of making fine instruments and doing instruments work in England was thereby advanced, that he made a real contribution. Some people thought the money which was spent on the partly complete difference engine was still amply returned to the British government by reason of the fact that the efforts to build this had contributed to the art of fabrication of fine instruments.

So it seems as if the technological difficulties are not quite the answer. You will find some places, like Encyclopedia Britannica for instance in the Fourteenth Edition, sort of a copping out on it. In a brief way they say that his plans were too ambitious. That can mean a lot of things. His plans were too ambitious. Well, indeed they were. They were very ambitious and the ambition far exceeded the salesmanship which he applied to this and that is one way, of course, of explaining what the failure was really due to. You can read again from available documents that Babbage was not the easiest character to get along with and he had a pretty sharp way of speaking apparently. I didn't bring any illustrations of that along but you get a kind of, well, delight you might say, out of reading some of the things he had to say about the British government when they turned off the money. After all, they started to finance him in 1823 or so. By 1828 or '9 they weren't so anxious about this and by 1832 I guess, about the time they decided they just weren't going to put any more money in it, but there was quite a while there where he was sort of teetering on the edge because he thought he could get money out of them but they weren't coming up with any. The dialog between him and various government officials who of course changed - you know how that is - they can change faster in England than they can here perhaps - well, some of them change here pretty fast too. I saw somebody sort of dissenting - I said they couldn't change fast. So, he would have to argue first with a Lord Wellington and later with a Lord Peel and so on to try to get money to carry on the

construction of his engines. So he was sort of put off by being told that, "We don't know if your difference engine would be any good if you did construct it and nobody knows how much it would cost to build it, so the government doesn't want to go into something like that, you know, a bottomless pit." And of course he had good arguments on his side, because the whole argument was like it is in many cases with us on this side of the Atlantic, that the documents produced by one proponent and the documents produced by the other person, instead of meeting head on sort of slide by each other. The point that's made here and the answer that comes back - totally irrelevant. Babbage told them, "If you want to know how much it's going to cost don't ask me; ask the reputable Society of Civil Engineers to estimate it. They're good at this. Get the Civil Engineering people to estimate how much it's going to cost to make this thing and let it be what they say."

But comes back, Lord Peel of course, "We don't know how much it's going to cost. Nobody can estimate it." He never asked the Civil Engineers. That's what is, as I call it, a sideways argument, you know. And so it went. Is the machine going to be any good? The Royal Society had endorsed it long before. The Astronomical Society had obviously endorsed it, and all these people. They said it was going to be worth a lot, but there were some people who were doubtful about this and Lord Peel and those people chose to refer to the critics who didn't necessarily know anything about it, while the Royal Society said, "This thing is important and this thing should go ahead."

So meanwhile of course the government was spending plenty of money in trying to compute navigation tables, ephemeredes and things of that sort for the good of England's commerce - spent a lot of money to compute that and still getting errors in them; and here was Babbage fuming because he knew how to compute tables that wouldn't have errors in them and nobody would back him. So he got more bitter and more fuming as time went on. It would seem then, as some people have estimated, that Babbage's real failures in part come down to, he wasn't a salesman and even the best friends he had couldn't overcome the fact that he started putting out all these challenges and almost scurrilous remarks about people from whom he would hope to get money. He killed his own goose, so to speak.

However, another aspect of that is what I call the better idea aspect and that is if he had persevered with the difference engine, Model I so to speak, and finished it, he could have met his critics on better ground. It was just in that interval where the difference engine wasn't quite finished and he wasn't getting the money right then, that he had a lot of free time to think about what else could he do and he thought of the analytical engine, which in today's terms would be a large computer with a lot of storage, program flexibility so that it could do all kinds of grouping or testing, the closest thing we can see in mechanical terms to what today is the modern stored program computer.

He got this idea and - gee, wouldn't you, if you had that idea in the 1830's, think that this is the thing that the world needs. Well, he couldn't look ahead of course to what it's going to be like in the 1970's but still this was a powerful concept and here was a man who had this concept and except for some mathematical friends and Italian engineers and things of

that sort, hardly anybody would listen to him. So he went off eventually, trying to complete this engine without the government help, spent all his own money. He had already spent more than the government had spent on the difference engine. Now he spent more and he wound up doing something which I find very familiar and I'm very sympathetic with and that is, he tried to see whether he could find a way to beat the horse races in order to get money in order to finish the analytical engine. In this endeavor and others he had the aid, of course, of the Countess of Lovelace, Ada Lovelace, who understood his ideas thoroughly and who wrote up problems, how to do programming on this machine. So she also apparently worked with him on seeing what they could do to get a horse race system, because she knew too that this was a wonderful concept that ought to be carried through and if you can't get those stupid people in the government to give us the money, by God, somehow we're going to get it! But they didn't. The horse racing schemes never worked either. For myself, when I needed some money, I thought I could do it by the stock market but I didn't either, so -.

Now, there's another interesting kind of myth which is not yet propagated this far, but I'm a little afraid that it might propagate the same way. We have a lot of interesting writers in this country, some of whom write science fiction and some of them write science and some of them do both. One of the men who does both is Isaac Azimov. Is he here today? I'm going to communicate this to him; I've already been slightly in touch with him, but there are, to me, some serious and misleading things which he has written, not in the name of fiction but in something called "A Biographical Encyclopedia of Science and Technology". I never saw the original book; however, I bought his edition in 1972. I bought it with great interest, thinking, "This is something I want to see." One of the first things I did when I got it was to look up computers. By these things ye shall know them, as I'm sure every person who has a field or specialty does the same thing. If you buy a new edition of Encyclopaedia Britannica and you happen to be an electrochemist, let's say, you look up the article on electrochemistry (if you didn't write it yourself) to see how good is this reference work. If you can trust it in your own field, then possibly you can trust it in the other places.

Incidentally, before I get to this one then I might say, that Fourteenth Edition of the Encyclopedia Britannica which I happen to own was published around '48 or '49, and it does refer to Babbage. No account of computers in it of course. So I went and I bought the 1949 or '50 Supplement, you see, in a few years after that (each year there's a Supplement) and they still hadn't gotten around to electronic computers. They now have it, I understand, in the Encyclopedia Britannica. They found out. The same is true of the other encyclopedias. In fact some of my best friends apparently have written articles for these various encyclopedias and so they now have electronic computers in most of the major encyclopedias, even in the Book of Knowledge I believe. According to Betty Holiburton some years ago they had a little story on electronic computers before the big encyclopedias did.

Now returning to Mr. Azimov, his work is selective reference. He doesn't try to tell you everything about everything; it's only one volume. He has less than 1200 biographies and

everything's done in biographical form. He arranges them in chronological form so that you can read it as sort of a history of science if you like, start from the first biography and go right through. So he's going to be selective about how a many biographies he included and he's covering not just this year or last year or this century, but he's covering everything from back of Plato or someplace like that. So you look up "Computers" in the Index. There are four entries; I'll read them to you: Computer, Electronic, 934 (934 refers to the number of the biography in this chronological sequence); Computer, Biochemical Research and Molecular Structure, 1109 and 996; and then finally, Computer, Mechanical, 404. That's all code but you computer people can understand of course that this code can be decoded.

Who would you guess 934, 1109, and 404 are? Well, Computer, Mechanical, 404 - that's Babbage. So there was an article on Babbage and that is the Mechanical Computer as far as this volume is concerned, this Index, this encyclopedia. Now Computer, Electronic, 934. I doubt if you'll guess. That is the biography of Vannevar Bush. Computer, Biochemical Research - one of the things about this encyclopedia of Azimov's is that he makes it a point to include all Nobel Prize winners, so it turns out that this is Mrs. Dorothy Hodgkin who won the Nobel Prize in 1964. She worked on such things as the structure of B12 and some other molecular structures which were deciphered with the help of a computer. So since the word computer was mentioned in her write-up, it got in the Index. Computer, Molecular Structure, the second reference to 1109 - or to 996 rather - is Sir Howard Florey. He's also a Nobel Prize winner, not one that I knew actually; I didn't recall that he was, but he was the fellow who took up the long neglected work of Fleming and pursued the penicillin path to the point where he found the molecular structure of penicillin. Then he knew something more about penicillin when he got through and he got the Nobel Prize for it. He also worked with Hodgkin, however, on molecular structure. So that is the extent of what you can find out through the Index here.

Now that is in itself not a myth, you see; the reason I include it in today's talk about myths about machines is, what do you find when you go to Bush's article to see what the electronic computer has to do with Bush? Well, it says in 1925 Bush and his colleagues constructed a machine capable of solving differential equations. Kelvin had worked out the theory for such a machine a half century before but Bush was the first one to construct one and to carry forward the abortive attempts of Babbage. I think this is a little misleading. Babbage was a digital man as far as I'm concerned and here we are taking the Kelvin machine and Bush is carrying this forward.

Now there's another little myth thrown in there which isn't serious but nevertheless just as Aiken and ourselves and others apparently in working on modern electronic machines hadn't heard of Babbage, according to Hartrey whose work I trust (after all he's an Englishman, isn't he) - he says that Bush did not know about the work of Kelvin. So Lord Kelvin's integrators were re-invented, you see. They were invented once by Lord Kelvin himself and then they had to be re-invented later, so anyway, we got Bush now constructing a differential analyzer and thus carrying forward the abortive attempts of Babbage, a half century earlier still, to build a computer. Well it's true they were both

trying to build computers. Bush's machine was in fact the first analog computer. That should straighten things out. Now I'm not sure that that's true either, that it's true either, that it's the first analog computer, but we'll list it. It was one of the first large analog computers, I guess, with flexibility in setting it up and so on.

Now, I skip a little bit through and just pick out the parts that I want to emphasize here. Norbert Wiener, who is also one of the biographies, so Norbert Wiener, biography 964, developed the science of cybernetics which guided men in the construction of computers while electronic switches which are much faster replaced the mechanical ones and the first electronic computer, the ENIAC, was built in 1946; and then extremely advanced and sophisticated computers of all varieties have been built in considerable number since. Well, this is a considerable condensation, you might say. When somebody's trying to condense something you can't be too severe on them, but it attracted my attention because I happened to have had something to do with computers and I wondered, where did this idea come from and I also of course referred to the Babbage thing. I might read that.

Azimov's biography on Babbage was a very good one in general. He cites many of the inventions of Babbage and refers to him, I believe, as an operations research man, which indeed I believe he was, even in the days before the phrase was coined. Babbage was interested in a lot of things and applied scientific and engineering methods to them. He was really an operations research man. One of the things he invented, for instance, was an ophthalmoscope. However, the myth now is that Helmholtz invented it. Why? Because nobody paid any attention to Babbage's ophthalmoscope and Helmholtz, when he came out with one, got the credit. There's a whole series of things like that that go on in science all the time, of course. The person that did it first isn't necessarily the one that gets the credit. In his case he gave it to a doctor friend of his - that is, Babbage gave his ophthalmoscope to a doctor friend, who never tried it out. He wasn't really interested in looking at the retina apparently, but Helmholtz made it.

When we get to the part that Babbage played in computers we find he thought out all the basic principles that guide modern computers but he had only mechanical devices with which to put them into action. That's the only reason he has, the usual one - only mechanical devices so how could he do it? A century later Norbert Wiener worked out the mathematical principles behind the computers and men such as Bush constructed them with the help of electronic devices far more delicate, responsive, and rapid than the gears and levers available to Babbage.

Babbage is thus the grandfather of the modern computer. Although this was not understood by his contemporaries, Babbage himself was probably aware of it. (LAUGHTER) I see that you have the same reaction that I did. I put down here, this is reminiscent of a coin which was found about 200 B. C. Well, that's one more reason why Babbage became so bitter, because he was no doubt aware of the fact that he was the father of the modern computer.

Where did this particular idea about computers come? Well, I decided, if he thinks that Norbert Wiener did it I'm going to go back and see. If he thought Bush did it, that needs a little examination too but I thought I knew that Bush had not ever claimed this, but Norbert Wiener has claimed a lot. I noticed this in some of his books so I went back and looked.

In "The Human Use of Human Beings" Norbert Wiener published in 1950 it says, "The motor idea of the first computing machines is much older than the work of Vannevar Bush. In certain respects it goes back to the work of Babbage. Babbage had the idea of the computing machine which was surprisingly modern. His mechanical means fell far behind his ambitions." So we again use the word like the Encyclopedia Britannica does - he was too ambitious, but we can't ignore the fact his mechanical means fell far behind. It might be his financial means fell too far behind, you know, but at any rate he only spent a couple hundred thousand dollars of his own money trying to do this, you know, more than the government ever spent. The first difficulty he met and with which he could not cope - get this - the first difficulty he met with which he could not cope was that a long train of gears requires a considerable energy to run it, so that its output of power and torque very soon becomes too small to actuate the remaining parts of the apparatus. Bush saw this difficulty and overcame it in a very ingenious way. Besides the electrical amplifiers depending on vacuum tubes and similar devices there are certain mechanical torque amplifiers familiar to everyone acquainted with ships and the unloading of cargo. This device is fundamentally a force or torque amplifier. By an ingenious bit of design Bush inserted such mechanical amplifiers between the stages of his computing machine. He was thereby able to do effectively the sort of thing that Babbage had only dreamed of theoretically. So right here in Wiener is the Webster, you might say. Whether it's analog or digital, who cares? It's amplifiers that did it!

Well, amplifiers are very helpful, I admit, but I am reminded steadily of the fact that in the 1950's Lew Radner wrote an article for the Scientific American about a computer, electronic digital computer. In it he just tossed off a little sentence there that there's nothing wrong with the modern electronic computer that won't be cured by the elimination of vacuum tubes. This was in the early '50's when we were just beginning to get into the solid state business, you see and here were UNIVAC's and things around there with 5,000 vacuum tubes in them; and here was Radner saying very competently, "Gee, when we get rid of those vacuum tubes everything will be fine. We can go ahead with computers, have something a lot better."

Well, that innocent little sentence got a reply in the next issue of Scientific American from a fellow named Lee De Forest. (LAUGHTER) Lee De Forest, who was then working in California - I don't know whether he was in semi-retirement or just what, but anyway - wrote a full column letter in, I believe. He did not want that vacuum tube to take a back seat to any of these fragile little things called transistors. In fact, a transistor from his point of view couldn't be trusted. Certainly it couldn't be trusted to run to WLW with a 50,000 watt broadcasting wave or something like that, you know, and he counted on this idea that this new thing the transistor, not only do we not know much about it, you

know, it hasn't really given us all its credentials yet, but it's never going to handle that 50,000 watts. Of course the point he missed entirely was that the object of a computing machine is not to handle power. The object of a computing machine is to handle information, so your only concern with power is to keep yourself above the noise level, to not be confused by (browning?) and no-motion or whatever kind of noise that may exist in your circuits, get a couple microwatts at least but nobody's going to get 50,000 watts. One of the very things we wanted to cure with respect to the ENIAC was to not make it take 50,000 watts, you know, but rather to run it on a penlight battery or something of that sort.

So it seems as if Norbert Wiener, excellent mathematician that he was, was a little bit confused here about the power and torque concept as applied to computing devices. Sure, if you went down and looked at the MIT analyzer with trains of gears and things, it takes a lot of torque. You have to have a torque amplifier to keep turning these things, especially if you want the final gear to turn faster than the first one, all of it depending on a little friction in a Kelvin disk and wheel drive, for instance, together with torque amplifiers. But what's that got to do with Babbage? Babbage did have to use mechanical devices but he did circumvent some of the main problems with this simultaneous carry. He was talking about doing all of this with steam power. To him steam power, I think, was an inexhaustible resource. He wasn't saying, "Can I turn it with my little finger? Can I turn it with my arm?" But rather, "Let's calculate by steam." So what really would have concerned him was not how much power it took to drive it but did it last, was it reliable? He apparently spent a lot of time on the reliability in trying to design these things so they would last, they wouldn't make incidental errors, and so on. With respect to how long they would last from the wear-out point of view, we can say right now since nobody has got any real information on that thing which has never been constructed - namely, the analytical engine - the only thing we can really say is you can do a lot better at designing a digital device to last, I think, than you can an analog device when you're thinking about reliability and things of that sort. I mean, in a differential analyzer - electrical, mechanical, or what - you've got to be continually tuning it up, so to speak; but in a digital device you know where the accuracy lies. It lies in units, in countable things, and you can see the things that are likely to fail of those things, usually.

This reminds me of another myth which I saw some place which had to do with the reason why these ideas of Babbage wouldn't work, had to do with backlash. Now maybe so but it didn't sound reasonable to me. Backlash is more of a problem in the analog devices and the differential analyzer. Sometimes you don't want it; sometimes you introduce it on purpose. But backlash is, to my mind, a problem you can deal with and get out of the way with respect to any reasonable implementation of digital devices even if mechanical.

Now I'd like to talk about a little myth, a little more modern. This is closer to home. One of them, for instance, occurs in the book (Art Ades' Spirals?), Harper and Row. The student is asked to read, at the end of a history chapter, any of three references. I haven't read those references myself so I don't know what they say. They are Burdick, "Computer

Age"; Hallisee, "Computers"; and Shirley Thomas, "Computers, History of Present Applications". But at any rate, the history Ades has given in the book before he asks the student to read these other things, says, "The first truly historic computers went into operation in 1949. The EDVAC resulted from the ENIAC and the advice of John Von Neumann at the University of Pennsylvania and a similar structure the EDSAC was completed at Cambridge University in England."

Well, that's a hard one to do. It's sort of a yes and no thing, because in a sense there was more than on EDVAC. In fact when Eckert and Mauchly first went into business they called their planned machine the EDVAC II. It became the UNIVAC in later terminology. The first EDVAC was planned early in the history of the ENIAC and here we thought we were wise at the time and I guess ever since I've thought that if we weren't wise, we certainly were lucky, because what we avoided at that time was apparently one of those things which did cause the trouble for Babbage. Even though we didn't know anything about it at the time, you know, if we had been able to read that and profit from it, the thing we would have profited from was not Babbage's ideas about how to build a machine, because ours were already you might say almost identical to it from the point of view of logic. The thing we would have profited from was realizing that where Babbage went wrong as far as getting support for this was that he didn't finish his first machine. He left the difference engine uncompleted and started to confuse the government supporters by starting to talk about his analytical engine which was going to do so much better that with the same money he could build that and have it finished and get a bonus out of it to finish his difference engine. Here we were at the University of Pennsylvania Moore School building that first ENIAC and got a better idea, which we called LOVAC at the time. Strictly speaking, these short names were coined by people down at Aberdeen or the Pentagon. It was convenient to have a name and they picked out the name and we used it. So the Electronic Discrete Variable Automatic Computer was in its beginning formulations not referred to as EDVAC; we just talked about, "What are we going to do with that electronic delay line?" Here we got the opportunity to store all the things which we always wanted to store, all of them now. So what were we going to do about it? We started designing this thing called an EDVAC.

But perhaps before I finish talking about that I should go back and say a few words about another peculiar thing. That is, when do you say a machine has a stored program and when don't you, because the dividing line nowadays is the ENIAC wasn't a stored program machine but the EDVAC was. Is that true or is that a myth? Somewhere in the things that I've been going through recently, for instance, I find again a reference to the fact that I guess is in another one of Wiener's books (he wrote about 6 altogether, I believe, you know) - the one on Cybernetics which contains a nice summary of what he thought a machine should be like. Wiener said, I believe, that the controls of that machine should be fast enough so that it did not have to wait upon slow things like humans in order to carry on the next step. Now, is that or is that not true of the ENIAC? Once you have preset the program in the ENIAC by punch cards, things of that sort, then the controls are fast enough through something called a master programmer which counts the number of iterations or decides when an iteration should be terminated for some other

reason. Those are things incidentally which Babbage planned in his mechanical machine. They are not things which are in the MARK I, so another little myth by the way is of course that MARK I was the realization of Babbage's dream. So it was called by Comrie, I believe, in reviewing the MARK I announcements and manuals. It was the realization of part of Babbage's dream but the MARK I had no facility for carrying out subroutines unless you put the same coding over and over again on the control paper tape which could never be read backwards; whereas Babbage's machine, working with punch cards - the analytical engine - he envisaged, talked about and so did Countess Lovelace the facility of running their punch cards backwards through their reader, so that you could go back to any set of program instructions and reread them and execute them as many times as you liked - a facility of course which every Turing machine has, reading that tape either way.

So we have several myths that I've struck at, one of them being that the Babbage machine is so much like we think now that it went beyond the MARK I which wasn't a Babbage machine until they supplied it with some ability to do some subroutines. We have the myths about gear trains. We have the myths about amplification, all these different things. And finally, we have the myth that I was trying to get at - namely, was the stored program a sudden flash of illumination, you might say, from any one person. Well, we think it was a flash of illumination in stages, you might say, in that we put as much of the high speed control of an ENIAC into this thing called the master programmer. When we had a chance in the EDVAC to put more in, we put it all in. This was before the days of Von Neumann.

I think I've said enough to indicate that there are more myths yet to be dispelled. Some of them are contained in this book which was written by a man who was with us at the time, Dr. Goldstein, as the Army representative at the Moore School. This is a well documented history of almost everything except for some reason the part at the Moore School, and that is likewise the case in some of the other documents I read. Some of them do very well on the more ancient history but don't do well now.

I understand that another group is now waiting for this room so I think it's time to abandon this formal part. I'll be around for a while if anybody wants to talk.

[End of colloquium talk]