This is Interview TC-24 of the IBM World History of Computer Technology, Larry Saphire interviewing Mr. Ralph Mork at Harrison on October 24, 1967.

S. Why don't you tell me a little bit about your background before you went to work on SAGE.

M. With IBM or otherwise?

S. Well, with IBM really and what your field was.

M. Well, my field was in electronics starting in 1949 in the Endicott Lab where I worked on what I guess you could say advance development in such things as high speed, non-impact printers and we experimented with cathode ray tubes for a number of purposes, with zerography, particularly the use of salenium coated materials for storage purpose and card reading purposes and about a year and a half after I started with the company, the company took the Bombing System Contract and started the Vestal Laboratory and I was one of the, we called it charter members of Vestal Lab. We were called together and handed a contract which said, you know here's this big contract that the company has signed and now you guys pull together the organization equipment and facilities and do it.

S. What was the Vestal ......

M. It became FSD Laboratory and it was put together entirely to design, development and get into production this

Bombing System which is used in B52's today.

S. So that was a special purpose computer?

M. That was analog equipment. We took over an original I guess you could say, advanced development of such a system that was done by the Perkin Elmer Company and we put the thing through the final phases of development and release and then it was manufactured in what is now the Owego, FSD Plant and Laboratory. It included radar and my part, after we had once built the laboratory up to a workable level and equipped it with all kinds of instrumentation and so on, I had the responsibility for the radar display part of the Bombing System. This was not the radar itself, that was a .... contract but the CRT and all of its circuitry for displaying to the bombadier the radar information plus the inputs from the Bombing System which showed on the radar scope where the bomb would fall and after Bob, well I guess we were about a year down the road with the radar system when the company took the SAGE Contract over at Poughkeepsie and that was started in what was called the High Street Laboratory. They pulled together a bunch of people from various parts of Poughkeepsie. I don't know whether you're interested in the names of some of those guys. You probably .....

S. Well, well

M. Well, there was Bob Crago, Nate Edwards and Mort Astrohan.

S. What did Astrahan do?

M. He was one of the sort of systems designer guys, the systems engineering at a high level of over-all systems architecture in the terms we use today. He's now in Los Gatos, Mort Astrahan. Anyway, there were a number of fellows like that and they had a very small effort going, I believe under Bill Batchelor who is now in FSD down in Gaithersburg, to develop a display console that would be used in the SAGE main center and thise console would show geographic, stylized geographic map of the territory being surveyed and would show the various aircraft, both friend and foe with suitable identification on each one. It would allow these control people on the ground by watching the displays to decide when to send fighters up, where the fighters would intercept the enemy craft which was being computed by the SAGE System and that was shown on the tube. What finally turned out was they felt they didn't have sufficient technical know how and were somewhat up against in terms of manpower and space and so on. So, the decision was made in FSD to subcontract the CRT console, the operators consoles to Endicott, actually to the Vestal Laboratory and since my group was the one in the Vestal Lab which had the CRT Display technology because of the Bombing System work, ended up moving off of the Bombing System Program and taking charge of the Display Console for SAGE. That was a crash effort.

There were a number of people that were working on that. John Walsh was the man in charge of the electronic portion of the machine.

S. The display ... electronic ...

M. The electronic part of the display console. And, I had a fellow named Don Wolfe who is now retired who was in charge of the mechanical group. Then, of course, we had to take our prime direction from the Lincoln Laboratory and up at the Lincoln Laboratory in particular, the man we interfaced with was Chuck Cordeman who is no longer with the Lincoln Lab. He and Norm Taylor of the Lincoln Lab were our prime interfacers in terms of questions of systems design and interfacing to the operator, the requirements for, well every matter right down to what the shape of the console looked like and, you know, how far one had to reach to reach control buttons, the human factors, in other words, and they joined with us in many of our dealings with the eventual tube vendors. It turned out after we got into the program a little ways that they were several choices as to how you would generate the necessary characters on the tube; all these little special symbols and letters and numbers and so on that were required and finally concluded that one particular type of CRT known as the Charactron which had been developed by the Convair Company out in San Diego, was the right one to use and the so called, Digital Display Tube which was a small tube on the side which just gave tabular information, just plain numeric. We used a tube which became known as the Hughes Typotron which was a Charactron gun with a storage type of screen rather than the conventional Phosphor. So, in the course of working on this display system, the people from MIT particularly Chuck Cordeman, a physicist, Dr. Frank Rogers, Norm Taylor, who by the way, is quite well known to a lot of IBMers in Poughkeepsie and other places, and a CRT expert named Pat Youtz, joined with me in many visits to the Convair Charactron Development Facility and also to the Hughes Company in Los Angeles, where we carried forward the development of these two tubes which at the start were both in their infancy as far as being at a product development level. We also got involved in going to such places as Corning Glass Company to obtain the necessary special glass bolbs which these tubes required.

S. What was the difference between these two, the SAGE and the one you had done for the display for the Bombing device.

M. Well, the Bombing System had a ten inch tube. It's kind of interesting in that that was a new development, also. It was a conventional cathode ray tube with a ten inch round screen and the main new feature was that it had an optically correct window in the rear of the tube so that one could photograph the tube with a camera to get a record of the picture on the radar screen without having the camera and its optics out in front of the tube where they would interfere with the bombadier and also we could project on the rear of the Phosphor previously developed films showing the area, radar map in other words, so that the bombadier could compare the projected image with that being picked up by the radar and thereby find his target more easily. The SAGE tube on the other hand had an entirely new electron optics that didn't have these optical windows in the back but it had an electron optical system which, in fact, was patented and the patents were owned by Convair which caused the cathode ray tube gun to project an electron beam having a cross section of the beam in the shape of the desired character and that's the Charactron principle. This was used in both the Hughes Tube under some form of license arrangement with Charactron and in the large Charactron Tube which was a 19 inch tube and if I remember the length of it correctly, was something over 50 inches long which meant the tube in its shipping container was the size of an office file cabinet. I understand it's probably the largest cathode ray tube that's ever been made in any quantity and as I say with very special electron objects which required a great deal of development, special deflection coils and so on.

S. Was it your job to develop that .....

M. Well, I had the job of the whole Display Console which included the electronics, the frames and covers, lights and bells and whistles and the responsibility to get these tubes. But, on the tight schedule we were working with, we had to do everything in parallel so as we developed the electronic driving circuits for the tube in Vestal, we had to continually match the work there with the electrical characteristics of the tubes that we were getting from Convair and Hughes. So, there was a great deal of back and forth communication, many visits. If I remember correctly, I visited those companies on the Westcoast on the average of a little more a little more frequently than once a month for a period of a year and a half and many of the characteristics of the tube itself that we desired were tradeoffs in tube design and peripheral circuitry so we had to work out there with their people experimental guns, so called .... tube set ups were used so that we could evaluate the results without building complete tubes. Then, of course, the people such as Pat Youtz played a very big role with Convair in getting them to set up a good tube processing facility. They'd never built cathode ray tubes other than the laboratory before, never manufactured them, so Hughes or Youtz contributed a lot of the process know how required to get high reliability, long life and good yield out of the manufacture of these tubes. You have to remember these tubes even in the quantities that they were built and I guess they were built, oh, a few thousand of them were manufactured and after they had been in production a long time, I understand that the price of the tube got down to somewhere around $1,200.00 for each tube which is, you know, ten times more than a color tube for TV.

S. SAGE wasn't known for its lack of expenditure, was it?

M. No. SAGE was done in a day of great urgency when, you know, the national concern about what might come to us from Russia and so most emphasis was placed on getting it going rapidly and because of the tremendous complexity there was extreme emphasis placed on it to obtain the most reliable components. They set up special tube manufacturing facilities to make what were essentially conventional mass produced tubes of the type found in the entertainment industry but they built them in special plants which had super clean, white coat, vacuum locks and all that kind of stuff, just in order to get around the fact that when you had 50,000 vacuum tubes that all have to work in unison, failure rate of conventional entertainment type tubes which is fine for radios, you can't live for more than a matter of minutes and a tube fails. So, reliability was of paramount importance in SAGE and it was no good to have a SAGE system operation on a rapid schedule if, in fact, you couldn't keep it running more than a few minutes a day. So, everything we did and everything the computer people did was aimed at looking at every individual component, resistors, tubes, capacitors and so on, with only a secondary consideration as to cost. If you could up the reliability a substantial amount, why you went ahead and did it, goldplated throughout, you know.

S. You talked about the driving circuits. Did you have a lot to do to match them to the output of the computer or was it ....

M. No, we had an interface established between the computer system and the displays and it was well understood how many wires were in that cable that came to each console. Exactly the voltage levels on those signals, exactly the rise time, the whole business. We designed to that, we did not design the part toward the computer although, of course, we had many negotiations over what that interface was going to be in the beginning until we had it set and after that, we did the internal workings of the console itself which had some very high powered display deflection amplifiers. We didn't have transistors in those days, this was all built with vacuum tubes. The power tubes used in driving the deflection you know, were tubes that were done by the Imac Company for UHF transmitters for television and FM stations, output stations. They were very high powered and ran 700 watts of power each. They were chosen primarily because of their reliability and their hour handling capacity running , you know, conservatively ..... in this particular job. There were a lot of analog circuits in there because we had to convert the digital coded signals from the computer to an analog voltage which was used to provision the beam on the face of the tube. This was not a TV raster (?), this was a random display and, in fact, the 2250 Display Console that we have in our product line today, can be looked at as a descendant of the SAGE.

The first of these, the laboratory model if you will, was delivered in a period of about seven or eight months, I can't remember exactly. From the time that we finalized what it was we were going to build and that involved all these questions of human factors, the shape and size and height and so on, once that was settled, we delivered the first prototype console up to the Lincoln Lab for test in connection to the system in about seven or eight months. Then the question came as to what about going further with the final release going into production and it was concluded for reasons that I guess I don't understand completely, the company didn't want to expand this particular activity in the Endicott area and, therefore, it was decided that we would subcontract the final release and manufacture on the outside and this was finally concluded to be done with the Hazeltine Company down in Long Island with some liaison engineering kind of a relationship to the High Street people. So, it was at that point that if I remember rightly, I think it was 1955, having delivered these prototypes and Hazeltine coming into the act, I departed the program and went into the commercial side of the Endicott Laboratory. So that's about that for the SAGE.

S. You said that the 22, whatever it was, the 2250 was kind of a descendant of the SAGE Display. Was there anything that IBM did in the mid '50's that resembled that kind of output or did they skip it completely?

M. Well, the SAGE kind of output didn't appear on our product line except I do recall we acquired from the outside a cathode ray tube display that was used on computers of ours, I think it was a purchased item of an outside company, kind of an RPQ, but I don't know the details of it. I happened to have see n one of these once. I understand there were a few of them made available on kind of a special order basis for I don't know whether it was the 704 or the 7090 system that this could be had on.

S. I recall something about a display ..... for the 704 or the 701, it's probably the 704.

M. I think it was the 704 but that was not developed by IBM. It was a subcontract with another firm and they supplied us a few special order basis.

S. Were you in a position to know why IBM did not pursue graphic display at that time around '54 or '55 or '56?

M. Well, I guess I can't say why we didn't. You know the big impetus and the big technical development work, all our skills were remoted to the promotion related to the military. We did take on shortly thereafter and I don't know the exact date, a project with the General Motors Company which we called, the GEM Program and that was in Kingston and it was some of the people who had experience in the product release end and manufacturing surveillance end of SAGE and who would also under some kind of R&D money that the SAGE Program gave out to work on improvements to the SAGE System after it was in production, these people had worked on a new display console taking advantage of some new thoughts about the way these consoles would operate and then they took on this so called GEM project which was a contract arrangement with General Motors. I can't remember exactly when that was finished and delivered but let's say it was somewhere like '62.

S. What year did that start?

M. That's what I'm not sure of but it was obviously, you know, it had been going on for three or four years when it was finally delivered so, I would guess it was maybe 1958 or thereabouts.

S. You know it's a funny thing. Charlie Bashe and I were discussing the other day the progress in electronics, versus progress in mechanical things. Let's say the electronic displays .... and mechanical. They're basically outside the computing system and here was a way with your work on SAGE an opportunity for IBM to get involved in some fairly sophisticated output devices. Was there just not a call for that kind of thing commercially?

M. We skipped something here. When I left the SAGE Console Project back in '55, '56, whenever it was, I went over in the Endicott Lab and took charge of a project they had there to develop a microfilm printer. This was to be a printer that would, in fact, take the output of a computer or from a tape drive and generate it on a CRT and the CRT space would be photographed by a microfilm camera and you would end up with extremely high speed microfilm and what we did there was very heavily based on our experience with SAGE and led eventually to a prototype machine which was generating microfilm at a character rate of 16,000 characters per second. It had the capabilities of plotting curves, drawing graphs, that kind of thing. Plus it had the straight page generation like a conventional printer. That machine never found its way into the product line because it was too expensive. When the thing was priced out, the rental was found to be somewhere about $4,000.00 a month. We were unable to get a forecast at that time for a machine which had the capability of that price. The forecast just wouldn't support going ahead with the program. It seemed as though the user just wasn't prepared in those days or didn't have an application that merited this kind of speed and the users, of course, weren't all that in love with microfilm.

S. This is an old story, that all our early forecasts had very limited uses for computers.

M. Yah, yah. Well, we were ahead of our time if you want to look at it that way. That particular program went two ways. The design was picked up by an organization we used to have in this company called, Special Engineering Products, SEPD. And, they bid and won the bid to supply one of these machines to the Social Security operation down in Washington. They took our design. As far as I know, they copied it cold with the exception that we had a 35 millimeter microfilm camera and the Social Security required a .... was a 16 millimeter and so they made that change on the camera end and that machine was installed down in Social Security somewhere, again, I don't know the date because I was off the program, but let's assume '58 or '59, I guess. And, as I understand, that machine was in down there doing productive work everyday for the entire time up to about the middle of 1966, and operated very successfully. But, we never found any further market for the thing at the kind of price we required. By the way, there was one kind of a hiccup in the program, besides SEPD going forward to making this special product one of a kind for Social Security, they, the management of IBM, again decided that we should look to an outside firm if we weren't able to make it for a price that was marketable internally, it would be a good idea to try going outside. This is a thing that the management of the company has looked to as a way out of these kinds of problems on several occasions. In this particular case, they went to the

Stromberg Carlson people who had taken over, I believe it was at that time, the Charactron part of the Convair operation since these tubes really had nothing to do with aircraft and General Dynamics owned Stromberg and Convair, they had a reorganization, and Stromberg took this over. Again, I wasn't on the program during the time this was going on with Stromberg but I understand after we paid them quite some considerable amount of money, they finally succeeded in developing the machine, a similar machine, which produced microfilm, used the Charactron tube in it which we had not used; we used a special RCA tube in our machine and the machine that they developed went through product tests, I believe in the Endicott Product Test Lab successfully. And, again, we bombed out on the basis of the cost of the product which resulted in a rental and the rental was too high for the market place, so that went down the drain. Having done all this and in effect, we practically I guess you could say, put Stromberg in business by virtue of the fact whatever we had spent on developing this product, Stromberg has since come on the market with that product under their own name and have not had a roaring success with it by all means but I gather they've sold something under a hundred of them and at a price which is apparently attractive in the market place. Just in the last year, the IRD Division of IBM has had some negotiations with Stromberg with a view to buying these from Stromberg and marketing them as part of their over-all microfilm program but last I knew, that hadn't worked out, either. So, we did take the technology and, you know, a lot of it was based on what we learned in the Radar Bombing Displays and then on the SAGE Console and make what appeared to be the best product that we could.

Now, to get around to just plain displays of the 2250 variety, as shown by the GEM, for General Motors which was a special kind of ...... to the 2250, the problem there has been one of using them. The technology has been there for some time. I'm sure we know how to do it better today. We have transistors and the like but the technical performance, speed of writing characters, the speed of generating ..... and the like on the face of the tube, has been with us for essentially ten years but how to use that function from the standpoint of a customer, from the standpoint of the engineer who sits down and tries to do the useful work with one of these tubes has been the big problem. There is a tremendous amount of software required to do the kind of things that you see on the 2250, draw geometrical objects, design automobile body shapes like General Motors is trying to do and it's been a long, slow pull to devise means by which through a digital computer you can handle this kind of information which is far different from processing mathematical formulai and doing accounting or that kind of thing, new concepts of how you handle physical objects shape in a computer, change its scale, rotate change prospectives and the like, had to be developed and as those developments go forward, the demand for these displays becomes a lot more widespread. So, I think from a pure product viewpoint, we've had the product but or at least let's say we had the product capability in our hands for a long time and I don't think we know how to make those products any cheaper today than we did then, but we didn't have a way or marketing them because the customer didn't know how to use them and we didn't, at that time, have the wherewithal of the software and what we called a methodology to help him be able to use it for productive effort on his own part. General Motors had to spend a tremendous amount of money in developing their own software all during this GEM Program. We helped but they done a lot of it.

S. Did you have just the display or ....

M. Well, GEM was a complete system involving displays and computers and so on of which the special part was just the display system and the software. So, it's an entirely new business and both us and the customer had to learn what the heck is going on here.

S. I think at the beginning you told me that you had come into Endicott in '49. Had you worked for another company before that or had you .....

M. I was with the Atomic Energy people out in the Oregon Lab in Chicago for about a year before that doing instrumentation for well a wide variety of physics experiments, atomic reactor experiments and so on.

S. Did you ever use a computer?

M. Not a digital computer. We had a very large analog computer made by the Reeds and it was called a REAC and it was a very excellent machine. Because I happened from previous experiences know something about those, I was the guy who had to buy that REAC and get it installed and teach some of the physicists how to use it as one of the things I did while I was out there. Before that, interestingly enough, I was in the pinball business. I was in charge of the Electrical Engineering Department of a pinball company, a pinball manufacturer on the south side of Chicago. Then during the war for four years, I was in the navy as a project engineer although I was a naval officer but in our terms of project engineer, doing development work for synthetic trainers. This was an outfit in the Navy Bureau of Aeronautics called Special Devices where we developed synthetic gunnery trainers, synthetic flight trainers, bombing trainers and the like. In fact, that's where I first got acquainted with IBM. I had a couple of projects which were handled by IBM in the Endicott Lab and I made several trips up there looking at these projects and working with the people up there. So, I ended up with IBM several years later. In fact, I started out with George Daley in Endicott whom I had gotten to know during the war and, of course, Wally McDowell whom I got to know.

So, that's kind of the history.

S. I was wondering before we conclude, could you give me a few more technical details of exactly what the electronics were in the display tubes of the SAGE System?

M. That's a little hard to do without drawing pictures but if you look at the electron beam coming out of the gun in the cathode ray tube, it's practically like a stream of water coming out of a hose only the stream consists of electrons and in the conventional tube this stream is focused to a nice sharp pinpoint, if you will, and it impinges on the phosphor, the electron beam energy is converted into light by the phosphor and you see a bright spot. In the Charactron tube, on the other hand, the beam when it first comes from the gun is passed through the equivalent of a stencil, a very tiny metal disk which has had characters etched through it and, in fact, there is an array of characters and in our case it was eight characters crossed by eight vertically so you had 64 little character apertures etched through this matrix and if you deflected the beam so that it strikes one of those etched through characters, the beam illuminates the character and where the character is etched through, the beam can go through there whereas the rest of the beam ends on the metal. So, in effect, coming out the other side of this matrix is an ...... electron beam which is extruded so as to have a cross section the same as the etched opening in the shape of a character. Therefore, by deflecting the beam to one of these 64 possible positions you can shape the cross section of the electron beam in the shape of whatever of the 64 characters you desire. Having done that, there is a second set of deflection circuits which redirect that extruded beam so as to cause it to strike in the desired position on the face of the cathode ray tube. Therefore, the first set of deflection we call selection circuits in that they selected the desired character and then after going through the matrix with some focusing and correction circuitry in the tube, we then had what we referred to as deflection system which was a conventional large magnetic yoke which put the character where you wanted it on the face of the cathode ray tube. Now the electron optics of that are extremely complicated because you cannot afford to distort the cross section of that electron beam by the deflection circuits. Otherwise, you would have an unrecognizable or distorted shape when it impinged on the Phosphor. So, the over-all circuitry with this tube had a very high degree of precision of voltages and focusing currents, deflection yokes and the rest all had to be very much tailored to the internal dimensions of the electron optics in the tube, otherwise you got gibberish on the tube face even though you had selected the right character to start with. Now, this was a fairly fast circuit. The whole system was such that we could put a character in any place on the tube face in a total time of about 60 micro seconds and then go from that point to any other random place on the entire tube face and put another character during the next 60 micro seconds. So, we not only had all these problems of maintaining the focus and not distorting the shape of the beam and the like but we had some very high speed circuits and yokes which had to arrive at a point stop and as we referred to settle, so that we could turn on the beam at that point and get a clear or non-fuzzy character and this was pressing the state of the art at the time. I think now with advances in transistors and the like, we would probably be able to do this twice as fast today as we were then.

S. What was the order of ..... of speed?

M. Of the what?

S. The speed of operation?

M. Well, the speed is the 60 micro seconds per character on a completely random, anywhere on the face of the tube which nets out to speed of around 16,000 characters per second but that's a far different 16,000 than you would have in a conventional printer where the characters are put on like a typewriter, you know, one after the other across a row and then move down to the next row and so on, because you could print a character in the upper lefthand corner and the next character after that was in the lower righthand corner or any other random spot on the face of the tube and that's a much more difficult engineering problem than a CRT where characters run sequential line by line, character by character basis. The 2250 can operate in this mode and does when it's drawing geometrical figures and so on. It has this same capability.

S. Was this faster than ....

M. Yah, I'm a little out of touch but I should know the numbers but I don't but it is possibly twice as fast as the old SAGE Display.

S. Is the SAGE System still in operation?

M. Well, I'm a little unclear. I know they've closed down some of the SAGE sites. They built quite a number of them and then over the last years, I understand they closed up several. The last I knew there were still a number of them in operation and there was a new one installed under some agreement with Canada, there is one located up in Canada now. The reason I know this is about six years ago, Kingston had to somehow or other go back into production and make one SAGE System for this Canadian installation which was quite a problem itself, you know, scrounging up spare parts and all kinds of jobs in building them, one of a kind after they'd really shut down production on the main thing.

S. How many installations did we build?

M. I can't use that number because that's, at least it used to be classified, I haven't heard if that's changed so.