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GENERAL ELECTRIC COMPUTER HISTORY

INDEX

ANALOG

I. Need for Aid in Analyzing Electrical Networks

A. D-c short circuit calculating board.

1. For own use 1928

II Other Systems Problems - Need for More Aid

A. A-c network analyzer 1935

1. Understanding and math for a-c networks came from this machine.

2. 14 sold.

III. Mechanical Differential Analyzer (14 order differential equations) 1938 - 1940

A. G. E. contribution - Polaroid Torque amplifier

1. Outstanding computer of W. W. II.

2. ~~4 sold~~. G.E. built 2 out of total of 5.

3. Can't be given away.

IV. B-29 Gunfire Computer 1941 - 1945

V. Simultaneous Liner Equation Solver - 1952

A. 12 x 12 - 3 significant figures

VI. Psychological Matrix Rotation Computer — 1952

A. 12 dimensions

VII. Jet Engine Simulator 1952 - 1953

A. Fastest and most precise Fastest real-time → largest in the world.

1. Function generators of 2 independent variables
   a) 0.1% in 10 millisecond

ANALOG - Continued

b) Solve problems in "real" time - time of gas molecule to clear engine.

c) Faster than digital

2. 6000 tubes

3. 2750 dials

4 1700 lights

5 8200 plugs, jacks

400,000 joints
140,000 ft. of wire
42 man-yrs to build

VIII. TPQ - 5

A. Signal Corp

IX. General Purpose Analog

A. G.E. did not enter

Why Digital?

1 Better accuracy

(a) ability to [illegible]

2. Logic.

Why didn't GE enter sooner?
(a) Philo - was against [illegible]
(b) Can't put all customers out of business

DIGITAL

I. Demonstration Unit Following Moore School. — 1948

II. Design for Common Wealth Edison - Chicago — 1950

- A. Cordiner said "no"

III Engineering Council - H. A. Winnie ~~1952~~ 1950

- A. For own use
- B. For sale to military

IV. Design for Medium Steam Turbine

- A. Could not raise the money

V. OMIBAC 1948 - 1949
Ordinal Memory Inspecting Binary Automatic Computer.

- A. Air Force money for own use
- B. First electronic floating point arith.
  1. Storred program
  2. 1500 number per drum
  3. 3000 tubes
  4. 80 operations/sec

VI. OARAC (Office of Air Research Automatic Calculator) 1948 - 1950

- A. Wright Field
  1. 10,000 word drum
  2. 10 decimal digit
  3. 100 instruction/sec
  4. 1400 tubes 7000 diodes
  5. Add time = 100 μsec

Computer Department

I.	Computer Section of GEL		1952
II.	Presentation to Board of Directors		1955
III.	Section of Tech. Products Dept.	Dec	1955
IV.	ERMA Contract - 30 systems		
	Letter of Intent signed	Apr	1956
	Contract signed	May 1	1957
	First unit in operation	Sept 14	1959
	First Solid State Commercial		
	Largest Comm. order to date $30M		
	Largest Bank in the World		
	Largest Elect. Mfg. in the World		
V.	Decision to Locate in Phoenix	Nov 2	1956
VI.	NCR Contract		
	Eng and Mfg of 30 units		
	First unit delivered		1959
	Last unit delivered		1962
VII.	GE 312 Control Computer		
	Shipped first unit	Nov	1959
VIII.	GE 225 General Purpose Computer		
	First unit delivered (to Portable Appliance Dept.)	May	1961

K. R. Geiser/jms
12-9-63

THIS IS AN INTERVIEW WITH KEN GEISER, MANAGER OF BUSINESS PLANNING, ON THE HISTORY OF GENERAL ELECTRIC IN THE COMPUTER BUSINESS.

General electric's history in the computer business started really as an outgrowth of the instrument business in the analog computer field, because the early analog computers, and we didn't have digital computers at all in those days, were nothing but elaborate instruments. To the extent of my knowledge, the first device that you could truthfully call a computer that General Electric built, was the short circuit calculating board, and it was built around 1920, sometime in there. The reason it was built was simply this: the short circuit computations on electrical systems began to be more sophisticated. The short circuit calculations were just so involved that you couldn't write down a formula and do it worth a damn. Somebody had this bright idea. "Why don't we build a little model of these things" and so he built what we later termed a direct kind of an analog computer, meaning that there was a direct analogy between the model he had built and the true system he wanted to study. Then by playing with this toy, so to speak, you could study the flow of currents in the model, and predict what it would really be like. This is a direct analog computer. There were a number of these built around the country at that time: Westinghouse built some, some of the universities built some, and short circuit calculating boards came into being. Some of them were pretty big. Some of them would have an array of potentiometers thirty long by ten high, 300 potentiometers on them, that you could stick your instruments in, in various places, and determine what was going on. There are still some of those operating. I think there is still one operating in Schenectedy and I think Purdue University still has one that operates -- just plain DC direct analog computers.

Q. Not the original, though?

A. The one in Schenectedy is still the original one, and I think the one in Purdue is still the original one. They're real old-time looking boards.

Following that, (still talking about the utility systems which were the only large systems engineering people were building at that time) these became more and more complex, and they found that there were other problems, not just pertaining to short circuit work, but to loading and transmission and other things, and they realized they needed one that would take into account the phase angles that they needed to get into studying AC systems, and so came into being, for exactly the same reason, because the systems were so complex they couldn't be written down in the way of formulas, what we now know as the AC network analyzer, and they were developed simply as models of things people didn't understand and GE was active about the same time Westinghouse was active in this, and some of the first AC network analyzers were finished about 1933, 34, 35, thru there, and we and Westinghouse both independently arrived at about the same frequency that these things should operate on, Westinghouse had 450 cycles, I think, and ours was 480 as an optimum frequency.

The really important thing about the AC network analyzer wasn't only the fact that it was useful from 1935 to 1960, to the people who have them they are still being useful. As you know, some of our real little low cost ones are still being used. The real important contribution to the world is the fact the model was built before the mathematics were available and from the computer came the mathematics that ultimately explained to the engineer how his system really worked. It was generated backwards from the way you think it would. He learned from plying with this model how things were related that he couldn't learn from a big system -- he didn't have enough control over it. It came about sort of backwards on him.

Well, GE built approximately fifteen of these big boards, and at that time they were the largest computers that any man had ever built. Westinghouse also built and supplied these things, and they built more than we did -- I'm not sure how many, but to the best of my memory they built twice as many of them as we did.

Q. Were they known as computers then?

A. We were calling these AC network analyzers but the engineers who dealt with them looked on them as computers -- they were called analog computers.

Following that, well, let's see, I should also mention, -- although it's not important to GE, -- M.I.T. built an AC network analyzer. They really showed the industry how to build this, they built a 60-cycle one before either GE or Westinghouse got into this. Following that, Dr. Vanderbush at M.I.T. built a mechanical differential analyzer. After some work that was done in England of using Kelvin wheel integrators and cascading these, the Kelvin wheel integrator allowed him to keep the loading on the integrator down sufficiently low that he could cascade them and thereby perform more than one integration successively so he could do intercalary equations to about the 10th order. Well, GE saw the power of this and we built a mechanical differential analyzer in about 1940 -- I'm not sure of the exact year -- from '38 to '40, in there. We built this machine and made a substantial contribution to it, whereas Dr. Bush's machine used what is called a string type torque amplifyer, so that you did keep the loading down on your Kelvin wheels.

A man by the name of Ted Berry in the General Engineering Laboratory invented a Poloroid Torque amplifyer that allowed the load on the Kelvin wheels to be absolutely zero and for it to drive quite a sizeable output. This was a real contribution to the mechanical differential analyzer. We built our machine along that line, and we ultimately built an identical machine for the University of California. There were not many of these built, I think maybe there was a total of five uilt in this country by various people of which we built two, all mechanical -- quite a monstrosity, really, because it was a computer some hundred feet long, with hundreds of shafts and gears--you changed multipliers by changing gears. You could differentiate to different orders by tying together the number of integrators you wanted to. It could add by differential action by using a gear differential. You could run two shafts in, each of them, when one turned one revolution, the other turned one revolution -- the output would be two revolutions. You can add, you can multiply; -- by fixed gears, -- when one could go around once the other could go around ten times. You multiplied by ten. You could integrate differentials and do these various things. Now this was really the first indirect analog computer. We called this indirect because, you see, here you're not simulating, or not building an analogy to the real thing, you're building an analogy to the mathematics that expresses the real thing, and these are called indirect analog computers.

Now the one thing that the mechanical differential analyzer did that no other differential analyzer ever did, was it allowed you to integrate relative to any arbitrary function instead of just time, as later indirect analog computers could integrate only relative to time. This could integrate relative to any function you wanted to.

Well, following this, and the reason that no more of these large mechanical beasts were built, and actually we had trouble getting rid of that thing, because it cost about $3,000.00 just to prepare a room to put it in. It was so long it had to be leveled and everything --

this thing couldn't work very much -- it was quite a beast, they really had trouble getting rid of it.

Q. Can you remember what it sold for?

A. Oh boy, about $100,000.00. Roughly $100,000.00 which was expensive for those days. We tried to give it to R.P.I. and we finally gave it to V.M.I. -- The company gave it to V.M.I.

The reason no more of these were built was that during the -- well, I'll say one more thing about them. Those mechanical differential analyzers were the hardest worked tools during World War II. These were the only computers available at the start of World War II. And so as we got into a semi-technical war, if you will, the most sophisticated device we had for solving problems were these mechanical differential analyzers and they literally worked around the clock during the whole war, trying to solve various kinds of ballistic equations -- it was a beautiful tool for solving ballistic equations -- there isn't today a better machine for ballistic work at all.

Q. Do you know whether Germany or any of those countries had the M?

A. England did. We don't know that Germany ever had any mechanical differential ones, but England did, and ultimately, the Mechano people of England, who are sort of like the Gilbert Director people here, produced a device you could buy and take home and build yourself, a differential analyzer in your basement if you wanted to. And they sold quite a few of those things to schools and even to private individuals who wanted to build a differential analyzer. We had no knowledge that the

German people or the Russian people had anything like this at all.

But -- I'll get back where I was -- the reason no more of them were built was an electronic version of it came about, and the Reeves Instrument people were leaders in this field early in World War II. They got into this and they produced a very adequate electronic differential analyzer, and this was the death knell to the old mechanic kind. It was lower in cost to build, and Reeves built quite a few of these things.

General Electric did not ever indulge in any standard electronic differential analyzers. We built some special ones but we didn't get in the business as Reeves did, and ultimately Goodyear became quite a leader in building these (that's Goodyear Aircraft) electronic machines.

Well, backing up on GE's history a little here, all of these computers were still really tools for the engineers to solve engineering problems. But during World WarII, some good work was done in England and some of this was picked up in thi s country and we thought about building digital computers, and some of the early thinking was done by myself and Dr. Akin down at the York Mine School, near Yorktown, Virginia, where he and I were both working together fighting mine warfare. He was at the Mine School, and I was down there working for GE. We were developing underwater minesweeping techniques and various ways of combating the German magnetic mines and some of the rather intelligent torpedoes that they had at that time. We used to sit on the dock down there and draw circuits of how to build digital computers out of relays. This was about the extent of our thinking in those days, just relays.

Q. Was this the beginning of digital?

A. This was the beginning of digital. This was really some of the early thinking of digital, and we were getting our ideas primarily from Dr. Williams in England at Manchester University, who was building a digital computer, a relay device, at that time and we started thinking about it here -- this was really the start of it in this country.

Now to carry that along just a little bit, -- he ultimately did go back to Harvard and got IBM to finance him in building a relay computer, and this was his original selective sequence calculator, the Harvard Selective Sequence Calculator, which was the first relay digital computer -- it was the first relay digital computer built in this country and it was a relay one, and it was only semi-automatic.

Q. If you weren't with GE then, could we say that GE was in on the original thinking of it, and get away with that?

A. Oh, golly! When you say thinking, lots of people can say they were thinking about it at that time -- in fact, we have often argued about who really did the early thinking. Neither Aiken nor I can prove that we were the original thinkers. A gentleman ultimately published a book who claims he was the father of the digital computer in the United States, and as far as we know we can't prove he wasn't, and he claims he was thinking about this and doing some figuring ahead of us, and his name was -- it escapes me but it will come back to me -- he lives in Burlington, Vermont, now and he's a consultant -- a corn-cob smoking, grey haired man now. I'll think of his name. But we've argued much about who really thought of these things and did the early work, and you can't prove it one way or another. It's been batted around time and time again.

Now let me add one more analog thing before we forget. We'll go back and forth between analog and digital -- we can't help it. About the same time -- I'm sort of running this in time sequence, really, instead of keeping it on analog and digital --

About the same time the B-29 was being developed in this country, and previously the only intelligence that aircraft armament had built in it was a cam that allowed a machine gunner to keep from shooting his propeller off and his tail off as he swung this thing around. But somebody picked up this idea and said, "Gee, we ought to be able to do more than that. We ought to be able to build up some more things." It's awfully hard to judge distances in the air. If you've ever tried to shoot at a moving target in a moving airplane, you'll realize what it's like. It's just awfully hard, a gunner has a terrible time hitting anything. So some people in the airforce said, "By golly, we think we can build in one in the lead" and this was the start of what was quite a famous analog computer that General Electric was the leader in, called the B-29 gunfire system, and we developed and built most of the gunfired systems for the B-29's. This was the old A.N.O.S. gang in Schenectedy that developed and built this. It was an electro mechanical device. It had some electronic, some electrical and a lot of mechanical stuff in it. These have performed questionably; I got in on it myself when the Jap's were knocking our B-29's out of the sky and we decided to find out what was wrong so a special task force was set up and I was the instrument consultant on this task force and it was our job to study the B-29 gunfire system and to find out what was wrong. We went so far as to ultimately use these things ourselves to find out why they worked the way they did.

We were working out of Brownsville, Texas. The company had a flight test base at Brownsville, Texas, and we went down there and really put the old B-29 system through its paces. To make a long story short on that it was a good computer, there wasn't a thing wrong with it. It was well designed and the service people on the field were able to service it. There was a side blister and a side sight on the airplane. The GI gunner sitting in the side of that thing would get so scared of his life, he'd grab hold of the sight on that thing. Well, you'd sit there with your feet up like this, looking out at that blister and you got so tense on that thing, you could actually bow the skin of the airplane. He could throw it off a degree or so and a degree misses a little old pursuit plane coming at you. Almost any of us who were technically trained could take that in our fingertips and hit anything in the air with it. We never did get Boeing to put a strut through that thing to reinforce. At the end of the war there still wasn't a strut in that thing. Well, that was the B-29 gunfire system, which was a successful computer GE built, and they built a lot of them.

Now, this is something I've been trying to pin down -- did we get into this in World War I or World War II? This sort of pins it down. We weren't in World War One and we didn't have any computers to speak of then, but this is World War II stuff.

Q. You said this was an electro-mechanical device.

A. It had some electronics in it. Not too much. It was potentiometer cards, A. N. O. S. developed a means of winding signed and co-signed cards so that when you rotated them you got a signed function out, not a co-signed function. A very precise, elegant devise for making this kind of function generators so that you could solve the geometric equations, that are associated with ballistics and space. That was a very successful development on the company's part.

Well, following that comes some digital activities of the company. We begin to see the digital computer looming on the horizon as an aid to the numerical analyst. None of us, at that time, even envisioned this thing ever becoming a product of commerce. It was just an aid to the numerical analyst. We could see that his problem was so tremendous that he needed some tools to help him.

Q. Was that at the end of World War II?

A. Yeah, this was at the end of World War II when things got quieted down and people got back to thinking about these things and Dr. Aiken built his relay calculator at Harvard. And Williams had his machine running in England that we began to think about these things. Then, the thing that really brought it to a head was two gentlemen from the University of Pennsylvania, Mockly and Eckert, who developed and built the first Univac, which was an all tube device. This is what they really did -- they took some of the early writings of Vandage in England in 1850 who completely described an automatic computer. They took that plus what Dr. Aiken had done at Harvard with relays and combined it with vacuum tube technology, because vacuum tubes are reasonably efficient in their utilization of power. So here was an economical component that allowed them to implement what Vandage had described. The only reason that Vandage had never built this machine was because he had no device that was as economical of power as a vacuum tube. So here the vacuum tube allowed them to do this and so they built a vacuum tube Univac. And this was a big tube machine but it was an automatic machine, completely automatic, whereas Dr. Aiken's relay calculator was not completely automatic. Well, after they had built this, the University of Pennsylvania realized what they had and they ran a school, and we sent one of our people down to this. It was one of our men working for me by the name of Howard Clark who went down to this school, and for six weeks, I guess it was ten weeks. We learned all there was to learn about digital computers. When he came back, we said: "Now, what will we do with this?" Dave Prince was running General Engineering Lab at that time, he didn't really understand this thing too well, and wasn't convinced that you could build a computer that would do these kinds of things, so we took what Howard Clark had learned down there, and we built for Dave Prince, meaning myself, Ted Barry whom I mentioned before, Hans Keeney who was our boss, built a laboratory demonstrator of a digital computer and we demonstrated at that time all the functions of a digital computer on the laboratory bench. We were sort of saying, "This is something we think General Electric ought to be interested in."

Q. Do you know what year that was?

A. No, but I can look it up. I've got some notes here. We have just gone through all of this for the patent people, so if I guess at some dates here, and you want to use them, you ought to check with George Ukrow because I have given all the information I can possibly think of to George and he has documented many of these things I am mentioning here with dates because we are attempting to bolster our patent position. On some of IBM's patents, we can possibly prove we did some of these things before they patented them, so we're trying to tie all this stuff down. But that was about '48.

Well, we took a look at this computer business and went so far at that time as recommending to the vice president of engineering of GE, Harry Keeney, that General Electric get into the computer business. Harry had a meeting of his engineering advisory council, and they concerned themselves with the problem. Mr. Keeney spoke in behalf of the company's entering the computer business. In one or two sentences, the conclusion was that The General Electric Company would go into the computer business, to build digital computers for its own use or for the military, but not commercially. As a result of that, the electronics department in Syracuse undertook a contract for the air force at Wright Field, and built a machine that was at that time, and still is known as Orrac. Orrac stands for Office Research and Automatic Computer. It was a general purpose drum computer, had a 10,000 word drum, 10 decimal digit, sign coded in the 8421 code, Bruce sender address logic and it could run at about 100 instructions per second. Its input and output were magnetic tape, and the machine was built at about 1400 vacuum tubes, and about 7,000 germanium diodes in it. Drum speed was about 3600 RPM's, it took about 20 kilowatts to run it. It was a decimal machine. It could do an addition in 100 micro seconds, had about 50 plug-in circuits. It had a pretty good sized drum, about 30 inches long and about 22 inches in diameter. Syracuse had an awful lot of trouble with that thing. All these germanium diodes and we were new in the germanium diode business then. These things had a plastic covering on them and the plastic had a sawdust filler. The sawdust picked up moisture and they all went bad on them. I think they replaced all those diodes twice before they finally got that working. Charlie Wayne was primarily responsible for that work at Syracuse and he is still there working on military computers, that was delivered to Wright Field and is still operating there. I understand that within the last three years the Bureau of Standards has replaced the drum memory with a large core memory, but the machine is still running. Orrac said we could go into business for ourselves or for the military government.

We also built a digital computer for ourselves. This was the ANOS gang I'm speaking of, and George Hobbs was primarily responsible for this machine and it was known as Omnivac. And this was built on air force money and the machine stayed in General Electric for our own use and was scrapped about two years ago. This was a stored program calculator that was built in the period of '48 and '49. So that other date had to precede this a little bit, that other '48 date I gave you. Now, one of the outstanding things about Omnivac is that it is the first electronic machine that had floating point arithmetic in it.

Q. First that was ever built?

A. First that had floating point arithmetic in it.

This was a drum machine, we didn't have core memories then. The drum could hold about 1500 numbers, it was a 3 address machine, it required 12 operational forms to achieve its flexibility, its logic and its arithmetic units. It had over 3, 000 vacuum tubes in it. In today's way of thinking it was slow. It could do about 80 operations per second. But, even so, IBM's 650 that came out following that, when it was programmed for a floating point, was several times slower than that. That particular machine had teletype equipment for input and output. It was a purbinery machine. It one time solved a problem that took over 300 hours to solve. We had a great time with that machine. George Hobbs built it, as I said, and it was with air force money.

Let me tell you an interesting story about this. Before the air-force was invited out to see it, the man running it at that time said: "Gee, we ought to run it for a week so we can say it's really reliable. It ran for a week solving the same problem."

So the first night George let it run all night and when they came back the next morning, it had just turned out Gobbledy Gook all night long. Just hash. Well, of course, this upset everybody and they really decided to find out what was wrong. They hung all kinds of instruments on it the next night to see if the voltage went down at night and what the heck happened. They didn't find any great disturbances, but, boy, it turned out nonsense all night long. So they

they really had a high level meeting on that now to find out what was wrong with it. Finally they decided they needed somebody to stay there and keep an eye on it and see what was wrong with it. So they kept a man there with it the next night all night, and boy, it purred perfectly all night long. Didn't make a mistake. So, they said, "what the heck goes? Is this thing getting lonely or what?"

When they'd leave somebody there it would work, and when everybody went home, it wouldn't work. So they told this guy, "you stay there, but you go away periodically, and come back and see how it works." When he did this, it still turned out good numbers all night, solved problems in fine shape all night long. Well, this was a long story, really, and they had general engineering and everybody else in to try to find out what caused this computer to misbehave when nobody was there. Well, to make a long story short, we ultimately found out that the computer would not work in the dark. And to the day it was scrapped, it would not work in the dark. Now, at hind sight these things are always easy. We ultimately found out exactly why. That machine utilized Jordan Eckles flip-flop circuits. The original flip-flop circuit was known as the Jordan Eckles. This was the patent on the flip-flop circuit. It had tubes in it and it had little neon lights in the circuits. These little neon lights stuck out in the front panel. There was a whole pack of these neon lights on the front of that computer. And these lights were sensitive to ambient illumination. The ionization potential of them shifted a little from 90 volts with ambient light on them. So in the dark the ionization potential was one value, and when you turned on the lights, the ionization was another value. They never did change that. That computer would never work in the dark.

Q. Did it just happen to be that computer?

A. No, other people found out the same thing, many other people later found out the same thing. These neon lights were essential parts of the flip-flop circuit. Ultimately, they put a little dab of radium on the outside of those little neon bulbs so that the ionization potential was always kept where it was supposed to be.

I'm going to stay on the digital here a little bit. I think the next significant thing that happened in the digital field was Commonwealth-Edison in Chicago, a good General Electric customer, wanted GE to quote on a digital computer to do their billing operation. IBM had made them a proposal and they wondered why GE couldn't make them a proposal. Hans Keeney worked up a paper design of a digital computer for the billing operation of Commonwealth-Edison, and they costed it, and actually through many negotiations with Commonwealth-Edison, they had a quotation ready to give them. Hans Keeney is really the father of computers in GE and he has had something to do with every one I have mentioned inside of GE, all the way long. He was responsible for the AC network analyzer completely himself. He was responsible for the mechanical differential analyzer, he was responsible for that laboratory demonstrator unit, and he was responsible for this one I'm talking about now.

But they thought they better go see Mr. Gardner about this, and

Mr. Gardner said, "No, General Electric Company was not going to go into the digital computer business."

Well, this was about '52, I think. Almost 4 years following the decision that we would be only for the military and for our own use. Mr. Gardner said again we would not go into competition with IBM. At that time Mr. Gardner's philosophy was that we couldn't put all of our customers out of business. He was very definitely keeping us out of the material handling business because these were the people we were selling motors to and he didn't think we should go into the computer business because IBM was a good customer. That was really the second attempt on the part of Mr. Keeny to get the company into the mutual computer business.

I might add that he gave up at that point in this business. He just naturally gave up ... said it can't be done and they aren't going to make a go of this business. He then lost interest in the computer business as a real contributor himself. I was working for him at that time and he said, "Ken, if you are interested in computers, why don't you just take over this activity?" So this is where I came into the computer picture myself.

Digital computers seemed to be out. The only thing for General Electric, and the only thing that was being done, was all this activity at Syracuse and so we and the general engineering laboratory got ourselves back into the analog business. I sort of revised this analog business along with Reeves success of the Electronic Indirect Analog Machine and we undertook to build some rather complicated and new kind of analog computers. Four of them stand out in my mind. We built a simultaneous linear equation computer. It was designed specifically for solving 12 by 12 linear equations, after the type that are solved by the Petroleum Industry in their refining activities; 12 equations with 12 unknowns in it. It turns out that a digital computer to solve such a matrix when it is not fully founded (meaning when one of the diagonals is not on zero), a digital computer has a hard and slow time doing it. It looked like an analog computer could do it more rapidly, so we designed an analog computer for doing this. This was for the special products people at that time, and they did not see fit to market it. Nothing ever came of that, other than that we built one and made it work. I guess the most interesting thing about that, as I remember, was in attempting to make the laboratory unit work. The engineers worked many many nights and the situation became ultimately so severe that I decided I had better sit in on these night sessions to see if I could contribute something too. After sitting in two nights and watching their work, I concluded that there must be something wrong with the test problem that they had. This test problem had been obtained from the Petroleum Industry; somebody in the Petroleum Industry had given them this test problem, and there again to make a long story short, there was a mistake in the test problem. The poor guys had been just driving themselves nuts.

Well another analog computer we built about that time was one for the signal corps, known as the Q5. At that time, it was classified as secret. It was a very elegant electronic mechanical indirect analog computer for the signal corps, and we built two of these. The signal corps thought they were going to have a large requirement for these and the purposeof the computer was to take a small section of the trajectory of a low angle high velocity artillery shell, as contrasted to a mortar shell which has a high angle low velocity, as you catch a tract of it on a radar screen, and then compute the balistic course back to its source, so you knew exactly where the gun was sitting. We built two of these in General Engineering Lab and Thorn Mays here in the lab was instrumental in working on that. These were taken down to Fort Sill and put into field operation and were proven to be successful computers. They were designed for field use, sand, dust, hot, cold, wet, dry everything. One of the unique features of them is we had a high speed printer associated with it, built around a technique called Ferromagnetography invented again by Ted Berry and that was the first commercial application of Ferromagnetography as a number printing device, and it was a success application of it.

Now I remember the man's name that I was trying to think of; his name was Dr. Stivitz, at Burlington, Vermont, who claims he invented the digital computer, and so says in his book in a number of places; maybe he did.

We took a contract from the signal corps to build computers for solving meteorological equations. These centrally tracked radio sound balloons and received from the balloon various information pertaining to its altitude, humidity and temperature and from the tracking equipment, it's direction and elevation as we tracked it. From this you computed certain meteorological equations. We had a contract to do this analog computer and then we had a contract to do a digital one. The signal corps wanted to find out which would be the better machine for doing it. They ultimately concluded that the digital method was better for this purpose. However, we had spent much money under their contract in developing an analog computer. We ran into a snag in getting the company paying for this. The signal corps did not want to pay us for it after they found the digital method was better. This was the cause of a suit which I collected from the signal corps. It took us about 2 1/2 years to get paid for that computer. But they finally did, and this was how I came to know Dr. Stivitz pretty well. He was the expert hired by the signal corps to establish the fact that we hadn't contributed anything to this computer and many many many things. It was quite a technical court battle, and at that time, was the most technical complicated case that I know of, as we were in the area of attempting to convey to the lawyers and such, what a very complicated computer did plus the fact that we were off into the area of attempting to prove invention in mathematical sense. When a man puts two pieces of hardware together, and has a new gadget that you can see and is maybe made up of gears and switches the same as many other gadgets. You see it is a new thing, and you say "Yeah, he invented something". But now when you do this in a mathematical sense, we got into some great philosophical arguments of what is just an extension of a formula and what is real invention in the mathematical sense. Bill Hennig did a lot of analytical work on this formula. He was in on the court trials, and we had a great time. It cost the company a lot of money to collect that. But the signal corps had led us to believe that there would be a larger market for these things and that they would buy many many of these things, so the company had been wanting to put its money in it. When it became apparent the signal corps was not sincere, we had the problem of getting our money back. Ultimately, we won this.

As far as the computer is concerned, nothing is really unique about it other than we extended the analog art. With this indirect analog art we did things in this computer. Bill Hennig and Clare Baettig did some things in this computer that had never been done before and achieved accuracies far beyond what anybody had ever done in an indirect analog computer. None were ever built and none were ever delivered. This laboratory sample was the only one ever built.

Well, about the same time, still in the analog game, we were interested in taking on analog computers that we thought would extend the analog art and we built for the Adjutant General's Office of the U. S. Army, a Psychological Matrix Rotation Computer. This was the first time anyone had ever attempted to mechanize the mathematics known as multiple factor analysis invented by

Thurston of the University of Illinois many many years ago, and recognized as being a most useful mathematics by all people who work in advance psychology. But it was such a cumbersome mathematics, it was almost useless. The mathematics is particularly useful to a psychologist in formulating attribute tests, not in scoring them, after the tests are made, but in making them up. The answer to any one question can be interpreted as meaning many things. I mean if the fellow who answers it gives a half way decent answer, it may mean he can read English for instance, you may ask him a question about mechanisms that implies he understands mathematics. There is an inter-relation between all of the questions of a really well thought out psychological test with different weightings. It is this weighting of these various questions that is the complicated part of making up these tests. That is what this mathematics was capable of doing. Actually refining this to numbers so that you could deal with it. However, it would take about 14 calculators working about nine months to get the results. So this mathematics was almost useless. Well, here was an analog machine that was capable of doing this by turning a knob.

The intriguing thing about it was that we were building a device that worked in 12 dimensions and Mr. Jacoby was carrying the ball on this, and he and I had a great deal of fun exploring our ability to think in more than three dimensions, because we had at our fingertips a machine that could work in 12 dimensions. Now this really isn't as phenominal as it may seem. When you write a mathematical expression, expressing the flight of a vector in space, you write it in 3 dimensions. Mathematically speaking, there is nothing to keep you from going on writing more dimensions. But a 3 dimensional mind has trouble thinking of what these other dimensions are. So we had a great time attempting to test our own ability to think in more than 3 dimensions. This was a very successful analog computer. It was delivered to the Adjutant General's Office. Mr. Hiffy tore that machine down, stripped it and shipped it to the Adjutant General's Office, re-wired it and put it back together without ever one mis-connection in it. That man remembered every doggoned wire in that computer.

Was this Mr. Hiffy's Baby? No, this was Jacoby's baby, and Mr. Hiffy was working for Mr. Jacoby at that time.

This computer is still working in Washington and still used by the psychologists. They have been busy ever since, re-testing many of the cases that they had worked out by hand before. Previously, the mathematics had been too cumbersome for them to optimize. Then they made a couple of rotations and they said, "Oh well, that's about right", but now they could go back and really optimize things because they could check it back and forth. By turning a knob, you could turn this thing to a diagonal rotation. Look at the projection of these on another plane and you could do this 12 times.

That was supposed to put the right man in the right job in the Army?

Well, it was supposed to set up a test that would allow you to do this so that you didn't get wrong people in wrong slots. There was alot of interest in this at the time because so many of the men had just previously been in the war and had been in the wrong spots.

We had alot of Science fiction attached to this because of the 12 dimensional aspect of putting people in the right spots, but it really implemented mathematics alot. Now about the same time we built another analog computer. This was along about 1952, wasn't it? Yeah, 1952 or '53 we built that one. This computer was at that time the largest analog computer in the world. This one we could build digitally or analog-wise in a way, but was quite apparent that the analog computer was faster than the digital one at that time for this purpose. This one grew out of fear that we might get into a shooting war with Russia and the length of time it took to develop a new jet engine was just too long. It took the engine designer about two years to bring about a new engine and it took the control designer about two more years to get a control on it and to keep the engine from burning up or blowing itself to pieces by overspeeding. So there was a four year cycle and these people who were responsible for protecting the country said this was just too long; we will have to find some way to shorten this. So they came to us and asked us if there was any way out, of us building an engine simulator, a jet engine simulator that would allow you to set up the characteristics of a jet engine so the control engineer could go to work and develop the controls before he had the engine done. And this is what we did.

We built a jet eingine simulator that you could do this. You could simulate any jet engine you could conceive of and it would solve the thermo dynamic equations in real time. You see if the control engineer was to hook his controls to this to try them out, the computer had to solve this problem in the same period of time that the engine would actually do this. This was the intention that the control engineer could attach his controls to this computer.

Was this the first real time computer? No, not really, because your B-29 gun-fire computer was a real time computer. I can't say it was the first real large one. This computer was the largest one built at that time. And just let me say one more word about this.

It is hard to convey this, but think of a gas molecule going in the front of a jet engine and coming out of that. That is the length of time you must solve all these other dynamic equations. See? That's the length of time you have to solve it. You see, there was not just enough time for a digital computer to look anything up in a table. It had to be faster than that. You had to solve all the dynamic equations including the burners, the burning oil, the burning of fuel, the way the burners reacted plus the turbines plus the thrust, everything. All the contributions that were made in this was primarily in the nature of functioning generators with two independent variables. Nobody had ever built these high speed function generator with two independant variables. Meaning if you came in with a desired X and a desired Y, that you read out a desired Z off of a 3 dimensional map, so to speak. And we have, I think, 6 of these function generators with two independant variables on this which was really the table hook up. You see, the function generator is the storage element of an analog computer. You simply look up from an analog table. You don't look up from a table of numbers, you look it up from a map stored in space, technically speaking. This then cut the four year cycle of a jet engine down to two years, right.

Why, this was a big computer. It had 6000 vacuum tubes in it; 140,000 feet of wire; 1700 indicating lights on the front of it and 2750 dials. There were 8200 plug jacks on it; 300,000 soldered joints on it; and 100,000 solderless joints. It was a real monstrosity. It had 150 HP motor and 4 generators to develop 103 kilowatts.

That's a lot of electricity to run 30 to 50 average electrical kitchen ranges. It took us 85,310 man hours, that the equivalent of a 42 man year of work in that computer. There was approximately 8,350 hours of drafting, that's 2 1/2 man years in drafting, approximately 23 man years of engineering and about 16.3 man years of manufacturing in assembly. It was done over a period of about 2 1/2 years. Mr. Jacoby was the responsible engineer on that.

. . . .

Now this thing was moved to our Cincinnati G.E. plant at Evendale and installed down there and used by the control engineers and is still there. Well, let's see what have I missed? Sometime along in there, about '53 or '54 there were two other little analog computers built. One was built by the Denver Service Shop, a little portable d-c Network Analyzer that field engineers could use out in the field in solving some small distribution problems. They sold some of these. I don't know, I think they may have sold 15, or something like that.

Also along about 1955 a gentleman in Manufacturing Services, I don't remember his name, developed a new analog computer -- a portable one -- and the Instrument Department built some 20 or 25 of those and sold them and this computer allowed a tool engineer to set up and solve a little tool formula which allowed him to work his carbolide cutting tool to the optimum point so that he wasn't quite burning up all the carboloy and yet was getting all out of him that he could possibly get. It told him how much fresh power he could get thrown into this. It's a complicated formula that was more easily solved by this little computer which this gentleman built. It was a little portable computer. I don't know they may still be making a few of those -- I haven't heard of that one for a long time.

Who would be making them? Instrument Department had the responsibility for it.

Now let's see what I didn't mention. I forgot one completely. I forgot one analog computer we built and this one was known as a (what in the world did we call that one?) Penalty Factor Computer, and this was about 1953 and '54.

The a-c Network Analyzers that I mentioned before allowed the power engineer to solve most of his problems associated with electrical distribution systems but they didn't adequately take into account the losses associated with transmitting electricity around and large networks. I mean supposing you had a large network that covered a machine that was built for American Gas and Electric Company and their electrical network extends all the way from Buffalo to New York City and as far south as TVA, it ties into the TVA system. They cover all that area, Indiana, Ohio, Pennsylvania; all those electrical companies are tied together into the American Gas and Electric systems.

If you had a big load generated, let's say at Pittsburgh, then you say, well where should I get the power from to supply this load? It may be more economical to get the power from Buffalo than it would be from Philadelphia for instance, depending on the losses in the line. And so, some very excellent work was done by Gabriel Krone using his tenser analysis that completely put into mathematical form the loss coefficients that could be put together to stimulate the network on a loss coefficient basis to determine the relative losses that come from this. It's hard to explain the real problem because the load in electrical system really doesn't know where each particular electron comes from and doesn't care. An electron is an electron and so you think of the loads as being lumped loads coming from an infinite supply of electricity. The problem really hinges around that. It looks like the electricity comes from every place and it really comes from very definite generators. Anyway Gabriel Krone worked out all these mathematics. He was a mathematician. A very well known mathematician. This was so complicated that no one could understand it, and we couldn't deal with it very well. The American Gas and Electric Co. said "Gee this looks like a real useful thing to us. We will just have to do something about it." So a young fellow, just new with the company at that time, fresh out of school by the name of Kirkmeyer -- Dr. Kirkmeyer, worked very closely with Gabriel Krone over two years to where he ultimately understood this very well and he thought that by making some assumptions he could get this down to a level that we might build a computer around it. And he and Gabriel Krone ultimately evaluated the assumptions and proved that the assumptions did not distort the results enough to worry about, and so Dr. Kirkmeyer put this thing in a shape that we could build a computer and we built this Penalty Factor Computer for American Gas and Electric Company and installed it at their dispatching headquarters in Columbus, Ohio and they are still using this for dispatching their electricity, on this basis. From this grew two other things. From this grew the automatic load control work West Lynn is now doing, which is a partial take-off of this but doesn't completely encompass all of the loss coefficients, but does enough of the job to satisfy the controlling of the load by the power company. West Lynn builds this automatic (ads) Dispatching System they call it today. Automatic Dispatching systems are built around this and also our own economic dispatching system that we built and supplied to Niagara-Mohawk. It is a later version of this early Penalty Factor Computer.

We might mention the Productron which I think we skipped -- this is a job we did in the end of 1955 or 56 for the Manufacturing Services people -- worked up in mathematical form -- a mathematical way of expressing the work load on the production centers of the factory floor and automatically told the scheduling man how he should load his factory and where he should load it -- depending on the product mix that he wanted out of it. They thought there would be a larger fire mix with this -- in fact, they got all the manufacturing people together in the Company and they all said they wanted something so we designed one. This was the first product of the Computer Department and we ultimately designed one and it did the problem that it was supposed to do very well. It was a successful computer, but it turned out that these manufacturing people really weren't as serious as they thought they were earlier and they didn't buy very many. They turned this product off. Did we ever sell any outside the Company? I cannot answer that -- I don't know. I know we gave one to Arizona State University and we gave one to RPI. Now what else did I miss?

I think the thing that I may have slighted a little was Hans Keeney's role in this. He is really the father of computers in the General Electric Company and you ought to get him to sit down.... ....he is going to be out here once more, April 24 I think, then he will retire. You ought to get him to sit down and tell you some of these stories. He is really the father of computers in GIE and should be so recognized before he retires. Yes, that's what we ought to do. Have an interview with him and run a news article on it. Maybe we should have a retirement dinner for the Father of Computers. Really have some fun out of this. We could get some local coverage on this. "The Father of Computers in General Electric is retiring...Phoenix celebrates ...." When is he retiring? In June I think. He is either going to go work at Arizona State University or SRI after he retires. He has these two choices. We tried to get him here--I would like for him to go to work here so we could use him on a retainer basis here. He is Swiss -- he is in my estimation, the most outstanding engineer in General Electric. He is a Consultant today in General Engineering Laboratories. He is equally expert in any field, whether it be Thermo-dynamics or mathematics, electronics or mechanics. When I was in the engineering section, I felt the need of some monitoring, if you will, of ERMA programming, which was very critical here, and we wanted to give it every chance of success and this monitoring is a very critical -- a very touchy kind of a thing for a manager to approach because you don't want it to look like policing. Your professional technical people don't like to be policed. You try to monitor in a way that doesn't upset them. Mr. LaPierre and some of the executives of the Company feel that this monitoring technique is a very valuable technique. It is used only because managers can't put it into effect without antagonizing everybody. We very successfully did it here, on the 304 program, without antagonizing a soul.

I borrowed Mr. Kirkmeyer for 3 months. He was here for 3 months. In his own quiet gentle way looking over the 304 program and suggestint to the engineers where improvements could be made or where problems might reside, and he is always able to do it in a manner where they thought this of themselves. He is a consultant in every sense of the word. A true consultant. He cannot take credit himself for anything, or he would not be a consultant. Once he starts grabbing credit, nobody will go to his door anymore. And Mr. Kirkmeyer is sufficiently mature -- he can do this in a nice way and the engineers respect him. They know if they take their problem to him they will get an answer and he will not take credit for it. A large degree of success of the 304 program really belongs to Mr. Kirkmeyer -- so we have used him recently and that answers your question.

I tried to cover it up to the start of the Computer Department, really, because you can pick up the rest quite easily from there on. When did IBM get into the computer business? When did the computer business as such actually industry-wise begin? ... to when IBM stumbled into this whole thing. Absolutely stumbled into it. They had been in the mechanical calculator business -- they had picked up the punched card which was invented by H__________ in England, many years ago, and a number of English companies built machines using the ability to read holes in these cards. And, it was not actually new with H........ The technique of reading holes in cards was first used by J__________ in inventing his loom in France and I don't remember the date on that. But J__________ was ultimately stoned and killed, but he programmed a loom by having holes in metal plates originally and then H__________ picked up this idea as a means of controlling a computer.

Back to IBM. They were building mechanical bookkeeping machines really, around these principles. And they developed very excellent ones. In building some of these early computers, I talked about, I used to bum cards from IBM. In fact I used to have a bunch of junk around here -- an old type bar -- they had a very clever type bar that allowed you to do some real clever things. I would bum them off IBM and then we would build them in our computers to print out information. They were in this mechanical business and then as I mentioned before, Dr. Akin talked them into putting up the money to build this selective sequence relay calculator at Harvard, which was successful. Then they saw the value of that and they financed a second one in Poughkeepsie, and built an advanced related calculator. This happened at the same time Mackly and Eckert built their electronic one and IBM quickly saw the necessity of converting it to electronics which they did, and they started out with their relay and electronic machine. I don't remember the name or the number of the first one they had, but this was in 1950. They started bringing out the simple ones. Then, the Government went to them for further development work on a big computer they wanted. This was earlier than that, because they wanted this one for the 1950 census. They wanted to handle the census on some automatic equipment. It's not a hard calculating job so much as it is sorting and collating, but they wanted equipment to handle it and IBM got in on that and got a lot of money from the Government on that and they developed many other sorters and their card handlers. Jack ____________________ then at the Bureau of Standards did some very basic work for IBM and they developed some of these early machines. The early one that was really a success was the 650. This was the first automatic electronic computer with a drum in it and it had a table look-up feature that engineers just loved. Engineers used it for solving engineering problems and this thing was just a success a hundred times over anything IBM thought it would be. The second coup, really that they had was that the Government went tothem and asked them to build a higher speed version and a bigger version of the 650. And they did for a fact develop for the Government a machine that was known as the 700 or better known as the Defense Calculator. They didn't know what to do with this. They didn't know whether it would sell or not, so they went around to the industries and said if we can get 10 orders for this we can offer this commercially. They weren't going to do it unless they got 10 orders, and they spent almost a year and half canvassing industry trying to get 10 orders and they came to General Electric and said would General Electric buy one of these? This thing rattled around all through the General Electric Company and most of us couldn't justify it ourselves, in any given Department or group of departments could we see that they had justification for this. But Mr. LaPierre, who was then running the jet engine business at Evendale, had enough foresight to see that one of these would be useful to General Electric and said "yes, we'll take one." So Jim placed the order for a Defense Calculator which ultimately became the 701, which was converted into the 702 and this was the start. IBM got her order for 10 and so they decided to make it commercially. That was the start of their 700 line. Jim LaPierre ordered one of these from Evendale and Herb Grosch came along a little later and he was the guy who was given the job of operating it. Jim got him from IBM. He was an IBM man. Jim brought him to run the 701. Mackley and Eckert ultimately left the university and set up their own Company. The Mackley and Ecker Company to build UNIVACS. They started out building two machines, but didn't keep themselves up technically and they got off building UNIVACS with more and more tubes in them and they ultimately went broke as a company and Remington Rand bought them out.

What ever happened to ____________ there were attempts to make it practica ....(Refers to Mr. Barry - but dictation not clear) .... it is interesting how he came to invent this. We wanted to build a High Speed Printer that didn't have moving mechanical parts in it. We tried to do business with ____________ who had bought the patents on Zerography from Batel (?) Institute, and they were just so nasty patent-wise that we just couldn't see our way to do business with them. So, Mr. Barry just sat down and invented a magnetic version of the Electro Static Zerography Technique. So he said "let's see if we can reduce this to practice", and there were three attempts to do this. The first thing he built was for the Navy. He built a facsimile recorder, --that was built and delivered to the Navy -- that worked on the Ferril Magnatography principle. Then he built the two printers for the Q5 that I mentioned, and then they delivered the third one to somebody. There have been three delivered and they have been successful but not without problems. The remaining problem is the handling of dry powder. It necessitates the use of a dry power, as the fixative, As you well know, powder is attracted to the magnetic images and then is fixed there by heat so it is visible to the eye. Dry powder just doesn't handle worth a darn. You just stop and think a minute -- you have trouble thinking of many successful devices that do handle powders in them. Dry powders are affected by micro-statics that make them stick to moisture -- it makes them stick -- they get in bearings, they goof up bearings -- they are magnetic. Anything that is magnetized they stock to them. They are just a darn nuisance. The only zerography works is that to make zerography work they have to charge all their particles with the same charge, they are negatively charged, and then all being negatively charged they want to repel each other. So they all want to push each other away and they don't ever stick because of force. But nothing more has been done with thermo-magnetics. IBM started off in the digital business but they have built analog machines too. They had a Government contract and actually built a plant for building analog machines and they built quite a few analog machines. But, they never went into the analog commercially. They sold all their analog machines to the military. We never did much digital until we formed out own Department.

Interview recorded on March 25, 1960.

GENERAL ELECTRIC PRODUCTS

Background Of Product Developments Within G.E. Computer Department:

PRIOR TO 1963:

During the years prior to 1963, the Department was in the process of learning the computer business and developing its product offerings. During this period, two major computer systems were developed and successfully offered to the public. The first of these was the GE-210 System which was derived from the ERMA Bank of America system and was first shipped during September, 1960. The second major system offering was the GE-225 which was derived from the GE-312 Process Computer. First 225 shipments were in January, 1961.

During this period, there were a number of hardware false starts, including such processor programs as the 250 and Y Systems and such peripheral programs as the re-entry printer and the full field proof encoder. Two peripheral developments were initiated, however, which have led to marketable products. Both of these products--the GE High Speed Card Reader and the GE-MICR Document Handler--are currently being utilized in system configurations.

The Department initiated a development program in the data communications area as a product "special" for the Apparatus Sales - Finance and Services Operation. Also initiated during this period were a number of technology developments, including such programs as cryogenics, optical character recognition and thermo-plastic recording.

PERIOD 1963/1964:

The period 1963-1964 has been, and will continue to be, marked by increasing acceptance of General Electric computer products. The system product offering has been considerably enlarged over that of preceding years. These new offerings are built around the program compatible family concept which has gained industry acceptance as the method of providing system growth capabilities. The first line offering was provided by expanding the basic GE-225 into a smaller GE-215 and a larger GE-235--these three systems are called the Compatibles-200. Announced during late 1963 was a new program compatible family known as the Compatibles-400, which currently consists of five (5) members: the GE-415/425/435/455/465. Early 1964 has seen the active selling of still another line of systems known as the Compatibles-600, currently consisting of a GE-625 and a GE-635. Selling strategies for these new systems are being aimed at the direct access environment and will include such equipment as communications processors/controllers, mass random access memories and remote terminal devices.

This period has also seen additional expansion of GE in-house manufactured peripherals. Both magnetic tape and random access file subsystems are currently being built in-house. Manufacturing rights for both mechanical subsystems have been purchased from vendors.

PERIOD 1965 AND BEYOND:

The Department's product offering will continue to increase significantly during the coming years with the ever increasing demands of the direct access oriented systems. A full range of mass random access storage devices, industry oriented remote terminals and data communications capabilities are basic requirements.

In-house development and manufacture of various peripheral subsystems will continue to expand as purchased mechanisms are phased out of the Department's peripherals. An in-house ~~printer development~~ [mfg printer] ~~program~~ is currently scheduled for early 1966.

The Department's technology developments ~~will~~ [should] pay off during the late 1960's with the planned introduction of a new line of systems employing cryogenics and large thin film memories. Various advanced peripheral programs currently directed toward media handling mechanisms, optical character recognition, etc., will provide improved peripheral capabilities for these new systems.

RJH/js
4/16/64

GENERAL ELECTRIC PRODUCT ~~REVIEW~~ Summary

Today's computer system offering is characterized by batch processing systems, incorporating a basic central processor, and basic peripherals such as card and paper tape, document handlers, printers, and magnetic tapes. Tomorrow's offering will be characterized by direct access and real-time systems, incorporating data communications processors/controllers, mass random access storage, and remote peripherals. Both of these environments strongly affect the computer products marketed by General Electric as well as those marketed by competition, and consequently, produces significant competitive product interactions in the market place. The impact of recent competitive product announcements is described on page __________. This section of the report is primarily devoted to General Electric products ---- their strengths, weaknesses, and futures.

200- Line:

The 200-line consists of four (4) basic system/processor offerings. Three (3) of these systems - the 215, 225, and 235 - comprise the system family called the Compatibles-200. The fourth - the 210 - although classified as a member of the 200-line actually bears no internal resemblance to the 225 oriented series and, hence, is not compatible with the other members of the line. Compatibles - 200 systems are being sold in the scientific and manufacturing markets. The GE-210, although no longer an active seller, was directed at the banking market. The following chart provides date of first ship, typical system lease price, typical purchase price, and performance indexes for 200-line systems:

	1st Ship	Lease Price	Purchase Price	Performance Index Business	Performance Index Scientific
GE-210	Sept.,1960	$15,000	$740 K	14	-
GE-215	Nov.,1963	9,200	467 K	7	3
GE-225	Jan.,1961	10,800	474 K	13	4
GE-235	Apr., 1964	12,500	530 K	38	20

The performance indexes shown above portray the relative internal processor performance of each member of the line as obtained by analyzing and timing typical business and scientific problems. The business and scientific indexes were derived independently and should not be correlated. A high index signifies a high internal processor performance in the given applicational area.

Line Strengths:

- ERMA (Bank of America) development leading to GE-210 banking offering.
- Compatibles - 200 offering (GE-215/225/235) for manufacturing and scientific users
  - Extensive department software library and applications packages
  - Active user organization - GET

- Family growth concept
- Data communications capability available
- Early system availability

Line Weaknesses:

- GE-215 system stripped to the point of not being an attractive offering to the data processing user.
- Software offering for minimal systems not attractive to business user.
- No competition for IBM 1440 and Burroughs 200 system when competing for smaller bank customers.
- Lack software/peripherals on Datanet-30
- Numerous other peripheral shortcomings (see peripheral comments in this section).

Line Futures:

- Price reduce the GE-215 to provide attractive small scientific system.
- Small system may be implemented as part of cost improvement technologies, new product line, extensions to current lines, or use of returned equipment.
- Continue to sell Compatibles-200 systems in manufacturing and scientific markets.
- Sell data communications capability - include basic software/ peripherals on DN-30.
- Emphasize cost improvements.

400-Line:

The recently announced 400-Line currently consists of five (5) basic system/processor offerings - the GE-415/425/435/455/465. This series also is program compatible and, hence, is called the Compatibles-400. The line is primarily oriented to the business data processing market, although the two higher members, the 455 and 465, also provide very competitive scientific capabilities. The following chart provides the date of first ship, typical system lease price, typical system purchase price, and performance indexes for 400-Line systems:

		Lease	Purchase	Performance Index	
	1st Ship	Price	Price	Business	Scientific
GE-415	June, 1964	$9,100	$424 K	34	-
GE-425	June, 1964	10,300	462 K	62	-
GE-435	Jan., 1965	13,000	578 K	109	-
GE-455*	July, 1965	20,000	890 K	196	87
GE-465*	March,1966	26,000	1,185 K	255	92

* Preliminary pricing only.

The performance indexes shown above portray the relative internal processor performance of each member of the line as obtained by analyzing and timing typical business and scientific problems. The business and scientific indexes were derived independently and should not be ~~correlated~~. A high index signifies a high internal processor performance in the given applicational area.

Line Strengths:

- Compatibles-400 offering (GE-415/425/435/455/465) for business users.
- GE-455/465 are designed to serve both business and scientific users.
- IBM 1401 Simulator package with 400-Line systems.
- Competitive price/performance characteristics.

- Family growth concept
- Data communications capability available
- Early system availability (GE-415/425)
- Thin film (advanced technology) being employed in GE-455/465.

Line Weaknesses:

- Late availability of certain 400-Line software offerings - COBOL, random access oriented software, etc.
- Lack certain required direct access oriented system features.
- Lack software/peripherals on Datanet-30
- GE-415/425/435 systems lack scientific capabilities.
- Numerous peripheral shortcomings (see peripheral comments in this section).

Line Futures:

- Continue to sell Compatibles-400 systems in business market.
- Sell growth potential of 400-Line equipment/configurations.
- Promote/extend Capacitrix Simulators.
- Increase system capabilities by broadening peripheral offering (see comments this section).
- Sell total systems competence in direct access market.
- Provide increased data communications hardware capabilities - controllers/remotes, etc.
- Emphasize cost improvements.

600 LINE:

The 600-line of systems currently consisting of the GE-625 and the 635 are actively being sold by the Computer Department's Headquarters marketing organization. The Compatibles-600, as the line is called, is the Department's first offering in the large scale computer market. By application, the 600 systems are very capable performers in the business, scientific and direct access environments. The line's software offering is taking full advantage of the programming talent within the General Electric Company - currently five different departments are participating in the development of program packages for this system. The following chart provides the date of first ship, typical system lease price, typical system purchase price, and performance indexes for 600-line systems.

	1st Ship	Lease Price	Purchase Price	Performance Index Business	Performance Index Scientific
GE-625*	April, 1965	$50,000	$2.3M	285	173
GE-635*	April, 1965	56,000	$2.5M	385	214

*Preliminary Pricing Only

The performance indexes shown above portray the relative internal processor performances of each member of the line as obtained by analyzing and timing typical business and scientific problems. The business and scientific indexes were derived independently and should not be ~~correlated~~ compared. A high index signifies a high internal processor performance in the given applicational area.

LINE STRENGTHS:

- GE-600 line provides a highly competitive offering for the large scale market.
- Fully integrated software offering
- The system is drum/disc oriented
- Compares very favorably in performance with present-day offerings
- User image
- Compatibility with military systems

LINE WEAKNESSES:

- Limited peripheral capabilities, especially random access storage
- Limited data communications offering - DN-30 is not fast enough
- Late entrance into the large scale market

LINE FUTURES:

- Sell G.E. competence and user image
- Sell total systems competence in direct access market.
- Increase system capabilities by increasing and broadening peripheral capabilities
- Provide increased data communications capabilities, controllers, remotes, etc.
- Emphasize cost improvements

Peripherals:

The following chart is presented to summarize General Electric's competitive position in the peripheral business. Peripheral categories are shown along the right vertical and the major system competitors along the top of the matrix. Within the matrix, lack of an offering is indicated by a 'Blank'; an offering with a purchased mechanism is indicated by a 'B'; and an offering built entirely in-house is indicated by a 'M'. Note, where General Electric currently has no product offering and also the great dependency on vendor mechanisms.

PRODUCT SPAN - PERIPHERALS

		COMPETITION							GE	
		IBM	SR	CDC	RCA	MH	NCR	BURR	1963	1964/5
MAGNETIC TAPE	LOW SPEED	M	M			M		M		M
	MED SPEED	M	M	M	M	M	B	M	B	M
	HIGH SPEED	M	M	M	M	M				M
MASS RANDOM ACCESS STORAGE	FAST ACCESS & LOW CAP.	M	M	B		B		M		M
	MED ACCESS & MED CAP	M	M	B	B	B	M	M	M?	M
	SLOW ACCESS & LARGE CAP	M		B	M	B				B?
	REMOVABLE	M					M			M
PRINTERS	LOW SP.	M	M	M					B	B
	MED SP	M	M				M	M		
	HIGH SP.	M		B/M	B	M			B	B
CARD READERS	LOW SP.	M	M	B	B	B	B	M	B	M
	HIGH SP.	M	M	M	B	B	M	M	M	M
CARD PUNCHES	LOW SP	M	M	B/M	B		B	B	B	B
	HIGH SP.	M	M	B/M	B	B	[illegible]	B	B	B
SORTERS	MICR	M	M				B	M	M	M
	OCR	M	B	M?	M	M	M		B	B
REMOTES	DATA COLLECTION	M		M	M				M	M
	KEYBOARD TERMINAL	B/M	B/M	B	B	B/M	B	B	B	B
	M-COUNT	13	13	9	5	6	5	8	4	9
	B-COUNT	1	2	5	7	7	6	3	8	8

M - MAKE
B - BUY

1965

Peripheral Strengths:

- High speed card readers, MICR document handlers, and random access disc files are currently being manufactured in-house.
- In-house programs are currently underway for additional random access storage devices, remote peripheral devices, and magnetic tape subsystems.

Peripheral Weaknesses:

- Current peripheral shortcomings:
  - . Dependence on vendors for most peripheral mechanisms.
  - . Lack of features/performance to compete with IBM's leadership offerings.
  - . Voids in peripheral offerings - (aggravated by IBM's System/360 announcement).
    - .. Removable Media Random Access Storage.
    - .. Large Capacity Random Access Storage.
    - .. High Speed Card Punch
    - .. Optical Character Recognition
  - . Marginal design of GE High Speed Card Reader and MICR Document Handler.
  - . No low cost/performance peripheral offerings to compete at low end of system spectrum.
  - . Very limited offering in remote type devices.

RJH/fls
4/16/64

Peripheral Futures:

- Provide low cost/performance peripherals for the data processing offering via TRIAD project; i.e., low cost card reader, punch, printer mechanisms.
- Offer same function through remote TRIAD (card/printer) terminal to large decentralized users, as an IPB service to small customers.
- Continue to emphasize the development and manufacture of in-house peripheral mechanisms.
    - . Random access storage devices - Disc and STRAM offerings under development.
    - . Printers - In-house ~~program~~ mfg ~~to start~~ in ~~1965~~ 1966.
    - . Card/document handling equipment - Media handling technologies under development.
    - . Magnetic tape subsystems - Two independent programs in progress.
    - . Remote terminal devices - Market studies currently being performed to define requirements in this area.
- Improve reliability of peripheral mechanisms by increasing in-house control of mechanism design, etc.
- Emphasis on cost and value control.

REVISED DRAFT

DEPARTMENT HISTORY

The Computer Department was formed as a Section of the Technical Products Department in February 1956 - primarily to perform the work required under contract with Bank of America to design, develop, and manufacture a computer system for demand deposit accounting. Because facilities were unavailable at Electronics Park, the Section was housed initially in temporary facilities at ~~Ithaca~~ Schenectady, and Syracuse, New York, and Menlo Park, California. The study to determine a permanent location was completed in August 1956 with the selection of Phoenix. During the latter part of 1956 and early 1957, the bulk of the operation was moved to Phoenix and housed in leased facilities.

The Bank of America contract commitments were met by the design and manufacture of the GE-100, called ERMA, system. This transistorized system incorporated the first use of magnetic ink character recognition, which is now standard in the U.S. Banking Industry, as a means of document reading. Thirty GE-100 systems were delivered to the Bank of America and still remain in service today.

In 1957, the Department undertook a contract with the National Cash Register Company covering the design and manufacture of what was then a relatively large computer, the NCR 304. These computers were sold to NCR for ultimate resale to end users. Production on this contract was completed in 1962 with the shipment of the 26th system.

On the basis of these two contracts and technologies derived from process computer developments, a completely new General Electric business was launched which has afforded the Company opportunity to participate as a major manufacturer in the data processing business.

The early years of Department growth were marked by the trials of learning the computer business, building headquarters and field organizations, and developing new products. This period saw the direction of a major portion of Department effort and resources to the "specialized" Bank of America and NCR contracts. Building on this product background, two major system offerings followed. The GE 210, a more powerful system which was derived from the Bank of America GE 100 and designed for banking application, was developed with the first shipment taking place in 1960. However, it was not until 1961 that the application of process computer technologies, the GE 312 system, culminated in the development and shipment of the Department's first general purpose GE-225 system. The GE 225 provided the necessary product offering to significantly broaden market participation. Inexperience and inadequate knowledge led to numerous false starts and costly product failures in both processor and peripheral areas. However, the GE 210 and GE 225 systems, with the announcement of the data communication line in 1963, have provided a sound product base for growth. The history of product activity is shown by the following summary of system shipments:

	System Shipments							
Products	1958	1959	1960	1961	1962	1963	Budget 1964	Total
GE 100	1	5	17	7	-	-	-	30
GE 210	-	-	3	9	15	14	3	44
GE 215-225	-	-	-	28	69	71	85	253
GE 235	-	-	-	-	-	-	17	17
GE 304	-	-	2	1	-	-	-	3
NCR 304	-	3	9	12	2	-	-	26
GE 400	-	-	-	-	-	-	15	15
Datanet 30	-	-	-	-	-	1	23	24
	1	8	31	57	86	86	143	412

Although the explosive formative period of market growth found the Computer Department a late entrant with limited offerings, the Department has enjoyed rapid growth since its beginning. Sales billed increased from $7.3 million in 1958 to $41.4 million in 1963 with shipments in 1963 equivalent to $62.3 million expressed in terms of shipments at outright selling price.

Profitability for the period 1958-1963 was subject to two major negative influences. First, the heavy costs of entering a new business and acquiring the necessary resources and knowledge contributed to substantial losses. Second, the transition from a sale to a growth lease business in the early 1960's produced the anticipated effect on profit - deferral of income.

The Department devoted a significant portion of its effort and resources, during these years, to the timely placement of essential professional and technical talents. This group of personnel comprised a large portion of the Department's 4600 employees in place at the end of 1963. The facilities were expanded to meet productive and personnel requirements and included 418,120 feet of owned and leased space at the end of 1963.

The above highlights of Department growth indicate the path toward achieving the Department goals of continued growth with profit. Additional details of performance have been included in the appropriate sections of the Business Plan.

Budgets & Measurements
April 15, 1964

COMPUTER DEPARTMENT HISTORY

February 1956 - March 1959

INTRODUCTION

The wheels of fortune always grind slowly but surely for all men, and so it was with General Electric's slow but wise entry into the computer business. Even though General Electric had been producing specialized computers for their own use, it was not until early 1956 that the Company decided to enter the competitive computer market.

Actually, General Electric may have been a pioneer in the computer field and may have developed the first practical computer when the d-c calculating board was produced at the close of World War I. This device, designed to simulate short-circuit conditions in network power systems, was used until 1923 when the 60 cycle a-c network analyzer was developed in cooperation with The Massachusetts Institute of Technology.

In the ensuing years the Electronics Laboratory and General Engineering Laboratory created an impressive series of digital and analog units. These equipments resulted from specific customer needs and were well known in their special fields of application. In addition to the activities at the General Engineering and Electronics Laboratories, KNOLLS Research Laboratory worked on programs for more than ten years in conjunction with the Electronics Laboratory to evolve solid state devices, magnetic techniques, high-vacuum technology, and computer circuitry which could be adopted for use with the most advanced computer concepts.

Thus, by forming a Computer Department, a separate group was established within General Electric and was given the responsibility of research, design and development for every phase of the computer art.

With its purpose so designated, the Department became dedicated to the creation of advanced products based upon careful study and analysis of overall customer needs. The basic aim of building equipment custom-designed to fulfill these needs enables the customers - industry, science, government and commerce - to maintain their own operations and procedures utilizing the most advanced data processing and computing systems.

"General Electric has actively entered the industrial computer field with the establishment of an Industrial Computer Section at Electronics Park", was the announcement which appeared in the February 1956 issue of The MONOGRAM, the General Electric intra-company magazine. Thus, the Computer Department had its beginning as a Section of the Technical Products Department, Electronics Division.

The establishment of a Computer Section not only enlarged the Company's activity scopes in the fields of specialized engineering and military computers but it also consolidated the formerly widespread activities. Prior to the official formation of a Computer Section, General Electric had developed specialized computers for its own needs within the Company in addition to one produced for the Air Force and another for the Department of Defense.

In May 1956 The MONOGRAM carried the story of the 40 million dollar Bank of America contract for the ERMA systems. This contract was the largest single order ever placed in the electronic data-processing industry. General Electric's Electronics Division and the world's largest bank, the Bank of America, had reached an agreement for the refinement and manufacture of giant electronic computers known as ERMA - Electronic Recording Machine Accounting. Since the Industrial

Computer Section was designated to manufacture the ERMA equipment, the Computer Laboratory was established at Menlo Park, California in May 1956.

ERMA originally was initiated for the Bank of America at Stanford Research Institute, Menlo Park, in 1950. Over a period of five years a prototype model was built containing 8200 vacuum tubes, 34,000 diodes, and nearly 200 miles of wire. This machine covered an area of 4100 square feet.

General Electric's ERMA was to be similar in many respects to the prototype model, but the agreement specified many "radical changes" including the use of transistors wherever practical.

Since ERMA was the most advanced data-processing and paper-handling equipment of its type, each system was designed to perform from a central location the daily accounting tasks for 55,000 commercial checking accounts - these tasks included sorting checks and deposit slips; entering amounts to individual accounts; maintaining correct balances, including the deduction of service charges; accepting stop-payment orders; giving notice of an overdrawn balance; and producing a complete monthly statement of each account.

One of the major technical advances resulting from ERMA research and development was magnetic character reading.

Other technical advances included the incorporation of peripheral equipment such as, electronic check sorters and high-speed printing devices.

Considering the events which had transpired since February 1956, it was only apropos that the Arizona REPUBLIC in its November 2, 1956 edition announce with a banner headline...... G.E. WILL COME TO PHOENIX".....confirming the establishment of the Computer Department's administrative, engineering and research facilities in the Valley of the Sun.

Department operation was scheduled to get under way by December 1 with H. R. Oldfield, Jr. as General Manager; K. R. Geiser, Manager-Engineering; Dr. H. R. Grosch, Manager-Computer Applications; K. L. McCombs, Manager-Finance; R. J. Barclay, Manager-Manufacturing; C. C. Lasher, Manager-Marketing; and A. G. Newman, Manager-Employee and Community Relations. In addition to this top management team, key engineering and management personnel from Schenectady and Syracuse were brought to Phoenix to form the nucleus of the Department staff.

After selecting Phoenix for Department headquarters, General Electric officials advised that the Computer Department would develop a line of computers designed for business, industrial, and military applications. With the paramount goal of producing "tailor-made" computer systems for customers, the first effort along these lines was the fulfillment of the 40 million dollar ERMA systems contract. The ERMA contract was the initial order which necessitated the establishment of the Computer Laboratory in Menlo Park; and even though the Department home site was Phoenix, the Computer Laboratory was retained because of its proximity to the bank headquarters in San Francisco.

Phoenix was chosen as the "home office" for a number of reasons. Strongest among these factors was the good business climate and the liveability of the Phoenix area. General Electric also wanted the support of a strong college or university which was available in Tempe at Arizona State College.

C. C. Walker, General Electric Commercial Vice-President, explained why General Electric wanted that "intangible thing" called university atmosphere near a facility such as the Computer Department. General Electric wanted the support of a strong college: (1) to encourage students in the pursuit of an engineering profession; (2) to have a convenient means of giving advanced academic training to Company employees; (3) to foster the work of a strong university faculty and General Electric teams on research of mutual interest; and,

(4) to simplify the recruiting of better engineers. In turn, General Electric would aid the college in attracting more competent professors; encourage enrollment of higher quality graduate students; offer part-time faculty members from the Company staff; and make available specialized equipment and facilities to students and staff members.

Arrangements had been made to "house" temporarily all personnel in the First National Bank Building of Phoenix. However, 14,000 square feet of office space was leased in the KTAR building, and personnel were moved into this facility in January 1957. At this time, plans were made known for building a permanent plant in Deer Valley Park.

In accordance with established Company policies to aid educational institutions with part-time faculty members, Daniel McCracken, a mathematician and manager of the computer programming training, began the first digital programming class at Arizona State in February.

In order to provide the Department with a manufacturing facility, a new building comprising 20,000 square feet was leased in Phoenix early in February of the same year. Construction of the building was scheduled for completion by May 1 at a cost exceeding $100,000.

To add further to the list of Department accomplishments during the first months as an entity, an IBM 704 computer valued in excess of 1 million dollars was installed at Arizona State for joint General Electric-Arizona State research use. In February 1957, the 704 was the largest computer in existence. Arizona State was the first academic institution in the world to install equipment of this type. The memory of the 704 was larger and the speed of the machine faster than any other computer installed and/or in use at any other university in the world.

March 1957 marked another milestone in Department history when the General Electric Company "rang up another first" with Stanley C. Allyn, National Cash Register President, announcing the Computer Department would produce a new electronic computer for NCR which would be known as the 304. The 304, an all transistorized computer, was designed for business data-handling operations. The department was to be responsible for production engineering and manufacturing major electronic equipments, and responsibility for the system's electro-mechanical peripheral equipments was assumed by NCR.

In commenting on the contract, President Allyn stated, "General Electric brings into this project its great knowledge in the design and manufacture of electronic equipment of virtually all types." The new system, which performs automatic accounting, auditing, reporting, and other record-keeping functions - all in one continuous high-speed operation, is a product of General Electric research and development work and is giving the computer industry what is expected to be its first all-transistorized data-processing machine. The 304 using General Electric developed transistorized circuitry is smaller in size, has greater reliability, uses a fraction of the power, and has none of the heat problems inherent in vacuum-tube equipped computers built to date. "This business records-handling device could make possible 'the most sweeping changes in office routine since the advent of the typewriter and the adding machine,' " said the NCR president.

With the number of Department employees at slightly over 300, the Department formally opened the Computer Center on the campus of Arizona State late in March. At this same time, the Phoenix portion of the Engineering Section moved into a portion of the school's new technology and industry building. The new block-long structure also houses the Computer Center. When the 704 was installed earlier this year, it fulfilled two important purposes: (1) to serve as an academic tool in Arizona State's digital programming course and in the Company's own computer training program; and (2) to serve as a problem solver in important research and development work on the computers of the future. The operating costs of the Center are shared by the Company and the college.

In conjunction with Company practices of granting scholarships, Computer Department grants totaling $4,000 were to be awarded engineering students attending Arizona State College and the University of Arizona.

Completed ahead of schedule, the Peoria Avenue Plant was occupied May 20. This leased facility added 5,530 square feet of additional office space and provided 14,470 square feet for a manufacturing area.

In late June, the Computer Laboratory moved from its temporary headquarters in Menlo Park to a new facility at 951 Commercial Street in Palo Alto. The new building provided 10,000 square feet of space, a two-thirds increase over the Menlo Park Laboratory which had been used since May 1956. At the time of the move to Palo Alto, the Laboratory employed 80 people including engineering, drafting, manufacturing, and marketing personnel. Even though Stanford Research Institute had developed many of the basic techniques for the ERMA Systems, General Electric had to perfect these techniques and develop additional skills to produce ERMA. Therefore, with a capital investment in the laboratory facility of $100,000, top personnel in their respective fields were placed in managerial positions. Dr. Robert R. Johnson was Manager of the Computer Laboratory operations.

By July the Department had 450 employees including 80 in Palo Alto and 45 at the new Peoria Avenue manufacturing plant. Another Department "first" was accomplished July 24 when the first Arizona made General Electric product "rolled off the line" at the Peoria Plant. The first computer to be manufactured by the Department was the Productron, a desk-size analog computer for solving day-to-day business problems.

Refusing to be overshadowed by the first Arizona computer "rolling off the line", the manager of computer programming training wrote the first book on the general subject of digital computer programming ever to "roll off the press". Daniel McCracken, author of DIGITAL COMPUTER PROGRAMMING, described his book as an introduction to the entire programming field - "telling the computer how to solve particular problems". The book has been selected as the text for the course on this subject which Mr. McCracken taught at Arizona State.

Meanwhile, Arizona State had been taking great strides to foster the growth of their engineering school, and it was in August that General Electric joined with other electronics firms of the Valley to participate in the scholarship program for engineering students at the college.

At the end of August employment had reached 500 and according to Valley newspapers the Computer Department had "moved into the circle of big business".

Two major contracts were received in mid-September. One contract amounted to $400,000 from the Company's own Heavy Military Electronic Equipment Division in Syracuse for computer applications services. The other, a $230,000 contract, was awarded by the Air Force to produce an Electronic Heat Rate Computer for Wright Air Development Center at Dayton, Ohio.

Eleven months following the announcement that Phoenix would be headquarters for the Computer Department, the decision was made to build the permanent plant at Deer Valley Park on a 160-acre site near the intersection of Black Canyon Highway and Thunderbird Road.

Up to this time, Computer Laboratory personnel in Palo Alto had been members of the Engineering Section. However, since the Laboratory group was concerned primarily with the Bank of America contract, the Palo Alto facility was separated from the Engineering Section and made an independent engineering-laboratory operation within the Department.

Early October brought another major contract to the Department. At the Army Ballistic Missile Agency, on Redstone Arsenal in Huntsville, Alabama, the Department contracted to perform the complete task of administration, operation, and programming for the digital portions of the Computations Laboratory. Under the $1.5 million annual contract, the Huntsville Computer Center became a subsection of the Scientific Applications Section at the Tempe Computer Center. Dr. H. M. Sassenfeld was appointed manager of the Huntsville operation. Even though the majority of the work was to be done at Huntsville, some portion was to be allocated to the Tempe installation.

In conjunction with Department growth (size and business), a decision was made to expand the Peoria Avenue Plant with an addition of 30,000 square feet at a cost of $225,000.

Slightly more than a year after the Department's formation, ERMA took a long trip and typical of a "woman" it took four vans to move her. The original ERMA computer, which had been developed and built by Stanford Research Institute, was brought to Phoenix so that a portion of the equipment might be given to Arizona State and the remainder used by the Department. Valued at $500,000, the prototype model was the first electronic bookkeeper designed specifically to handle checking-account bookkeeping. A Phoenix newspaper reported that this gift to the college was an excellent example of how teamwork between industry and education creates benefits throughout the community.

One week after the "original" ERMA arrived in Phoenix, the first completed part of one of the series of ERMA systems was shipped from Phoenix to San Jose.

With the Department beginning its second year, the Phoenix city planning committee approved garden type industrial zoning for the Deer Valley Plant early in December.

In March 1958 bids were solicited for the construction of the new Deer Valley Park Plant. April 28 the contract was awarded, and construction was scheduled to begin in May for the main building of the proposed three million dollar plant.

Operation Upturn was officially launched in the Department with ground-breaking ceremonies for the new plant. General Manager Oldfield manned the controls of a giant steam shovel, bearing an Operation Upturn symbol, to scoop away the first load of dirt.

The June 1958 issue of The MONOGRAM carried the story of a second Department gift to Arizona State. This contribution was a special purpose analog computer designed to solve practical laboratory problems.

August 1958 brought the first "plant shutdown" for employee vacations.

The middle of September a $1,700,000 renewal contract was granted by the Army for the Huntsville operation of the digital computing facility. Because of the nature and importance of this installation, the most modern equipment and facilities were procured for its activities. In addition to the extensive facilities and equipment utilized by the computations laboratory, the professional personnel from the Computer Department provided the competence to analyze needs, to design equipment and to produce the most efficient systems to meet the most exacting and complex military requirements. Thus, the computational contract between the Army and the Department did not hinge on General Electric equipment, but on the personnel provided who possessed the "know-how" to operate the facility.

Paramount interest was centered around the Department's "Think Business" or Operations Analysis subsection with the appointment of Dr. L. E. Saline as Manager for the group and additional placement of personnel in its two locations -

Washington, D. C. and Phoenix. Even though the group had been formed nearly eight months prior to this time, it was not until late July that a major contract from the Air Force was awarded. Thus, at this time the Department wished to promote Operations Analysis as its medium for defining and developing man-machine systems.

By October, the Department had greeted its 1000th employee, and according to the newspaper's standards General Electric in Phoenix had progressed to the status of even "bigger business".

In the interim, construction was on schedule for the new plant, contracts had been secured by Marketing for many varied computer systems, and Department-wise new techniques were being developed within the Engineering Section and Manufacturing processes and methods were being improved each day.....all reflecting the rapid growth of the Computer Department.

Shortly before the Department's second anniversary, arrangements were completed to transfer the Operations Analysis personnel in Washington, D. C. to their new home in Arlington, Virginia.

The move to the new Deer Valley Plant (more commonly known as the long, hard trek) began in mid-December with Engineering and Finance personnel being the first to occupy the building.

With the New Year came a new Engineering Section mode of operation. This rearrangement of the Engineering-Manufacturing relationship made it possible for the Engineering Section to become a product-line-oriented project-organized group in a more advantageous position to meet the competitive computer market.

Simultaneous with the Engineering Section reorganization was the activation of the Advanced Development Subsection as a proving ground for new technology applicable to Department products.

Shortly after the move to Deer Valley was completed, construction began on an adjoining 86,400 square foot manufacturing area.

On February 25, 1959, Arizona's Governor Paul Fannin cut the aluminum ribbon across the main entrance to Deer Valley Park officially dedicating the new building. In his ceremonial speech, Governor Fannin expressed his appreciation to General Electric for providing Arizona with a manufacturing industry and a great plant, and in closing he added that General Electric people are the type of people Arizona welcomes to their community.

To add further to our accomplishments, the Merchandise National Bank of Chicago placed an order for a computer designed for banking automation systems.

With the Computer Department less than two and one-half years old, the products.....complete or currently in production..... are numerous and diversified. Some of the Department's products being manufactured and marketed are:

HEAT RATE COMPUTER - A computer for airframe testing having both analog and digital components.

ECONOMIC DISPATCH COMPUTER - An analog computer now enabling electric utilities to compute their most economical daily power dispatch schedule.

GE 310 DATA ACQUISITION SYSTEM FOR PROCESS MONITORING - These systems use both analog and digital components. Accurate information is provided for process control, quality control, inventory control, and cost control applications in such diverse industries as chemicals, petroleum, steel, and utility.

GE 100 ELECTRONIC DATA PROCESSOR FOR BANKING APPLICATIONS - This digital machine will handle 50,000 or more separate checking accounts.

GE TRANSISTORIZED MAGNETIC INK CHARACTER READER - Originally a part of the GE 100 Data Processor, this input device reads characters printed in magnetic ink directly from the original document.

309 GAGE LOGGING SYSTEM - This is a computing and data processing system for the metals industry. The 309 automatically counts and records the occurrence of selected events in a process. The primary application for the 309 is in the logging of gage measurements on a rolling mill.

GE 306 PRODUCTRON (Desk-Size Analog Computer) - The analog computer for solving general business problems as.....production schedule analyses, budget syntheses, material explosion, and operating reports.

AUTOMATIC INSPECTION DATA ACCUMULATOR FOR TINPLATE - Designed especially for an industrial environment, the Data Accumulator inspects at line speed on the delivery end of the tinning line. This system provides a complete, typewritten record for quality control and billing purposes immediately upon completion of each coil.

GE 312 CONTROL COMPUTER - A general purpose digital computer especially designed for real-time industrial calculations. The memory size and performance complexities make it suitable for operation in steel mills, petroleum refineries, gas and electric utilities and other heavy industries.

INDUSTRIAL CARD READER - A static reader which enables one row of a Hollerith card to be read at one time. One of the greatest advantages of the Reader is that it can be operated under conditions of high temperature and humidity.

As of March 1959 the Department has expanded its product scope to include the development and manufacture of equipment suitable for use in military systems as well as in heavy industry.....steel mills, petroleum refineries, and gas and electric utilities. With a well-established reputation as a producer of banking automation systems and business data-handling equipments, it was not difficult for the Department to diversify its products and to create a backlog of orders amounting to nearly 43 million dollars. Less than 10 percent of these accumulated efforts stem from military orders.

By utilizing its own special building blocks.....well-equipped laboratories, the most modern equipment and facilities, unsurpassed engineering abilities, and exceptional management capabilities.....the Computer Department will surely add many more chapters to its remarkable history. For, as the wheels of fortune move more rapidly in the computer business, the General Electric Computer Department, too, gains momentum in its "venture" in this new and unlimited field.....the COMPUTING INDUSTRY.

COMPUTER DEPARTMENT HISTORY

March 16, 1959

AN ENGINEERING SECTION "FROM SCRATCH"

BY: Kenneth R. Geiser

MANAGER - ENGINEERING

GENERAL ELECTRIC

ENGINEERING SECTION
COMPUTER DEPARTMENT
PHOENIX ... ARIZONA

TECHNOLOGY
Advanced component design
Analog or digital computers
Creative thinking
holders of advanced degrees in physics, mathematics, electrical and mechanical engineering
Computer
MATHEMATICAL STATISTICIAN Ph. D.
To Assume a Position of Senior Responsibility
• RESEARCH
• DEVELOPMENT
• MANAGEMENT
CREATING WITH ELECTRONICS
ELECTRONIC ENGINEERS
RESEARCH AND DEVELOPMENT
Unusual and challenging openings exist in the following
PHOENIX
ENGINEERS
ELECTRONICS.
PHYSICISTS
TAPE
RESEARCH
PROJECTS
ELECTRONICS
MAGNETIC
TRANSISTORIZED DIGITAL
SYSTEM COMMUNIC
DATA PROCESSING
PHYSICISTS
ENGINEERS
MATHEMATICIANS
B.S. M.S. Ph.D.
ENGINEERS
SENIOR RESEARCH SCIENTIST
MATHEMATICIANS
The growing importance of DIGITAL TECHNIQUES
AUTOMATIC
PRODUCTS
SENIOR SCIENTISTS AND ENGINEERS
DISPLAY
READOUT
product development
TECHNOLOGY
Instrumentation
Process control
Servo systems
Solid state devices and applications
Telemetering
automatic control
Automation
Data conversion, transmission, processing or display systems
ELECTRONIC COMPUTERS
PHYSICISTS
Design of intricate mechanisms
Electronic packaging
Research
Digital Computers
Modern Industry
DESIGN ENGINEERS

A GENERAL ELECTRIC ENGINEERING SECTION - "FROM SCRATCH"

K. R. Geiser
Manager - Engineering

General Electric Computer Department
Phoenix, Arizona

August, 1959

1. Forward

Early in 1956, an executive nucleus set to work on the task of creating a Computer Department for the General Electric Company. As a separate, independently active organization, this new Department would be responsible for the design, development, manufacturing, and sale of computer equipments, systems, and services.

Among the many activities imperative to these ends were the building and integration of an effective engineering section.

Now, three years later, that new Engineering Section has moved from birth through the not always certain steps of youth to approach the sophistication of a mature team which knows what it wants to do and how to do it. Many problems have been met. Some mistakes have been made. The over-all progress, however has been dynamic and for those concerned, a generally satisfying adventure.

The pages which follow are a brief review of the Computer Engineering story - "From Scratch"

2. Strictly Personnel

In retrospect, it would appear that the impossible is not what will be achieved tomorrow, but what was accomplished yesterday. For, even as this handful of individuals began to build their new department, to establish its table of organization with much of the establishment still on paper, the Bank of America awarded this Computer Department in genesis the largest single order ever placed in the electronic data processing industry - the $40,000,000.00 ERMA contract.

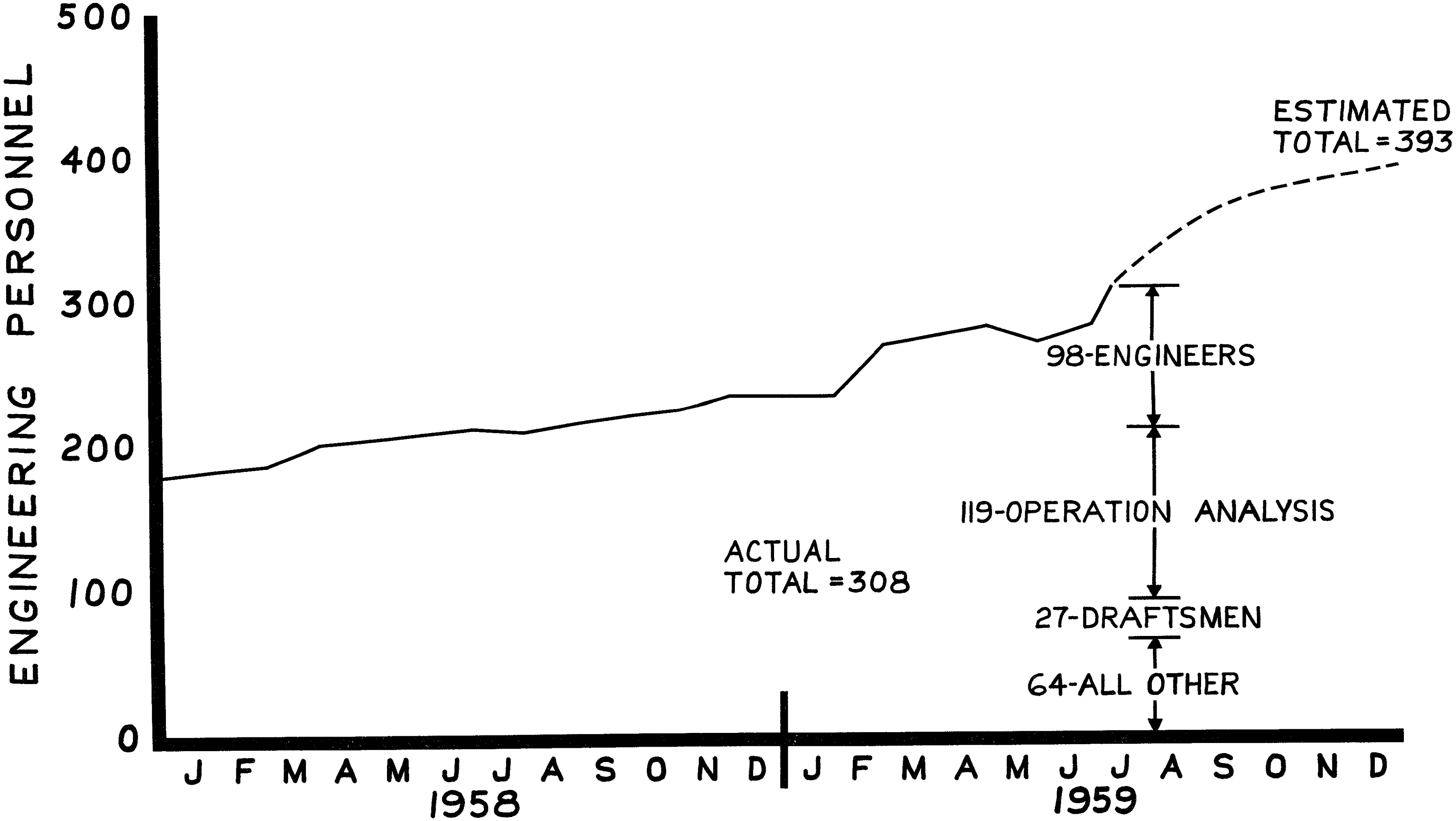
Whatever the hypothetical personnel load anticipated in the planning stage, there now was an enormous engineering job to be faced immediately. Engineers were not a dime a dozen. In truth, beyond some fifteen recruits from the General Engineering Laboratory, it seemed there were not a dozen competent engineers to be had for the hiring. Black market tactics in the procurement of engineering personnel were all too prevalent. Engineers with electronic data processing equipment experience were as much in demand as they were scarce. For these reasons, particular credit must be given to those few General Electric engineers who took to the road as recruiters. They built enough of a team to establish the initial Computer Laboratory group in Palo Alto area in May of 1956.

A group, however, is not an Engineering Section. Neither was the Computer Department to be located in California. Department operation was scheduled to get under way in Phoenix, Arizona, in December of the same year. This it did with the Engineering Section located temporarily in the Engineering Building on the campus of Arizona State University (then College) at Tempe.

One measure of growth for the Engineering Section from point of origin in Arizona to the present is in a comparison of personnel both by number and classification. The following table reflects the change from January 1957 to January 1959. The accompanying chart, "Engineering Personnel Buildup," graphically presents the growth to the month of August 1959.

Personnel Classification	January 1957	January 1959
Managers	16	24
Engineers	43	74
Operation Analysts	0	37
Draftsmen	1	15
All Other	41	90
TOTAL	101	240

ENGINEERING PERSONNEL BUILDUP



It is interesting to note as an aside, that the mushrooming of the new Computer Department was favorably comparable to the historically phenominal growth of the Ramo-Wooldridge Company which began when Simon Ramo left Hughes one morning with approximately 70 individuals, a complement which expanded to roughly three hundred in just one year's time. Actually this was exceeded by the Computer Department in general, and by the Engineering Section in particular which had begun with some fifteen engineers out of GEL.

Aside from the indefatigable efforts of the dedicated individuals who set out to build the Engineering Section, it is felt that three factors contributed to the Section's accelerated growth:

1. The stature and the stability of the General Electric label,
2. The challenge of a new product line in a dynamic, swiftly advancing field,
3. The general appeal to individuals of the western desert location.

3. <u>The Palo Alto "Split-Off"</u>

To return briefly to the Palo Alto operation, now wholly concerned with the Bank of America ERMA contract - by mid-1957, the situation stood as follows:

1. ERMA was the Computer Department's major contract. The entire future of the Department could depend upon a successful performance of this single project.
2. Dr. R. R. Johnson, whose services had been procured by the Engineering Section, was in complete charge at Palo Alto and was served by a staff of the finest personnel available.
3. The ERMA operation was well integrated and making excellent progress.

4. The ERMA operation had its own particular goals, techniques and problems. In general, these were separate and apart from the multiplex projects and activities in Phoenix.

Therefore, because of the exceeding importance of the ERMA contract, management directed Mr. Oldfield, then General Manager of the Computer Department, to give attention and status to the Palo Alto operation equal to that given his other sections.

In a letter dated September 5, 1957, Mr. Oldfield wrote:

"...the successful completion and acceptance of the first ERMA system is of sufficient importance to the continued successful achievement of the Department objectives that it should require management attention equal to that which I would give to any other functions of the business enterprise ..."

In consequence, the Palo Alto ERMA operation was "split-off" and made an independent Engineering operation, reporting directly to the General Manager.

While the Department with this separation accomplished a unique and efficient Engineering autonomy, the Engineering Section continued to serve the Palo Alto group with the following specialized services:

1. Component Engineering
2. Drafting
3. Standardization

4. Integration of the Section

Parallel with the problem of procuring engineers where few seemed available was the problem of integrating those who were obtained into a smoothly functioning team. With a number of commitments on hand in the Department, all dependent upon the "working engineer," the rapid integration of new men was exceedingly urgent. A great many of the engineers had other company backgrounds. Ten other General Electric Departments were represented. A few of the young men were fresh from university work. Sixty percent of them had had no previous computer experience. Two of the writer's subsection managers were "old timers" at the GE way of doing things. They, with the writer in his managerial capacity, set about integrating this cosmopolitan group into an efficient GE team with departmental and company differences forgotten, a team capable of advancing the state of the art in a brand new field. That this was accomplished, that a spirit of oneness did develop, is an achievement in organization of which the Section is justly proud.

Also, as is true of any organization, there were moments when discussions of how-to stood in the way of actual doing. Almost always, however, there was a General Electric precedent which could become the order of the day - altered, perhaps, to fit the peculiar business of computers - but aimed at the intention of getting on with the work.

Integration, of course, is never done. It is a part of progress and the constant change necessary to advancement. Here, in the Computer Engineering Section, it has become a constant, fluid ingredient. In the beginning, for example, there was a disproportionate need for the creative engineer. New ideas, new products, new systems, and new technologies had to govern the thinking of most of the Section. Tomorrow's products were needed now!

Sometimes it appeared that paper work might become the most important product. But from this productive creativity, hardware, systems, and services did emerge. Moreover, the Section was able to ascertain which of its personnel were best suited for creative engineering and which for the vital job of production engineering. Realizing then, that the step between new design work and production design is considerable, a Production Engineering course was initiated to accelerate the transition of a new section seeking new products to a mature section with a variety of products on the horizon, on the boards, and on order.

5. Room to Work

Another aspect of the growth in the Engineering Section is evident in the amount of space necessary to house the expanding working section:

December 1957 ....14,000 sq ft

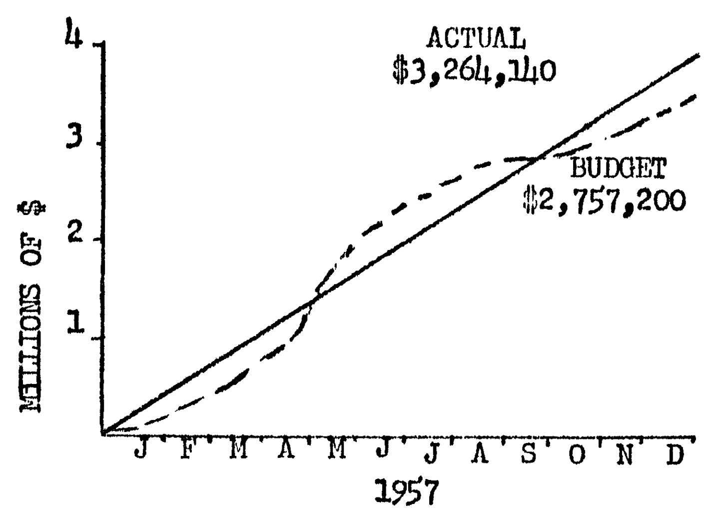
December 1958..........21,000 sq ft

July 1959 ....40,500 sq ft

The first two figures represent rented space. The last figure follows the first of the year move to the new General Electric Deer Valley plant. One subsection, Operations Analysis, remains in rented quarters; a situation which will be remedied when the mezzanine of the new manufacturing facility is completed probably in mid-September. While the main body of the Operations Analysis Subsection will move to Deer Valley at this time, special units will remain in rented quarters in Arlington, Virginia, so that they may continue to work in close association with Air Force and other Defense services.

6. Money to Grow On

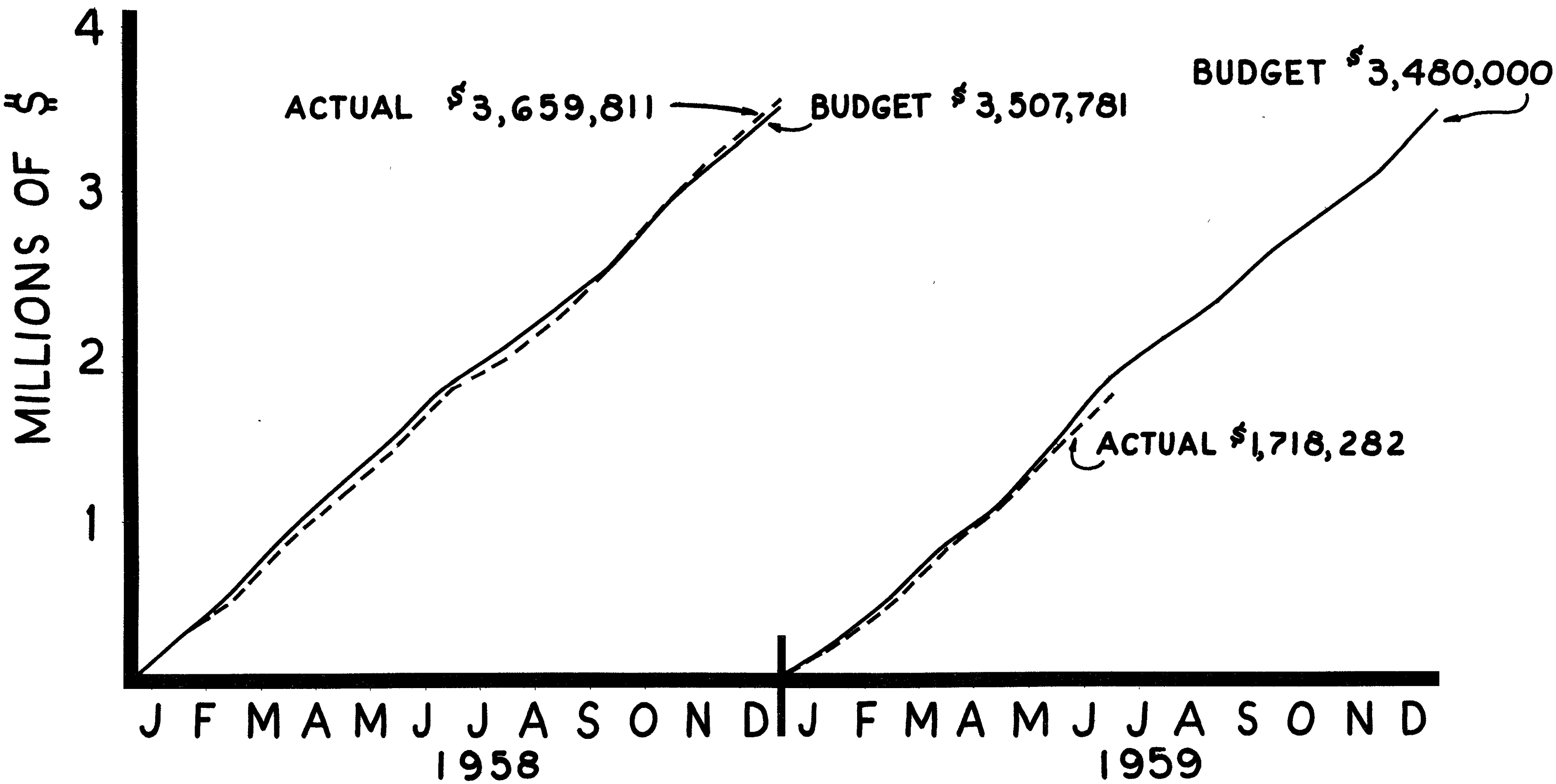
Graphs best present the picture here. As is the case with any new and major, exceedingly complex engineering operation, the struggle to remain within the budget was not, and is not, a simple thing. The first two years were close to budget and hard fought in the effort to remain within budgetary limits. As is illustrated in the accompanying figures, the fight was not quite successful. Nineteen-fifty-nine is another story. The actual expenditure line climbs evenly below the allocated budget, perhaps the most sensitive indication to date that the Section is maturing,



7. Policies and Practices

In the beginning, not a single instruction, nor policy statement, existed as an established guide for the Engineering Section. Moreover, Engineering Management was determined not to impose upon the new section, any policy or instruction not eminently suited to the fluid dynamics of the electronic data processing industry where the shadow of obsolescence threatens every product even as it is created.

BUDGET EXPENDITURES



Although it was necessary as has been described in an earlier paragraph to borrow from other GE Departments certain policies and procedures to keep work moving, such decisions were considered temporary until such a time as the policy or instruction could be defined, analyzed, and rewritten to suit computer activities Also, for a policy or instruction to become the rule in the Engineering Section, majority approval by Subsection Managers was required. This has been and continues to be a time consuming operation. The Engineering Instruction Manual grows slowly and steadily.

It is felt by the Engineering Section that too much emphasis can not be given to written policies, procedures, and instructions. First, because they establish the General Electric way of doing things, and second, because they provide a good morale factor of no small dimension. For, with the rules clearly written, the differential treatment of individuals is pretty well eliminated; an important consideration when dealing with a great many individuals of professional stature.

8. Charters for the Section

By the end of 1957, the first Engineering Charter for the Section had been prepared. In conception, its purpose was twofold: As a complete definition of Engineering activities and responsibilities, it would serve to measure the proficiency of the Section in fulfilling its multiple obligations to the Department. Also, it would be the means of achieving a complete understanding with the General Manager of what was to be expected of the Engineering Section. In both of these areas, the Charter was successful. Furthermore, the General Manager was able to use this document to delineate and otherwise study functional areas covered by other Sections of the Department.

Subsequently, Engineering Subsection Charters were written to further clarify the special areas of activity to be allocated to each of the subsections. An interesting outcome of the subsection charters was the following conclusion: That each subsection would not need so much to conserve its functional skills as it would its technological skills. Functional skills were defined as advance engineering, development engineering, product engineering and production engineering; technological skills as magnetic core techniques, magnetic drum techniques, electro-mechanical input-output techniques, microwave techniques and such. Therefore, each subsection so concerned could develop its own product lines from inception to production independent of any other subsection even while it developed certain highly specialized technical skills and knowledge which would be available to and not duplicated by other subsections.

So valuable did the subsection charters prove that they have become an integral part of the Engineering Section and are subject to an annual updating.

9. Required Skills

The minimum of technical skills required to constitute a basic computer engineering organization are listed in the following tabulation of what was available in the Section at the end of two years. Not present are many of the more esoteric skills which often are necessary on short assignment for the solution of extremely specialized problems such as may occur in the areas of heat transfer, vibration, the complexity of chemical actions and reactions under unusual conditions, and the like.

Associated with the skills are the approximate number of man years accumulated by the Computer Engineering Section as it existed in January of 1958.

Electrical	100 Man Years
Electronics	295 Man Years
Mechanical	25 Man Years
Physics	20 Man Years
Logicians	10 Man Years
Mathematicians	60 Man Years
Operations Analysts	25 Man Years
Programming	(Purchased from the Scientific Applications Section of the Department)

Currently the possible over-all benefits to be derived from the full time employment of additional skills are under study. This study was begun by visiting Engineering Consultant, Mr. H. P. Kuehni. It is still in progress and under advisement. Meanwhile, among the skills listed above, the major change in the current year's activities will be reflected in an advance in the number of man years devoted to the work of the Operations Analysts. For it is an interesting reflection upon the current state of the art that within the field of electronic data processing, thinking ahead of the machine, using the rigorously specialized disciplines of machine language and machine techniques, must determine both what the computer may do and how it must be built to accomplish its purpose.

10. Products and Services (Completed)

The following products and services have been completed. As will be noted in the text, completion does not necessarily mean the end of a job. NCR engineering models are complete, for example, while the production units are in various stages of development for a series of systems. AFCIN has completed a number of phase studies which are simply a part of the whole in the building of a classified system.

Operations Analysis:

Model of Hickory Tank Shop (a complete and exhaustive study of product flow in a specific industrial activity)

AFCIN 3 - Phase I Report
AFCIN 3 - Phase II Report
AFCIN I - Phase I Report
(a highly classified development of a working system of data handling for the USAF)

New Index Concept (for storage and retrieval of information by a computer)

Computer Program Package (a combination of coordinated systems to handle massive data handling job)

Analysis of Competive Industrial Computer (the scientific and exhaustive study of a a major product)

Investigation of the Nature of Industrial Processes (as applicable to applications of the GE 312 and 311 computers)

Business and Scientific:

NCR 304 Electronic Data Processing System

304 Central Processor
320 Media Converter
322 Printer Controller
330 Tape Controller
340 Buffer Electronics
(Prototypes and product design complete; initial units in service as engineering models; production in progress on all units; delivery of production models of all units in the immediate future.)

Design Automation Techniques	(Development of practical advances in the techniques of design automation; absolutely essential use of computers in the development of new computers)
Back Panel Printed Wiring Techniques	(Major advances in printed circuitry production)

Industrial Computers and Systems:

Economic Dispatch Computer for Niagra Mohawk	(Electronic data processing to calculate the economic loading of a major electric power disbursing system)
New Servo Design for Economic Dispatch Computer	(A servo set potentiometer development of great value in multiplexing the dispatch computer)
Digital to Analog Computer for Industrial Control Dept.	(A custom-designed computer for digital to analog conversion)
Analog Transistorized Operational Amplifier Analog Transistorized Multiplier Analog Transistorized Function Generator Analog Transistorized Low Level Amplifier for Thermocouples Analog Transistorized Thermocouple Linearizer Thermocouple Reference Junction Analog Power Supplies	(Series of analog modules which could be purchased separately to provide a customer with semi-independent units of value in system developments)

302 Data Accumulator

Customized for U.S. Steel Plant, Gary No. 1 Customized for U.S. Steel Plant, Gary No. 4 Customized for U.S. Steel Plant, Fairless Customized for Jones & Laughlin Steel	(Major date accumulation systems developed from a basic general purpose computer system)

309 Gage Logger Standard Customized for Inland Steel	(A process monitoring and data printout device designed to serve industry in critical gage control areas)

Digital Printed Circuit Boards (Developed for Specialty Control)

Special Products:

NCR Analytical Tester	(Special test equipment developed in conjunction with the NCR component systems of the Business and Scientific Subsection)
Industrial Card Reader Prototype Production Units	(Sold to Industry Control as a general industry product line)
Heat Rate Computer	(Developed for the Wright Air Force Development Center)
High Speed Data Acquisition System	(Developed for Jet Engine Department)
Miniature Network Analyzer	(A 10,000 cps, 4 generator device designed to serve power station networks - a major sales item in number of units sold)
Analog to Digital Converter	(Developed as a component of the low speed data logging line)

11. Products and Services (Active Projects)

Reference to accompanying chart, "Computer Engineering Active Projects," reveals the current Engineering Section work load. Many of the products and services where prototypes, production models, and phases were shown as complete in their initial contracts continue to appear as open, active projects. Of these, the NCR 304 System is, perhaps, the most striking with 33 systems on order.

Among the new products, the GE 311 Data Processing Systems and 312 Control Computer Systems most reflect the growth and sophistication of the Section's capabilities. Here the devices for computation have progressed from the acquisition of data, the fundamental step for all computers, to the processing of such information for specific types of consumption, to the processing of data with industrial control factors recognized and acted upon by the computer itself.

The success of this major move forward by the Engineering Section is evidenced by the sale of 18 general purpose Control Computer Systems to

COMPUTER ENGINEERING

ACTIVE PROJECTS

GE-250 LIBRARY SEARCH COMPUTER (1)
(WESTERN RESERVE)

GE-302 DATA ACCUMULATOR (3)

GE-309 GAGE LOGGING SYSTEMS (1)

GE-310 DATA AQUISITION SYSTEMS (3)

GE-311 DATA PROCESSING SYSTEMS (3)

GE-312 CONTROL COMPUTER SYSTEMS (18)
(YOUNGSTOWN - J & L - SOUTHERN CAL.)

GE-304 NCR CENTRAL PROCESSOR and MEMORY (33)
UNIVERSAL MEDIA CONVERTER 320
PRINTER BUFFER ELECTRONICS 340
PRINTER CONTROLLER 322
TAPE CONTROLLER 330

NCR IMPROVEMENT PROGRAM (dev)
212-L MEMORY (dev)

AFCIN WASHINGTON CENTRAL (study)

AGT HIGH SPEED DATA AQUISITION (2)

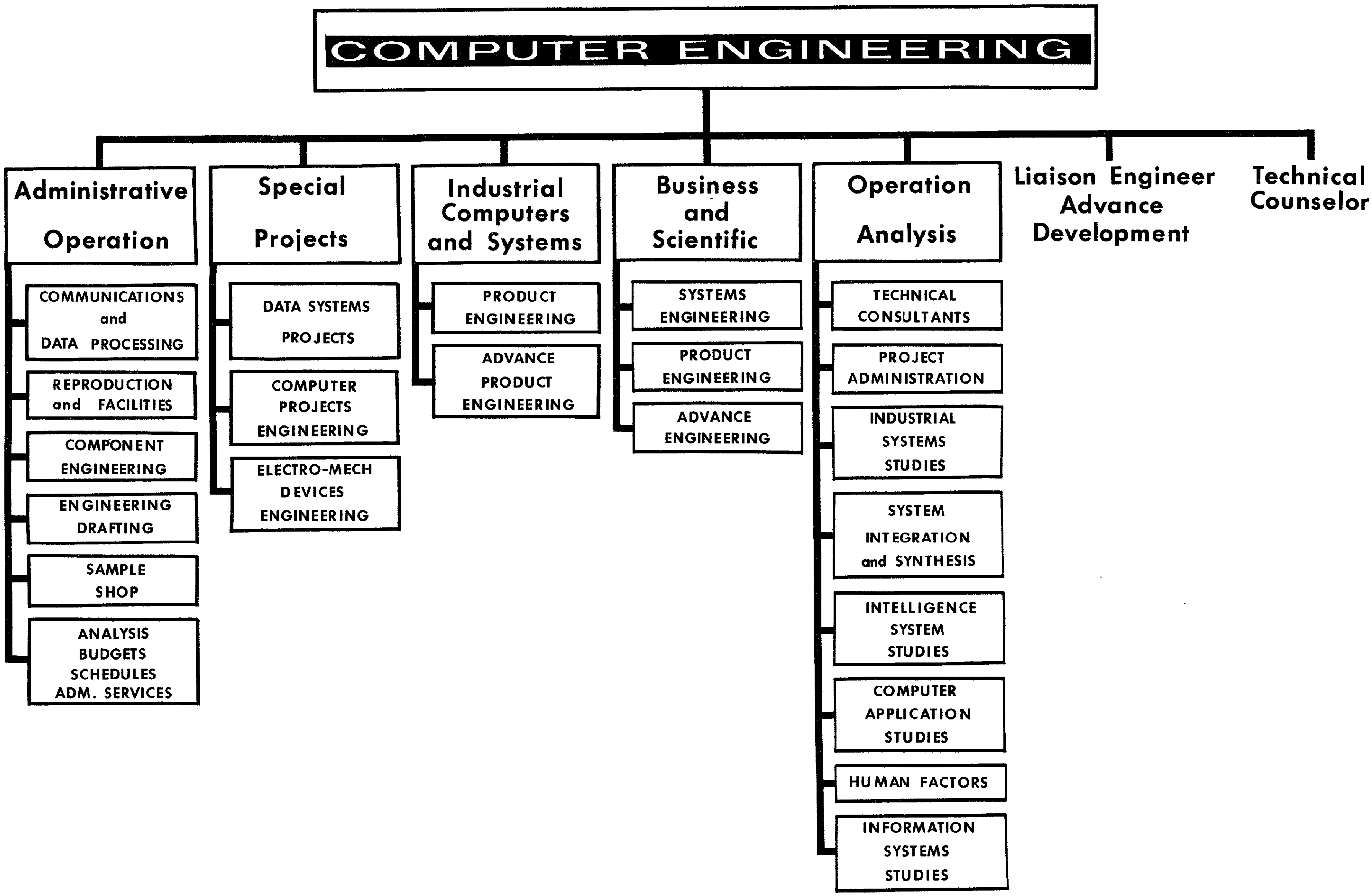
diverse markets. Furthermore, some of these systems are being tailored to "close the loop" in automating certain industries and utilities.

12. Organizational Activities

The Engineering Section is divided into five subsections: (1) Administrative Operation, (2) Special Products, (3) Operations Analysis, (4) Industrial Computers & Systems, and (5) Business and Scientific. The subdivisions within the Subsections are shown in the accompanying chart, "Computer Engineering." While most of these subdivisions are self explanatory, it is believed that special attention should be called to Operations Analysis, a relatively unique group for an industrial engineering section.

AFCIN PROJECT

Early in the history of the Engineering Section, Operations Analysis became an important and concrete Subsection as the result of the structuring and implementation of the AFCIN Project. This it turned out was a particularly difficult organizational job. First, this highly desirable contract came into the Section before the Section was adequately staffed with the relatively esoteric skills the contract demanded. Here, a group was required where reasoning must be of the highest magnitude. Moreover, a special sort of intelligence was in demand, part engineer, part mathematician, part geo-politician, and part logician - a strange sort of combination to justify by budget. Finally, when the search did begin to implement the AFCIN project, it was discovered as it had been in computer engineering that competent specialized personnel were a very rare comodity.


COMPUTER ENGINEERING
Administrative Operation
COMMUNICATIONS and DATA PROCESSING
REPRODUCTION and FACILITIES
COMPONENT ENGINEERING
ENGINEERING DRAFTING
SAMPLE SHOP
ANALYSIS BUDGETS SCHEDULES ADM. SERVICES
Special Projects
DATA SYSTEMS PROJECTS
COMPUTER PROJECTS ENGINEERING
ELECTRO-MECH DEVICES ENGINEERING
Industrial Computers and Systems
PRODUCT ENGINEERING
ADVANCE PRODUCT ENGINEERING
Business and Scientific
SYSTEMS ENGINEERING
PRODUCT ENGINEERING
ADVANCE ENGINEERING
Operation Analysis
TECHNICAL CONSULTANTS
PROJECT ADMINISTRATION
INDUSTRIAL SYSTEMS STUDIES
SYSTEM INTEGRATION and SYNTHESIS
INTELLIGENCE SYSTEM STUDIES
COMPUTER APPLICATION STUDIES
HUMAN FACTORS
INFORMATION SYSTEMS STUDIES
Liaison Engineer Advance Development
Technical Counselor

That the Section was successful in its search for and development of such individuals is evidenced in the table and the graph showing personnel growth. In January of 1957 there were no operations analysts in the Engineering Section. In January of 1959, there were thirty-seven, and in July of 1959, one-hundred-and-nineteen. Many of these are at present in the Arlington, Virginia area, working closely with Air Force Central Intelligence. Now, what precisely is Operations Analysis as defined by the Engineering Section? Operations Analysis is the generic term used to describe the activities necessary to define and implement complex man-machine systems. These activities include systems studies, systems design, equipment procurement, and conversion. The Computer Department as a whole, and the Engineering Section in particular, promote Operation Analysis as a means for developing man-machine concepts, advanced computer design and application concepts, and markets to fit these complex and advanced products.

As has been observed, the current major effort is focused on a multi-million dollar Study of Air Force Intelligence Directorates. For this, the Operations Analysis team has prepared and presented a system design, including hardware recommendations, for one directorate, and is developing a systems design approach for a second. While these systems are designed to fit a vast military need and market, it should be noted that many of the analysts' efforts and concepts are applicable to many business and industrial applications. As a result, the Operations Analysis Subsection is submitting proposals to many civilian customers for additional analysis work.

NCR 304 PROJECT

Meanwhile, the Business and Scientific Subsection was working its way into the initial National Cash Register Contract with the development of a prototype of the NCR 304 Electronic Data Processing System. This prototype was then used to test the validity of system assumptions, to solve logic design and other problems, and to evaluate certain programming techniques. Experiments with this prototype system provided the opportunity to take that vital "second look" before releasing final designs to production.

During the course of prototype development, vast amounts of information concerning the NCR 304 System came into existence, much of which was locked in the minds of the design engineers. The problem of disseminating this information was solved by having a team of these engineers plan and organize a training course on the system. This caused many of the engineers to become part-time instructors, an occupation in which they still are engaged while instructing Quality Control and Product Service personnel.

This program has included both written reference material and classroom instruction on all parts of the 304 System built by General Electric. The aim has been to train technicians for testing and/or maintaining all 304 production equipments. Further, an important, residual result has been the preparation of five engineering manuals, covering the five separate General Electric component systems.

Before leaving the NCR 304 project, note should be made of an extremely important development which played a major part in the over-all development of the systems involved and which will affect much future work by the Engineering Section in the design of new computers. This was the

AUTOMATION OF ENGINEERING DESIGN.

Such automation consisted of using computer techniques and developing computer programs which performed automatically a large part of the routine design, record keeping, and the preparation of engineering drawings. Although the engineering expense of initiating this automation was somewhat higher than it otherwise might have been, the experience gained, and the superior accuracy of the data delivered to manufacturing over manually prepared data have been of concrete benefit to the project and to the Section as it looks to the future.

In this process of automated design, an integrated set of over 50 routines was adapted to NCR 304 circuits and product design. Because the overall program accepted logic equations as input data, any machine could be designed by these routines if it used the NCR 304 circuits and product design. Further, by modifying these routines, a machine not using NCR 304 design also could be designed with the extent of the modification directly proportional to the degree to which the circuit and product design were changed.

Again, looking forward, an entirely different use may be made of such automation routines. For, certainly, they can be used to assist in making vital design decisions which can have a pronounced and measureable effect upon total production material costs. At present, most such design decisions are made by intuitive processes - decisions which surely would show a marked improvement in achieving their ends if subjected to the more precise and exhaustive processes of design automation.

312 CONTROL COMPUTER PROJECT

In the Industrial Computers and Systems Subsection, the General Electric 312 Program was organized on a project basis in order to reduce costs and the design fabrication time cycle. In essence, this meant that all project activities were under the direct supervision of one project engineer with no other management boundaries to be crossed and no other decisions to be obtained to prosecute the work. The results of this project was the 312, a general purpose digital control computer especially designed for real time industrial monitoring, calculations, and control. To date, eighteen have been authorized. The versatility of the equipment, the facility with which peripheral equipments can be added to or subtracted from the system, already have provided a wide divergency of markets. For example, Jones & Laughlin Steel Company has ordered a 312 to monitor a continuous tin plate annealing line and to control vital temperatures; Southern California Edison has ordered two to act as supervisory control equipment for boiler-turbine-generator equipments in a Steam Station.

HEAT, SPEED, AND LITERATURE

The Special Projects Subsection continues to deal with the potpourri of the computer industry. Its charter grants the responsibility for peripheral equipments, for government projects hardware, for equipment which is primarily electro-mechanical, and for other side areas of activity.

This Subsection, for example, has contributed its diverse talents to the electro-mechanical problems of the Printer Buffer in the NCR 304 System, continues to work on high speed date logging equipments which will read from four hundred points per second and up in jet engine tests; and on the heat rate computers so necessary to the solution of thermal problems in ultra high speed missiles and vehicles.

At the same time, in conjunction with a hardware contract from Western Reserve University, a Special Projects team is working on a high speed, Literary Search Selector capable of a great degree of selectivity and discrimination.

A final area where Special Projects performs a special function is in the design of units which vendors cannot supply in the degree of quality and specialization required by a computer system. At present, in keeping with this philosophy, the subsection is at work on an efficient and reliable tape transport.

ADMINISTRATIVE OPERATIONS

Administrative Operations was set up primarily as an administrative and service subsection. It gathers under one administrative head a number of services to be shared by the other subsections.

Communications and Data Processing brings order and efficiency to the paper work of the entire Engineering Section and establishes lines of liason and data exchange to all sections of the Computer Department.

It formalizes the methods, routines, and standards for the dissemination of engineering data; and furnishes technical writing and editing services where required.

The subsection maintains a reproduction facility to provide office type duplication and printing services as well as standard drafting room duplication. It handles assembly, storage and distribution of all engineering information and documents. This includes an advance type of engineering release on punched paper tape which can be handled by automatic devices in manufacturing. On a one shift basis, the weekly output of the reproduction facility can reach 162,000 square feet of engineering paper.

Component Engineering provides specification and evaluation services for all design engineers; and the subsection's industrial designer has developed and established a solid, handsome conformity in the industrial products appearance standards.

Engineering Drafting efforts have continued to take the draftsman out of drafting. This has been accomplished on the premise that electronic circuit work does not usually require a draftsman to make a picture to show a wireman where to run a given wire. So, the current drafting complement stands at twenty-seven, as compared with forty-nine a year ago. (The forty-nine peak included subcontract personnel.)

Three activities have contributed to holding down the total number of draftsman required:

(1) Design automation techniques which permit a good portion of computer design to be done by computers.

(2) An automated engineering data release system which can utilize punched cards for engineering releases and which maintains a "where-used" punched card file.

(3) A strict segregation system wherein the qualified draftsmen do the drafting work only while the clerical personnel do <u>all</u> the clerical areas.

That the draftsmen who do remain are capable may be seen in their ability to interpret logic diagrams sketched by engineers and in their preparation of the extraordinary "art work" required for printed board and printed back panel reproductions.

Of particular value to the Engineering Section is the Sample Shop maintained by the Administrative Subsection. Here, a basically complete engineering shop, employing five skilled craftsmen is capable of fabricating parts, modules, cabinets, printed wiring boards and such, as well as doing critical machine work for the Engineering Section. Capital investment in the shop's facilities approximates $23,000.00.

Budgets and Schedules, also a part of the Administrative Subsection, analyzes and prepares the Engineering budget, controls hourly applied time by project, prepares progress charts and controls the Engineering Project Authorization.

EPA

The Engineering Project Authorization (EPA) system establishes a standard routine for the communication of all pertinent engineering project information, including; the project work statement, budget per individual project, schedule, expenditures and delivery status. It consists of two standard documents: the project cost sheet and the project schedule sheet. It provides for each active engineering project: time and cost estimates, work assignments, manpower loading, cost collection and reporting, and performance measurements. It has proved an excellent project monitoring and project control instrument.

13. Other Engineering Activities

THE LIASON ENGINEER

An individual activity of exceptional importance to the Engineering Section is that of the consultant to the Manager, Liaison Engineer, Advance Development. This activity occupies the full time of one of the Section's most knowledgeable computer engineers. His is a constant job of search and discovery, of travel and individual enterprise, and finally, of course, of consultation. He's a familiar visitor at many GE Departments and at the Laboratories. If exceptional data processing work is going on at M.I.T. or Cal Tech, he looks into it. If an important conference on computers is in progress, he attends. If there exists an individual making important contributions to some phase in the state of the art, he may contact that individual to the Section's benefit. He reviews and scours the literature concerned with the computer field. Returning from each investigation, research, or appointment, he disseminates pertinent information both through the Section at large and into the specific areas where it will be of the most value.

One of his means for spreading his general and specific information is his internal news letter, "COMPUTOPICS."

THE DIVISION STANDARDS TEAM

Early in the development of the Engineering Section, it was felt that much of the work being done by Component Engineering and Standards Unit was duplicate effort and that much of the basic electronics evaluation either had been done or was being accomplished concurrently in other Engineering Sections of other General Electric Departments. Because of Mr. Strickland's interest in standardization and the better use of building block principles, Engineering Management proposed a Division Team Effort. The objective was, and remains, to obtain maximum economic utilization of Company resources through integrated component engineering, standards, reliability, and value efforts.

As a result of the original suggestion, the Electronic Standards Council was born January 15, 1959, in Syracuse. CD, CPD, ICD, ID, LMED, HMEDradar, HMEDguidance, MSVD, SCD, TPD, TRD, and XRD met and agreed to participate. A convenient no-extra-paperwork Evaluation Memo form was adopted for fast group communication between Departments so that all will be kept advised of what the others are doing.

PATENT EVALUATION COMMITTEE

This committee has been active since the early formation of the Section.

It consists of the Division Patent Council, Patent Attorneys, the Engineering Subsection Managers, and the Manager-Engineering, the latter serving as chairman. The committee normally meets once a month, and in the past two years has evaluated over 300 disclosures and referrals, and has recommended the filing of well over a hundred applications. In addition, this committee takes care of related patent matters.

PERFORMANCE MEASUREMENT

Each Engineering Subsection Manager was asked to rate the performance of each of his units, and of his subsection as a whole, on a scale of Below Minimum (0), Minimum (1), Below Standard (2), Standard (3), Exceeds Standard (4), and Far Exceeds Standard (5). The Manager-Engineering also independently rated each subsection.

The ratings for each unit and subsection were made on these categories (and % weight):

Productivity	Schedule Adherence	9%
	Project Cost	7%
	Overhead Cost	7%
	Engineer Utilization	8%
Advance Engineering:		11%
Design Engineering:	Optimum Design & Standardization	11%
	New Techniques	9%
	Packaging	7%
Product Engineering:		10%
Communications & Personnel:		12%
Marketing Relations		9%

A Bar-chart indicates, for each subsection, the Manager-Engineering rating and the subsection managers rating. A code permits each subsection manager to identify his own subsection, but not the others, so he knows his position with respect to the other ratings.

The Manager-Engineering ratings ranged from 40% to 108% of corresponding subsection manager ratings as shown in the following table:

	(A) Subsection Manager	(B) Section Manager	Difference $(\frac{A}{B} \times 100)$
Section Composite	2.8	3.5	80%
Advance Engineering	1.4	3.5	40%
Overhead Cost Minimization	4.0	3.7	108%

14. Problem Areas

QUALITY ASSURANCE

To date, all General Electric computer equipments have been designed on a "worst case criteria," and on the basis of known component reliability. These, of course, are not enough. For optimum performance and reliability, accurate systems and equipments predictions must be accomplished on a far broader scope. When enough GE computer systems have been established in the field, feedback will aid this problem enormously. But beyond that the important problem of adequate and efficient foresight must be solved.

Analysis of other companies' methods in search of plain-fact answers would seem to indicate there has been much more in the way of talking, writing, and organization than in tangible results.

FINANCIAL CONTROLS

As yet, proper integration of sufficiently directed reports from Finance and the requirements of the Engineering Section has not been achieved. The Engineering Section continues to accumulate and analyze applied labor vouchers, and to make weekly labor runs on a computer for fast feedback of information on each project that is active in the Section. This, however, remains a problem area.

UNDERSTANDING BY MARKETING

Computer products range from reasonably to exceptionally complex. In certain areas of marketing, feedback is not adequate on how well such equipments are understood by the marketing personnel. As a result, a large part of the application engineering effort and the actual selling of new products to the customers' technical personnel has fallen back on the shoulders of the Engineering Section - a serious drain of valuable engineering and engineering administrative time and effort. The solution of this problem is apparent, and the Engineering Section is eager to assist Marketing in a program of product familiarization for its own personnel.

15. Reorganization

On April 9, 1959, the Manager-Engineering released a letter to the General Manager of the Department and the managers of other Sections which stated in part:

> "I am pleased to inform you that the Engineering Section has taken the lead in streamlining itself and otherwise putting its house in order for more effective performance in 1959.
>
> A copy of the letter to the Engineering Subsection Managers is attached for your information. This outlines the general changes, and the white attachments contain the specific recommendations to the various subsections. This action was effective as of noon, April 8, 1959, and all Engineering Section personnel were so informed at 3 pm, and all individuals affected were relocated with a new home by 5 pm of the same day. The question was raised whether or not the other Sections were contemplating similar action and my answer was that they could all be depended upon to achieve or better their 1959 budget.
>
> Basically, we have done three things:
>
> (a) Forcibly brought to the attention of each and every individual and awareness of our budget situation, our efficiency or productivity, and the necessity of improving if we are to remain in business.
>
> (b) A reduction in the Section overhead which will reflect itself in a lowered cost of the engineering portion of our projects.
>
> (c) An elimination of a number of small subsections with their attendant high overheads."

The subsections referred to in subparagraph "c" were:

The Peripheral Equipment Subsection

The Advance Development Subsection

The Standards and Quality Subsection

In each case, the move was made to consolidate efforts and reduce costs. In no instance was it felt that the area of activity was unimportant. The Engineering Section simply had grown too fast.

It was necessary to trim the budget realistically with the sincere determination to work "in the black," to let the products Engineering designed pay their own way and show a reasonable profit. The work of the eliminated' subsections was assumed by the other subsections. An outline of their activities has been covered previously in this report.

Particularly in the areas of the NCR 304 Electronic Data Processing System, and the GE 312 Control Computer Systems, the Engineering Section is learning to pay its way. Additional orders subsequent to the reorganization have given strong evidence of this fact.

In the field of electronic data processing equipment, systems, and services where the state of the art is jumping like a hare ahead of the hounds, where the threat of obsoletion presses upon every product devised before it is produced, there is still much to learn.

Still, two-thousand years ago, the Romans had a phrase for it.

"Ad astra per aspera!"

To the stars through difficulties. Not a bad motto, perhaps, for the Engineering Section.