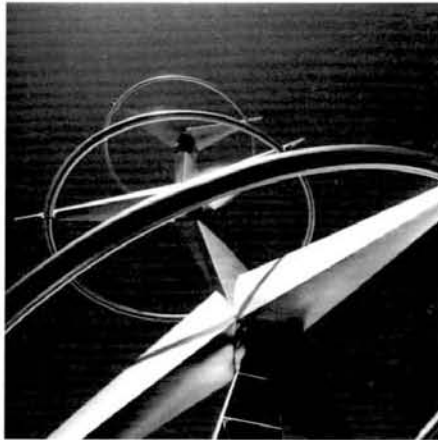


IBM

IBM San Jose  
A Quarter Century of  
Innovation





IBM San Jose  
**A Quarter Century of Innovation**

*by*  
*David W. Kean*



## **Preface**

This brief history has been prepared to commemorate the occasion of the twenty-fifth anniversary of the founding of the IBM San Jose Laboratories. It recalls the major technical, product and organizational events which portray the innovative spirit of IBM San Jose.

It was not possible in this small volume to cover the entire 25 year San Jose history in appropriate detail. Chapters 1 through 6 concentrate on the formative years of the Laboratory, specifically from its birth in 1952 through 1958 when the notion of the removeable disk pack was well established. The text traces major product innovations, organizational highlights and personalities of those years in sufficient detail to provide new generations of San Jose IBMers with some insight into their heritage and old-timers with a measure of nostalgia. Chapters 7 through 9 cover the later years in considerably less detail.

It was also impossible to cover uniformly the large number of organizations resident in San Jose over this period. And some important members of the San Jose family are either missing or treated only lightly: DP Education, Patent Operations, Field Engineering, and Product Test, for example.

For obvious reasons there could not be an exhaustive attempt to mention all of the hundreds of individuals who have been involved. Yet the story cannot be told without mentioning many names. It is hoped that the reader will understand why the names of a large number of contributors do not appear.



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## Prologue

Walnuts, prunes, apricots. Twenty-five years ago that's all there was on the old Rancho Santa Teresa at Monterey and Cottle Roads, where the IBM San Jose facilities now stand. The "Valley of Heart's Delight" was mostly orchard then, and the city of San Jose a bustling market community where every spring busloads of picnickers rode out on weekend blossom tours.

Industrial growth over the past quarter century has transformed the Santa Clara valley from the "Prune Capital of the World," as it was once unofficially known, into "Silicon Valley," one of the nation's most important electronics research and development centers. IBM has been an important contributor to this industrial growth. The impetus for its contribution came from the work of a small band of engineers who, in February 1952, came to work in a former printing plant at 99 Notre Dame Avenue in downtown San Jose. Their product was random access disk storage. It is ranked as one of the most significant contributions to modern data processing.

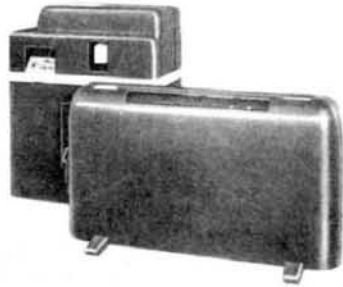
What was the magic formula a quarter of a century ago at Notre Dame Avenue that gave birth to a development which filled a need so vital to data processing that it has spawned an industry reckoned today at several billion dollars annually? The narration will reveal that the enchanted brew consisted of many ingredients: unusual circumstances, freedom to choose and to learn from mistakes, unusual personalities with the will to succeed, and a generous measure of good luck.

But the story is also much more than this, for the development of disk storage was by no means the outcome of a well-conceived corporate plan. Rather, it was the result of a perceptive management decision which recognized the need for innovation and established an environment in which it could flourish.

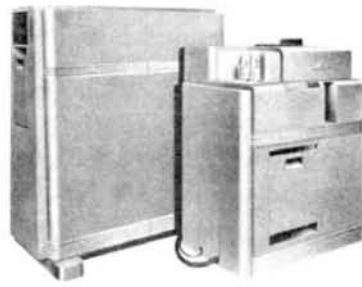
A young computer scientist today can be forgiven for holding the opinion that both the need for and the solution to large-scale random access storage were obvious back in 1952. They were not, and what became a crusade by the San Jose group in pursuing it was the result of a daring challenge thrust upon the colony of young engineers founded twenty-five years ago in San Jose. What they did, how they did it, and the major new industry that was created by those that came later, is the story told in this volume.

in New York. But large-scale computers tended to be regarded at that time as little more than curiosities. And so, when Remington Rand started manufacturing and selling UNIVAC's, IBM found itself (for the first time in its history) in a game of catch-up.<sup>3</sup>

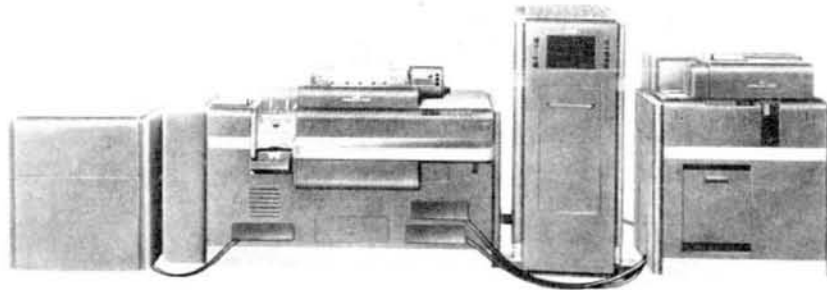
IBM responded to the UNIVAC challenge by initiating the development of a magnetic drum computer in Endicott, later to be announced as the IBM 650. And in Poughkeepsie the work underway on magnetic tape processing machines was expanded and redirected to the "Defense Calculator," so named because it was to be designed to meet the national defense needs brought on by the Korean War. This was the first large-scale electronic computer manufactured in any quantity by IBM, and made its appearance as the 701 in 1952.<sup>4</sup> Another national defense related effort was started at the Watson Laboratories in New York by Byron Havens which resulted in the Naval Ordnance Research Computer (NORC).



603



604



CPC.

*The first IBM production line machine to incorporate electronics was the 603 Electronic Multiplier, announced in 1946, followed in 1948 by the 604 and in 1949 by the CPC.*

These major new development efforts in electronic computers required IBM to initiate an extensive recruiting campaign, for up to this time the company's product designers were largely electro-mechanical specialists; electronics talent was scarce and resided primarily in the then relatively young Poughkeepsie Laboratory. There Ralph Palmer, Jerrier Haddad, Jim Frenekees, Byron Phelps and Jim Williams had developed IBM's first electronic calculator, the 604 in 1948. An electronic multiplier, the IBM 603, had been developed in New York in 1946 by Phelps.

Nevertheless, IBM was then still largely an EAM producer. Over the years competition had largely been from ledger cards and ledger posting machines; IBM salesmen had battled for years to convince prospects of the efficiency of batch processing as opposed to direct ledger posting. The phrase "we are not wedded to the punched card" was often heard, but if it was not matrimony it was surely a rather intimate liaison. As the 1950's opened, IBM had 6,000 customers renting 100,000 machines, and consuming 16 billion punched cards annually. Because it was the nature of the punched card that a large quantity had to be accumulated before processing could be done efficiently, batch processing was the way of life for the "tab room"; few, if any, in the industry perceived then that there would ever be anything else.

#### *California, Here We Come*

With the new emphasis on electronic computers, IBM found itself in need of still more engineers with electronic design backgrounds, and a large untapped source appeared to be in the West. Teams of recruiters were thus dispatched to California, only to return home consistently empty-handed, unable to convince prospects that they should give up the well-publicized advantages of California for life in New York. It appeared that IBM would have to go to them.



## Chapter 2. Planting the Seed

Thus it happened that in mid-January of 1952, W. Wallace McDowell, IBM Director of Engineering, dropped in on Reynold B. Johnson in his office at the Endicott Laboratory and presented him with a challenge that he was confident would not be refused. “Rey,” Johnson recalls McDowell saying, “the Company after much deliberation has decided to establish a small research laboratory on the West Coast, far from home base, and I’d like you to head it up. It will be an assignment without precedent in IBM.”

McDowell had apparently been concerned for some time that rapid growth and the heavy product commitments in Endicott and Poughkeepsie would leave little room for the kind of dramatic, unexpected payoffs that could come from less directed research. This, along with the burgeoning of a significant computer community on the West Coast that IBM was having difficulty interfacing, led to the logical, though unprecedented, decision to try to establish an environment in California where it hoped to encourage more innovation.

As for choosing Johnson to head the new laboratory, McDowell has explained it this way: “Any R & D is a gamble, but Rey Johnson had a reputation as a far-out thinker and many of us felt that someone like him would make something happen that would pay real dividends. It paid off.”<sup>5</sup>

### *Gambling on Rey Johnson*

Rey Johnson’s reputation as an innovator went back to the early 1930’s, to the days when he taught science at the high school in Ironwood, a mining, lumbering and dairy community in the far northwest corner of Michigan’s Upper Peninsula. There he had been working on a scheme to relieve fellow teachers of the drudgery of correcting multi-choice examinations by hand. The first model of this machine had been constructed by two students sentenced to work for Johnson in lieu of a punishment for stealing a radio from the school. Johnson’s machine was written up in the local newspaper by his wife Bea (who was also a teacher) and the news got wide publicity. Eventually it came to the attention of G. W. Baehne, IBM’s manager of institutional sales.

Under the encouragement of Benjamin Wood, then head of Columbia University's Bureau of Collegiate Educational Research, IBM engineers were working on a test scoring machine that turned the pages of the test booklet, reading the student's answers by photoelectric means. This approach proved cumbersome and costly. Johnson, however, had a simpler machine which read a student's recorded answers by sensing the conductivity of his pencil marks. By using a swamping resistor large enough to overwhelm any differences in the resistance of marks left by different people, Johnson was able to use a standard ammeter to indicate the percentage of right and wrong answers.

Baehne informed Wood of the new development, and Wood recommended that Johnson be invited to New York to explore the possibilities of proceeding with his work under IBM auspices. Johnson has commented on the visit made during the summer of 1934. "After six weeks of conferences [I] was called in to meet with a group of IBM executives who announced that they had come to the decision that my test scoring machine was an incomplete invention in which they had no further interest. . . . Fortunately for me, however, the next day Dr. Wood got in touch with Mr. Watson, who was vacationing in Maine, and assured him that the invention under consideration was a sound one and that the inventor who went along with it was probably worth investing in, too. Within a couple of days, IBM decided to go ahead with the development...." <sup>6</sup>

This somewhat unorthodox inaugural to Johnson's IBM career proved no hindrance. The 805 test scoring machine was first marketed in 1937 and more than 1,000 were produced, some of which are to this day busily outguessing students. His subsequent activities proved that Johnson was not a one-shot contributor. His invention record grew (by the time of his retirement in 1971 he had more than eighty patents); he proved himself an effective manager, first as head of time clock development (then of commercial importance to IBM), next as head of the team that developed the 021 printing keypunch (to which he contributed the basics of the wire matrix printer), and later as manager of a number of wartime developmental projects. Furthermore, his interest in finding ways to challenge the minds of young people, starting back at Ironwood, rounded out the reputation that made him a responsible choice to head the new West Coast facility.

## Rey Johnson, Pioneer Extraordinary



*Reynold B. Johnson*

A group of "old-timers" met in May, 1976 to consider how the 25th anniversary might appropriately be observed. The conversation ranged widely and many insightful comments from the tape transcripts have found their way into this text. With some minor restructuring the following segment of the conversation is appropriate here:

*Lou Stevens:* What do you suppose it was that made the experiment at San Jose a winner where others failed? I mean, it was more or less the vogue in those days for large technically-based companies to set up small groups of what were perceived to be highly inventive and competent individuals at remote locations and to give them relatively free rein. All of us can think of a half-dozen examples right here in Santa Clara Valley, most of which have long since disappeared without a trace. Yet our little experiment at Notre Dame Avenue spawned an industry that amounts to several billion dollars annually. What was the crucial difference?

*Bill Goddard:* Well, for one thing, we were well financed. Also, we were in the right business at the right time.

*John Lynott:* Also, there's no doubt that Rey and you had assembled some exceptionally talented people who, although they were never told so in so many words, knew that the San Jose Lab was highly expendable if it didn't produce.

*Stevens:* But couldn't all of that be said of all the other experiments?

*Ray Bowdle:* Yes, but they didn't have Rey Johnson. Now there is a unique personality with some sort of magical combination of personal creativity and unorthodox management techniques. I remember his favorite joke which he liked to weave into his talks of those days. About the two old friends who meet on the street and after some chit-chat Joe says to Charley, "By the way, how's your wife?" and Charley responds "Compared to what?" Rey liked the story because he identified with Charley. Never accept things on their face value, even a question.

*Jack Harker:* Remember all those crazy programs that we laughed at in those days? They were in some sense an extension of the environment that

Rey was able to create. Remember Howard Singhaus and the coherers? That project was a target for lab jokes but really was not more grotesque than the disk concept at the same time. We all laughed at the first disk array when we saw it in the flesh. Called it the "baloney slicer". It just happened that the right inventors came along at the right time for the disks. Rey had the knack, at a certain point in a project, of predicting whether or not the right invention was in the cards.

*Jim Beaumont:* Another Johnson gift was a genius in the assignment of people. Prior to coming to IBM I had spent two years on exotic analog-digital converters and since ADC work was going on at San Jose I naturally expected to be assigned to it. I couldn't have been more surprised when I found myself on electrostatic printing. In fact, I remember reminding Rey of my background and he said "That's great, Jim. You can be a consultant to the ADC project." And it really worked out better

*Goddard:* Another remarkable thing about Rey is that he never wrapped his arms around, and clung to, a suc-

cessful project. At the very verge of success of the 305, he removed himself from its leadership and gave it away.

*Stevens:* Well, you know why, don't you? Rey often said that success is the most inhibiting thing to progress. If you get trapped in your own success you tend just to keep on doing what brought you the success, assuming that lightning will strike again. Not many people have that trait; the self-confidence, having achieved a success, to walk away from it and start again.

*Wes Dickinson:* Could it all happen over again today in, say, a small town in Oregon?

*Stevens:* No way in today's environment. But wait a minute. Would Rey Johnson be available?

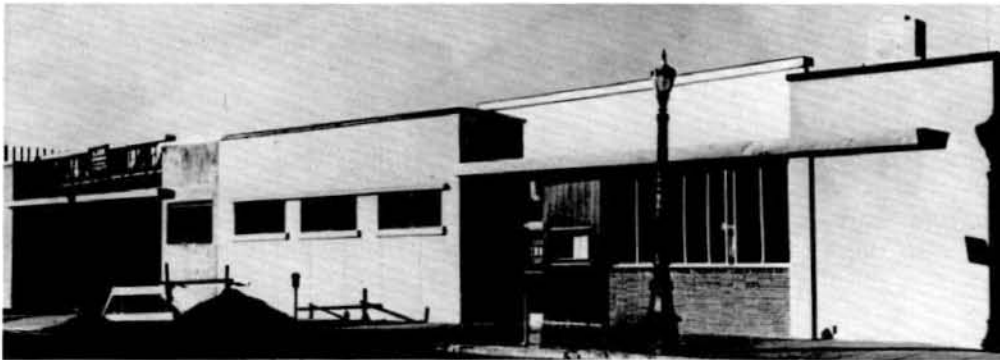
Returning now to their 1952 meeting, it is easy to imagine Johnson leaning forward at his desk, chin so characteristically resting in hand, and not fully believing the words he was hearing from McDowell, which were to the following effect: "If you take this job, Rey, I should warn you that you're not going to get much guidance from me or anyone else. You will do your own recruiting and we want you to hold the laboratory to about fifty people. You can take one or two assistants with you to help you set up shop, but otherwise you will find your talent on the West Coast. What will you work on? Well, on technologies that we're not pursuing back here. I'd be willing to suggest that non-impact printing should be one of them. Also, you know that Bill Reid (special engineering products) has been asked to look into analog data reduction and I think that, say, fifty per cent of your effort could be mutually agreed to between you and him. Otherwise, you'd be on your own. Well, how does it strike you?"

Replying that it was quite a challenge to toss out without warning, Johnson asked when and where he would start. "Well, as a matter of fact, we've already considered a number of West Coast cities and have narrowed it down to the vicinity of San Jose. Main reason is that we already have a card plant there, as you know, and Roger Williams has managed to establish an excellent reputation for us in the city. You'll find him a big help, by the way. Ken McKenzie has already been out to survey potential sites within San Jose. Now as to when you go, this is Friday. How about Monday? You see, we have an option on an existing building that Ken believes is the most promising temporary home for the laboratory, but it runs out in two weeks. I'd like for you to have the final say in the site selection. Rey, I gather that you're accepting the assignment. It's going to be a tough one and I'm sure you will appreciate that the company cannot carry the experiment indefinitely without reaping some concrete benefit. My parting advice to you is, don't get yourself into the position of the credit manager who got himself fired because he had no bad debts." Replied Johnson, "Wally, will you have dinner with Bea and me tonight? Your selling job is only half done."

### *Setting Up Shop at 99 Notre Dame*

McDowell's second selling job was obviously not too difficult because the following week found Johnson, James Hood, Harold Martin and William Reid meeting in Roger Williams' office in the former laundry building on 16th Street, which had been converted to a card manufacturing plant during World War II. Hood and Martin, both from Endicott, were Johnson's chosen assistants, Hood because of his established capability in laboratory administration and Martin, a recent California Institute of Technology graduate and already a member of Johnson's staff, because of his familiarity with both California and science. Reid had been assigned to assist when he could in the early weeks. The quartet again went over all the proposed sites, visited the most promising, and wound up signing a five-year lease on an old stuccoed cement-block building at 99 Notre Dame Avenue that had previously been occupied by a printing establishment. Renovation began on February 1, 1952.<sup>9</sup>

The San Jose Mercury for that day devoted only a few short paragraphs to the event, noting that Johnson would reveal only that work at the new lab "will be devoted to advanced research and development work required on future IBM machines." News that 1,047 aircraft had been lost to date in Korea; that San Jose was drying out from a long drenching rain that had caused unprecedented flooding; and that Elizabeth Taylor announced her engagement to Michael Wilding, all received bigger play.



*The first home of IBM engineers in the Santa Clara Valley was this building at 99 Notre Dame Avenue, across the street from the Rosicrucian Press and next door to the Department of Motor Vehicles building. The building still stands. It remained an IBM location until 1968.*



## Announces

*a new laboratory for Engineering  
Research and Advanced Development in  
Santa Clara County, California.*

The laboratory staff will include scientists and engineers with advanced degrees or outstanding experience in Applied Physics, Electrical and Mechanical Engineering; Bachelors of Science who have exceptional creative or analytical ability in these fields, and precision tool and model makers.

*Inquiries may be addressed to:*

Mr. J. D. Hood  
International Business Machines Corporation  
Laboratory for Advanced Development  
99 Notre Dame  
San Jose, California

*This recruiting notice appeared in several West Coast newspapers in February, 1952. It drew over 400 responses.*

One of C. Northcote Parkinson's corollaries is that an organization adequately housed is already obsolete. Ninety-nine Notre Dame admirably shielded the young group from this hazard. Drafty in winter, so hot in summer that a sprinkling system was installed on the roof in a vain attempt at evaporative cooling, the structure offered little in the way of comfort and nothing at all of luxury. Yet many of its inhabitants will still tell you that their most enjoyable working days were spent at 99 Notre Dame Avenue.<sup>10</sup>

As the building remodeling proceeded, an advertisement appeared in all major West Coast newspapers announcing the new laboratory and soliciting applications. Several hundred responses were received and in mid-February Louis D. Stevens, a member of the Defense Calculator design crew at Poughkeepsie, was brought out temporarily to assist with the interviewing and returned in May as Johnson's technical assistant. In the light of today's practices, old-timers are inclined to marvel at the fact that they were for the most part hired on the basis of a single interview, and it is a monument to the judgment of the interviewers that so few disappointments were brought aboard. Of the first year's new employees (see Appendix A), only a handful had previous digital computer experience. It is striking that over 50 percent of the surviving original cadre are still associated with IBM either as retirees or employed with the company.

Johnson laid down three principles to guide the new arrivals:

- It is essential that each engineer be familiar with the purpose, function and environment of the machine or machine component on which he is working to the degree that his work affects the proper performance of the function in the ultimate environment. (To this end it was an early practice to invite guest lectures by IBM customers, salesmen and executives, who were asked to emphasize the shortcomings of the product line as it existed, rather than to extoll the virtues.)

- It is the responsibility of every engineer to be conversant with all other projects going on in the laboratory.
- It is your most important assignment in this laboratory to give assistance, in the form of consultation, experimentation or suggestions, when you are asked to by another engineer; and the second most important is that of carrying forward the project to which you are assigned.

Perhaps such principles which lead to cross-fertilization are not as likely to be practical in a large laboratory, but to the small group at 99 Notre Dame these principles were intended to be taken seriously. The result was a close-knit cooperative operation so free of rancor that it is difficult to write about today without appearing either addlepatated or mawkish.

At any rate, by July 1952, a reasonably smoothly functioning organization of some thirty people had embarked on a number of projects, with each engineer normally working concurrently on more than one. Many, of course, such as the coherer research, tape-actuated binary accounting machine, and others, were terminated without ever having any impact on the product line.



*Participants in the opening session of the education program at the San Jose Laboratory, December 19, 1952. (See list at right)*

*Front Row, L-R*  
*Hal Martin*  
*Rey Johnson*  
*Hal Woolf (District Manager)*  
*Bill Needham*  
*Jim Hood*

*2nd Row*  
*Harry Wisdom*  
*Joe Price*  
*Al Lutus*  
*Frank Maurer*  
*Jack Harker*  
*Anita Sullivan*

*3rd Row*  
*Bill Holman*  
*Hale Zimmerman*  
*David Kean*  
*Dean Hodges*  
*John Lynott*  
*Paul Pecchinino*  
*Gloria Doolittle*

*4th Row*  
*Warren Christopherson*  
*Lou Stevens*  
*John Haanstra*  
*Len Myers*  
*Lloyd Allen*  
*Ray Bowdle*

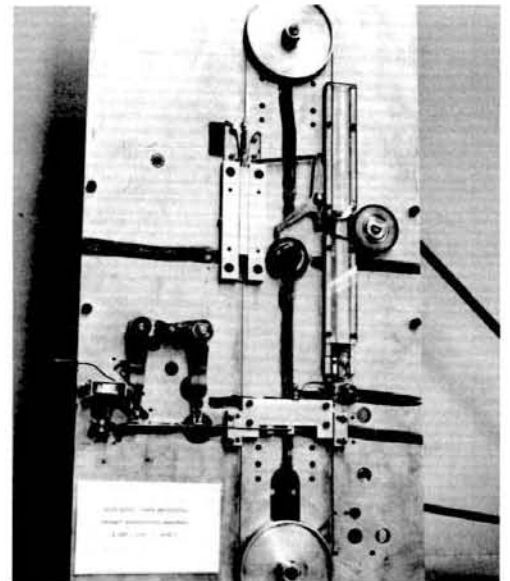
*5th Row*  
*Bill Maron*  
*Doug Dethlefson*  
*Bill Crooks*  
*Jim Welch*  
*Victor Westerfield*  
*Jake Hagopian*

## A Few That Never Made It

*Coherer Storage:* A loosely packed mass of conductive particles placed between two electrodes presents a high impedance to low voltages, but becomes highly conductive when a threshold voltage is passed and remains in this state until physically disturbed. Coherers were thought to be potentially useful as memory elements in certain EAM applications.

*Tape Actuated Binary Accounting Machine:* This machine made use of type elements attached to a steel tape that travelled through an intricate system of rollers. In response to a binary input code representing the character to be printed, the tape would move the desired type element before a hammer which would then strike it, leaving an impression on a sheet of paper. A similar principle was used in the Printer Plotter, a device which was intended to print with high precision (at 600 per minute) any character or symbol randomly at any location on a sheet of paper. Both developments suffered from the dimensional instability of the steel tape under varying stresses and temperatures.

*Passivity Phenomenon Storage and Switching:* This project was an attempt at duplicating "some of the work of R. S. Lilly as described in 'The Passive Iron Model of Protoplasmic and Nervous Transmission and its Physiological Analogues,' *Biology Reviews* 11:181-209." However, the final report noted that the state of art was not sufficiently developed for practical use, and that "problems of renewal of iron wire in nitric acid do not appear easily soluble."



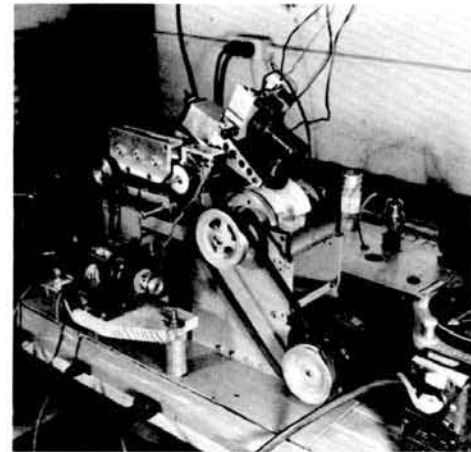
*Plate model of the binary actuated accounting machine mechanism.*

*Sentential Calculus Machine:* This was a relay device for performing purely logical operations. Its purpose was to examine the logical relationships that exist between given non-numerical information, and it could be programmed to determine whether one class of such information was a logical consequence of some other given information. This intriguing device, with its clacking relays and flashing lights, proved something of an embarrassment, since visiting dignitaries sometimes took it to be a much more significant development than it actually was; they envisioned it as virtually the route to solution of upper management problems, a cure for international strife, and the pathway to the meaning of life.

*Electrostatic-Dielectric Memory:* This was a metal disk with a thin sheet of dielectric cemented to it, above which was placed a set of writing, reading and erasing electrodes. Charged spots on the dielectric could be written with a pulse of voltage and read out through the non-contact reading electrodes while the disk rotated at 1,200 rpm. (Note the interest in the disk configuration as early as June 1952.)

*Non-mechanical Printing:* McDowell's suggestion that non-mechanical printing might be a worthwhile pursuit for the new laboratory was picked up in two forms. One was based on the use of special electrolytic paper of the kind then commonly used in plotting instruments such as the electrocardiograph. Because of the need for specially treated paper and its generally poor resolution, this approach did not last long.

A more significant program under the direction of James Beaumont employed the then primitive electrostatic or xerographic principles, a technology which had been of interest to Johnson for some time. Xerographic plates were exposed to the light emanating from a cathode ray tube. Eventually a complete printer comprising most of the essential elements (character generation, electrostatic plate, automatic transfer to paper, thermal fixing), though possessing little of the refinement and performance required for a product, was completed before the project was transferred to Endicott in early 1953.



*Laboratory setup of some early componentry for the non-mechanical printer project.*

### *Data Reduction and Source Recording*

For several months the main effort at 99 Notre Dame was an investigation of systems for automatically converting analog electrical signals from sensors used in wind tunnels and other applications into a form that could be operated upon by IBM's standard equipment, punched cards. This was done under the San Jose Laboratory's charter obligations to Bill Reid. But when Douglas Aircraft accepted a proposal for the automatic reduction of data from its wind tunnel, the effort became something more than a paper study. Although the task did not encompass the actual design of the sensors themselves it was, of course, necessary to understand their idiosyncracies in some detail in order to design an overall system to accommodate them. Analog-to-digital converter projects flowered in many corners of the laboratory and, to back them up, there were a number of low-level switching and direct-current amplifier projects. Even a few alternatives to the punched card were looked at. One in particular was called "micro-hole recording" and consisted of piercing paper tape with a high-voltage arc.



*The cafeteria doubled as a class room.*



*Interior of the original section of the building at 99 Notre Dame. Note the clock, at that time an IBM product.*

However, a project entitled "Source Recording" was destined to have the most pervasive consequences for the San Jose Laboratory, and indeed for IBM and the data processing industry. Source Recording was defined as encompassing "all processes which take alphanumeric data from any source and transcribe it in a way so that the resulting document may be handled by machine methods." The punched card was such a document.

Initially consideration was given to eliminating the cards altogether, but then the definition was narrowed to mean either minimizing or eliminating the key punching task itself. As this process was studied in detail it became apparent that a very large proportion of the data that had to be entered onto transaction cards was not new information but, rather, relatively unchanging data that existed in, and had somehow to be extracted from, the user's own files. In order to simplify the transfer of this sort of information to transaction cards, the industry had invented the "tub file," to be described further in the next chapter. Tub files were awkward and costly adjuncts to machine accounting and so the goal of Source Recording gradually switched to, first, the mechanization of the tub file and, later on, its replacement. It was this search, commencing in the fall of 1952, that would lead to the invention of the random access disk memory (or RAMAC<sup>11</sup> as Jerrier Haddad labeled it) and the subsequent reshaping of the computer industry.

### Chapter 3. Wild Ducks Amongst the Orchards

In order to see what actually led to the RAMAC, it is necessary to step back in time a bit, and elaborate on machine accounting as it existed at mid-century. The introduction of the punch card obviously held profound implications for the way in which accountants went about their business, but there were other consequences that were not so obvious, at least not to the outsider. One of these is implicit in the term batch processing.

As a vehicle for this explanation, and because it occupies a crucial place in the RAMAC history, consider the classic problem of inventory control in, for example, a large wholesale house with many customers and thousands of catalog items received from hundreds of suppliers. What did the wholesaler do with his IBM equipment when a customer order came in for, say, 500 pairs of black shoes and 200 pairs of brown, in various sizes and styles? He did not simply punch the item and customer numbers into a keyboard, select the customer order routine, and sit back while the machine performed the myriad tasks that such a transaction entails. Rather, he punched into a card the item numbers for size, etc., the quantities of each, the customer number, shipping instructions, and so on. Then he would lay the card aside until he had accumulated a "batch" large enough to permit an economical sorting run. After sorting he would have to make collating runs against his entire master file of customers and his entire master file of commodities, etc., in order to extract from them the unchanging information necessary to submit to the tabulating machines so that they could make up the required shipping room instructions, packing slips, invoices, shipping labels and bills of lading. And what if the batch contained orders for more pairs of Style 4A2, size 9C shoes than were in stock? Well, things got fairly complicated.

This general problem came in for considerable discussion at 99 Notre Dame, particularly as it focused on the billing and inventory control operations of the Zellerbach Paper Company.<sup>12</sup> Zellerbach, and some other enterprising businesses, recognized that they needed random access (although they did not call it that) to their master files. As a result, they had resorted to what became known forthrightly as the "tub file." Tub files were very large rectangular trays containing master cards (or commonly several copies of each) arrayed in sequence (by customer number, item number, or whatever). In a typical

operation, clerks would search the tubs and pick out cards containing the needed customer and item order information. From these it was possible to go directly to the tab room and produce the needed documents. Thus the tub file offered a crude approach to direct access in-line processing at the expense of an incredible amount of clerical effort involved in servicing the master files.



*This sketch showing a "tub file" operation of the 1950's era, is from an illustration in the Technical Report Proposal for a Source Recording System by Arthur J. Critchlow, dated February 2, 1953. The artist was James Welsh.*

#### *A Crusade for Tub File Automation*

The introduction of magnetic tape-based electronic data processing machines in the early 1950's made very high-speed sorting and collating feasible, although being sequential it represented a step in the opposite direction from random access. Meanwhile, there were individuals who were determined to automate the tub files. Notable among them was Ed Perkins, special representative in the IBM San Francisco branch office, who had devoted much of his life to a crusade for such automation.

Perkins first came to the San Jose Laboratory as a guest speaker at one of the frequent lecture sessions held in the cafeteria. He soon became a regular visitor to the Laboratory, wheedling and cajoling until his message was thoroughly understood. He arranged visits for the engineers to witness for themselves the horrors of tub file operations on the premises of important San Francisco customers; his enthusiasm caught on. It can truly be said that it was Perkins more than any other individual who opened the eyes of key San Jose engineers to the systems significance of automating the tub file.



*Ed Perkins, a special representative in the San Francisco branch office, was a frequent visitor in the laboratory.*

But how does one go about doing this? Quite naturally, the first inclination is to follow the task description literally and devise a mechanical hand to reach down into the massive box and pluck out the desired cards. Although this approach never got beyond the talking stage, it was considered.<sup>13</sup> When, in September, 1952, Arthur Critchlow was specifically assigned to lead the Source Recording project he stated the problem as follows: "The problem of reducing the need for punching cards from keyboard controlled card punches...is acute. Means are required to reduce the cost by using machine methods of punching cards directly from data being handled. I am to study the forms in which information is now being made available to key punch operators and endeavor to determine means of supplying information in better form." It is intriguing that despite this initial description of the project Critchlow would actually turn to transferring the fixed data from the tub file to the transaction cards. This shift undoubtedly represented his early realization, under Perkins' influence, that the major stumbling block was not the keying of source information but, rather, the transfer to transaction cards of the relatively stable file information.

#### *Identifying the Goal*

Out of all the debates that thus swirled about the problems of tub files in general and Source Recording in particular, it became clear that some type of magnetic recording device permitting random access would be required. Years later Johnson would call the decision to experiment along these lines one of the best he ever made.

Precisely what kind of device this might be, however, was not at all obvious. Besides the punch card there were then three principal means of storing information: magnetic tape reels, core arrays and drums. Each of these had serious drawbacks. Cores, for instance, permitted rapid random access but were expensive; drums, with their low surface-to-volume ratio, were also expensive, although less so than cores.

If the problem of "tub file automation" had been formulated (which it was not) in terms of providing a randomly accessible medium with a surface/volume ratio much higher than that of drums, relatively straightforward thought would have

led either to the disk geometry or to strips of magnetic tapes, depending on the engineering problems envisaged and the access times sought. However, there was one glaringly obvious problem with the disk approach: how to maintain the necessarily minute spacing between the recording head and the surface (typically 1/1,000 of an inch). Ample experience with compliant reeled tapes had shown that the medium and head could be operated in contact with one another without excessive wear of either, but this could not be expected of rigid media.

Sometime in mid-1952, McDowell had been approached by Ward Beman, President of the Telecomputing Corporation, a company that was marketing a digital x-y plotting device. It had occurred to Beman that if the plotting head of his company's product were to be replaced by a plucking mechanism, it might provide random access to bins of magnetically recorded tape strips.<sup>14</sup> McDowell arranged for IBM support of this work and assigned Johnson to monitor the contract.

Critchlow, meanwhile, had been working on a variety of alternate proposals for automating tub files. By November, 1952, they had narrowed down to two. One of these was an endless belt with (master) cards attached to provide the operator with a visual selection of the desired card, and a readout at which the desired card was "electrostatically photographed." The "photograph" was then read with electrical sensing into a (new) punched card. Perkins favored this idea because of the visual selection feature, a principle he strongly advocated at this time. The second contender had first been suggested by Johnson; it was a matrix of parallel vertical wires, each one foot long, with a card's worth of information recorded magnetically (remember the audio wire recorder was still on the market in those days). This was similar to the Telecomputing idea, except that wires had replaced tapes.

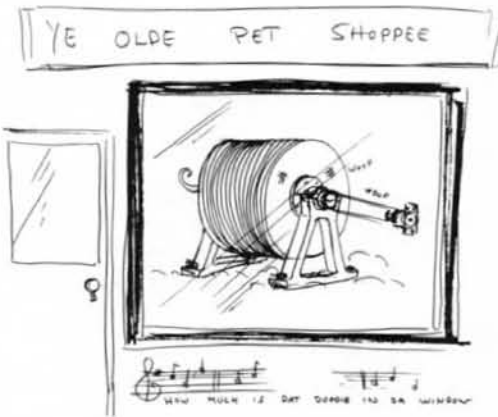
Outside IBM, Jacob Rabinow of the National Bureau of Standards had described a "notched disk memory array in which each disk was rotated independently."<sup>7</sup> His paper circulated around the San Jose Laboratory and appears to have given rise to the idea of stacking several magnetically-recorded disks along a continuously rotating shaft, each disk containing a number of concentrically-recorded tracks. An access mechanism capable of transporting a read/write head to the proper track on the proper disk was also conceived.

### *Betting on Disks*

Johnson later noted, "Every configuration that an ingenious staff could think up was investigated, including magnetic cards, plates, strips, bands, wires, disks and rods." However, the disk geometry offered two major advantages not readily offered by any of the others: data were continuously available (so that one character per revolution of the disk could be read out to a card punch), and the geometry would permit multiple access to the same information (i.e., several access mechanisms could be arranged around the disk stack). These advantages were so appealing that after the usual long debating session Johnson decided, in mid-January 1953, to go with disks. A work order for that month reads: "Magnetic Disks have been selected as the best medium for the Random Access Memory to be used for File Maintenance. Disks will revolve continuously at 16 r.p.s. so that any of 200 columns of a record may be read out in any sequence, from any of 20,000 records..." On February 2, Critchlow postulated objectives for a disk storage configuration which did not miss the final figures by a great deal.<sup>15</sup>

Was the disk decision a popular one with Laboratory personnel? Hardly. Very few of those then aboard can look back on those days and declare "I was a believer." Jack Harker recalls advising Johnson that he was backing a mechanical folly; the popular nomenclature for the disk array was "the baloney slicer;" deprecating cartoons appeared on bulletin boards.

To appreciate why the decision was unpopular, consider the state of the art of digital magnetic recording at the time. The most nearly analogous geometry was the drum. Although the ratio of available recording area to volume occupied was very low, drums had the advantage that they could be made structurally rigid and stable even at high speeds. The magnetic recording elements, therefore, could easily be kept close to the surface by relatively simple mechanical supports. Disks, however, were an altogether different matter. It was not reasonable to



*This lampoon of the disk idea quoting a popular song of the day appeared on the Laboratory bulletin board one morning and reflected substantial group opinion.*

expect that the periphery of a disk of large diameter/thickness ratio could consistently provide anything like that sort of stability. Runouts (wobble) of as much as one-tenth of an inch were observed in carefully assembled laboratory models of disk arrays. How could one possibly maintain close head-to-surface spacings under such conditions? Indeed the problem--which would sometimes be described to non-engineers as roughly equivalent to trying to keep a large airplane flying within a few feet of the ground--seemed so awesome that the disk decision was temporarily set aside and alternatives reexamined.

In such an environment it must be recorded as a most courageous decision on Johnson's part to return to the disk configuration on April 14, 1953, a decision that would stand from that time forward. Although there is no record of precisely what led to this reaffirming of disks, it was very likely the result of two things. The first was simply Johnson's great confidence that some very formidable technical problems would yet be resolved. The second was that he had people available to tackle the assignment.

#### *The Air Force Requests an Inventory Control System*

During this period the concept of literally automating the tub file had clearly given way to one of replacing the function altogether. Yet the general idea was still that the disk memory would be part of a "File-to-Card-Machine." Basically, information was to be stored in the random access memory from master card input and retrieved by addressing the stored information with a location number, the output appearing as a reproduction of the original master card, produced on a modified 026 key punch. Conceptually it was an automated tub file. A prime motivator toward a more ambitious concept soon appeared in the form of a request for a proposal to provide an inventory control system for U.S. Air Force base supply. Such a system, called Material Inventory Flow Device (MIFD), would require a very-large-capacity randomly accessible memory not unlike what was being considered. In addition, however, it would require information processing capability. John Haanstra and some of the Laboratory's systems people were assigned to respond to the Air Force request, and a proposal was submitted on April 1, 1953. Even Rey Johnson's confidence in the disk



*J. W. Haanstra.*

Those whose lives he touched will always remember this man of genius. He might have become a great teacher. He had the personality and charisma to be a successful salesman or a statesman. He had that unusual array of talents that would have assured his success in almost any undertaking, a true generalist. But John Wilson Haanstra chose to become an engineer. Here is an excerpt from an article "Sunlight, Roses and Jukebox Genius" which appeared over his name in the April 21, 1956 issue of *Saturday Review*:

"Of course, I am happy to belong to the engineering group that is perfecting what I believe will be the 'brain' of the automatic office of the future. I am proud to be among those who have developed what is popularly called 'the jukebox memory', which files away 5,000,000 bits (sic) of information at a time on disks like phonograph records. I enjoy the sense of living on the frontier of knowledge, sharing ideas with members of the more than fifty technical and learned societies that are active here. But I would be something less than truthful if I did not confess that

my greatest pleasure comes from the almost perfect climate (of Santa Clara Valley)."

Ironically, less than two years after this article appeared, John found himself in White Plains, N. Y. as assistant manager of product development for the Data Processing Division. His abilities were too great to permit him to remain to enjoy the climate, and he never returned to live here.

John liked winning and winners. He was an unabashed Yankee rooter in the days when Yankee-rooting was anathema. He was a company man and revelled in the strategies of upper management. He rose to become the President of Systems Development Division in 1965 and the attitudes and visions that were instilled in him in San Jose indelibly stamped IBM product philosophies over the years.

His career came to a tragic end in 1969 when the private plane he was piloting crashed on the high plains near Cline's Corner, New Mexico.

configuration was still not sufficiently high, and to satisfy the random access memory requirements of MIFD a complex of ten magnetic drums, each capable of storing 3,200 twenty-decimal digit records was recommended. An appendix to the proposal suggested that at a later time the drums might be replaced by either magnetic disks, magnetic plates or magnetic tape loops.

There was to be one final see-saw in the disk debate, however, and by May 25 Johnson's faith had risen to the extent that he felt willing to commit himself to a change in the MIFD proposal, replacing drums with disks. "The problems involved in a Magnetic Disk Random Access Storage have been identified," he wrote to McDowell, "and a program is well under way to find a solution.... It is the considered opinion of the responsible engineers concerned that the engineering problems associated with the development of a (disk storage device) are no more formidable than those associated with the use of 10 drums."

What had happened to raise Johnson's confidence? Two very crude experiments that apparently alleviated any concern, on his part at least, over whether or not a disk array would actually work. The first of these merely involved putting 125 two-foot disks on a shaft and finding that they could be run smoothly by a motor without drawing excessive power, and that a person could place his finger on a disk and follow it as it turned. The second experiment involved proving the concept of the air bearing to support the magnetic head, the account of which will be found in Chapter 4.

In retrospect, it is probably a blessing that the Air Force selected another contractor for the MIFD, for it seems inevitable that the task would have completely engulfed the (by then) seventy-man laboratory and severely affected the work on what has turned out to be a vastly more significant development. But the MIFD proposal effort did bring home that there were immediate problems in the real world for which the laboratory had a potential solution. It also set in motion the thinking that led to the notion that the disk storage device might become the center of something vastly more powerful than an automated tub file. In particular, the vision of the modern time-shared teleprocessing system that John W. Haanstra gained through his MIFD experience went on to permeate the entire IBM product line.



*There was a question of the feasibility of rotating a large number of disks mounted on a shaft. Almost the first thing that was done after the disk idea gained serious consideration was to assemble a model, as shown.*

## Chapter 4. Evolution of a Concept

When the decision to concentrate on disks was reaffirmed in April 1953, the fledgling San Jose Research and Engineering Laboratory had on its hands a fragile infant with a staggering assortment of birth defects. In those days product planning for the company was concentrated at IBM World Headquarters, and it was an unorthodox reversal of roles for engineers to define new product opportunities in the way Critchlow, for instance, had done by specifying design objectives for a disk memory. Johnson says of this period, "The practice of having engineers assume the initiative for identifying the problems for research programs was the subject of many discussions in the months that followed."

### *The Disk Project Gets Off the Ground*

With the April 14 decision to abandon all competitive technologies and concentrate on the disk configuration, the project really got off the ground. William A. Goddard was put in charge of developing a file model, and he was assisted by D. D. Johnson, J. J. Lynott, G. Hotham and Warren Gonder. Edward Quade and his group were asked to design a magnetic read/write element that in order to fit between closely-spaced disks could be no more than one-tenth of an inch high. The magnetic recording aspects were assigned to Haanstra and Alton E. Ewing; David W. Kean began the design of the File-to-Card machine and another group headed by Haanstra <sup>16</sup>, undertook a more serious investigation of the extended systems implications of large-capacity random access memory.

If any single contribution was the key to success, the idea of maintaining essentially constant spacing between the magnetic elements and the badly wobbling disk by means of air lubrication must be accorded that ranking. A successful product could not have been built without it.

Recalls Goddard: "There was no 'eureka' experience when I learned of the head/disk problem; air bearing was just the only way to do it. In line with the laboratory philosophy that each engineer should be concerned with the totality of laboratory problems, I drew up a sketch of a simple air head and submitted it to the group concerned. But the idea was not pushed." However, on May 4, after he had become project leader, Goddard handed another sketch of the idea to

Don Johnson and asked him to try it out. Within two weeks the first physical embodiment had been successfully “flown” on a badly warped disk. With this very significant experiment, Rey Johnson could now claim the problems remaining were no more formidable than those associated with using ten drums.

On June 2, the third model of the air head, this one containing a magnetic read/write element of the type used on the 701 drum, was used by Haanstra and Ewing to write 51 bits per inch on a spray-coated aluminum recording disk. The read-back signal showed surprisingly little modulation and the very first checked readback ran for four hours before an error occurred. Static measurements showed an essentially constant head-to-surface spacing of 0.0024 inch over a wide range of air pressure.

The proving of the air head instilled a new sense of confidence in the young laboratory and the disk file project soon absorbed the best efforts of most of the personnel. Sub-groups were formed, dissolved as they completed their tasks, and reconstructed to meet new challenges as they arose. Such organizational fluidity was to continue until the 305 RAMAC was announced. Indeed, overreaction to a problem sometimes led to a shuffling of people. Goddard was concerned about this and wrote at the time that he “had considerable discussion with Hood and Stevens about the situation generally.” Some feared that the sweet smell of success threatened the earlier spirit of composure and cooperation; in fact, in the hectic days ahead, there was little serenity but much cooperative participation.

### *Three Tough Problems Besides Air Heads*

As important as was the proving of the air head, it by no means eliminated all the obstacles facing the builders of a working file. Three additional problems loomed, all major: getting a sufficiently flat disk surface; finding a way to coat the disk; and designing an access mechanism that could transport the air heads bearing the magnetic read/write elements to the desired track on the correct disk.

*The Disk Surface:* Initially the disk effort was directed toward finding a material flat enough to allow holding the head close to the surface solely by means of a mechanical support. Aluminum, brass, glass, plastics and magnesium were all considered, and the very first array was built up from 24-inch disks cut



*This is the first air bearing successfully to demonstrate a practical means of maintaining a spacing between the disk surface and the magnetic element.*



*By June, 1953 successful reading and writing had been accomplished using a modified drum magnetic element in a revamped air bearing design.*

*The first disks were spray coated, but uniform quality was elusive. The pouring technique, using centrifugal force to do the spreading, was a quick success. On the right a disk emerges from the spin-coating operation.*

from sheet aluminum with a Stanley home workshop router. Initial experiments to spin a large stack of disks proceeded cautiously for there were no computer models then to predict the aerodynamic and inertial forces that would be developed. The experiment reached the desired 1,200 rpm without calamity but the experimenters were dismayed to observe their “flat” disks wobbling wildly, with runouts of one-fiftieth of an inch and greater. The first successful disk was turned from magnesium lithographer’s metal, but it soon gave way to aluminum laminates clamped under pressure between platens and heated in an oven above the annealing temperature.

*The Disk Coating:* The first successful magnetic coating was a paint formulated to specifications developed by Hagopian. It used a dispersion of iron oxide particles in a paint base similar to that used as a primer for the Golden Gate bridge. Initially the aluminum disks were spray-coated with the paint, but neither this method nor dipping produced a sufficiently uniform surface. This problem plagued development into the fall of 1953, when Hagopian was assigned full-time to the project. He came up with a spin method for applying the dispersion, a major contribution. Bill Crooks produced the first truly successful disks by filtering the dispersion through nylon hosiery and using paper cups to measure out just the right amounts for spin coating. Though they continued to be used for over a year, both cup and hose were supplanted by an automated process; however, the essentials of the process remained intact. The ultimate solution to disk coating paint was to occur somewhat later with the invention by Marcel Vogel, Don Johnson and Ralph Flores of the formulation which is basically the same as the one still in use.



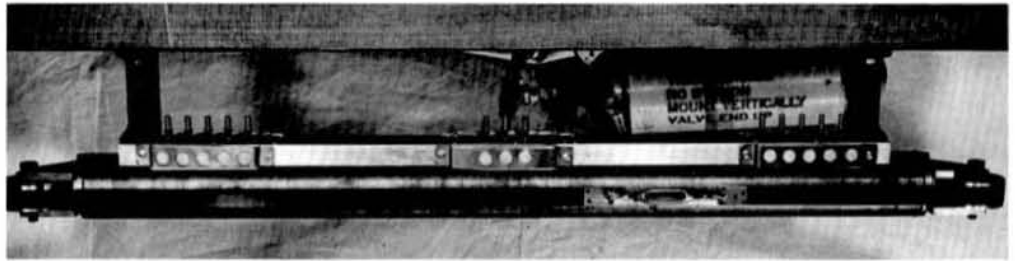
*The Access Mechanism:* This proved to be one of the toughest design problems. One difficulty was that a stiff load had to be applied to an air head for it to work. In early embodiments loading was provided by a spring, but this caused problems when the heads (one on either side of a disk, supported by arms) were moved from disk to disk. A number of alternatives were considered in turn and abandoned until the ultimate answer was devised by Norman Vogel. He showed that with a properly designed air head a self-loading force could be developed.



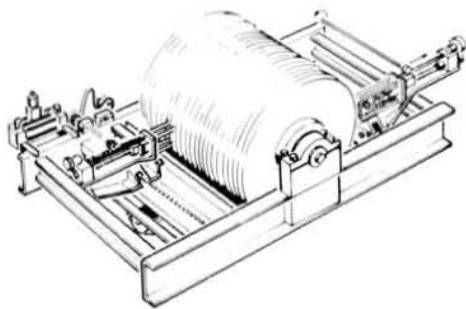
*The early Lab privy council waxed and waned but generally included (from the left) R. Manning Hermes, William A. Goddard, Reynold B. Johnson, Louis D. Stevens, Arthur J. Critchlow and John W. Haanstra.*

At the outset, three teams were set up to consider three candidates for providing the disk-to-disk and track-to-track accessing motions, which at that time were considered entirely separate problems. Crooks and Haanstra were to work on an electrical servo-drive system; Don Johnson and R. Manning Hermes were to pursue an approach based on the IBM 402 type bar mechanism; and Gonder was assigned a system using cams and spring clutches, the details of which have been lost in antiquity. The servo approach was the early favorite for the track-to-track drive, but was somewhat suspect for the tougher job of moving the heavy carriage from disk to disk. James Davis and Lynott went to work on the track-to-track servo detail design. After a number of redesigns, Davis, on October 28, was able to relocate a previously recorded track for the first time.

*The pneumatic access mechanism.*



Goddard, meanwhile, had returned from a visit to Rabinow at the Bureau of Standards with an idea for a pneumatic servo approach to the disk-to-disk drive, only to learn that Lynott had proposed something similar six months earlier. Now the idea had two champions and so a bench model was constructed and successfully demonstrated. But there was already growing concern about the size of the air compressor that would be needed for the head lubrication, and the additional large demand for air was cause for rejection.



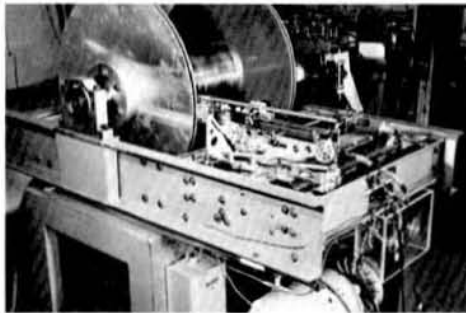
*Artist's conception of what the finished random access file would look like. Again the artist was James Welsh.*

On November 1, 1953, Johnson assigned Louis D. Stevens responsibility for the development of the magnetic disk memory and its adjuncts concurrent with his promotion to senior engineer. Stevens, who as Johnson's technical assistant had his fingers into everything, was to see the IBM 305 through its announcement and early manufacture.

Also in November, Lynott found a way to use an electrical servo system in a multiplexing mode so the same servo could be used to drive the carriage from disk to disk as well as to access the heads from track to track. This simplification eliminated a great deal of hardware and vastly improved prospects for reliability.

While the foregoing may sound relatively straightforward, anyone who has worked with servo systems knows that they do not go together without a struggle. Those present recall that when power was first applied to the servo system one Saturday evening, the carriage responded perfectly to disk addresses keyed in manually. Then, while all hands stood about congratulating one another on this further show of substantial success, the carriage suddenly began an uncommanded motion southward (the shaft at this time was still horizontal), gathered

momentum, sped on toward the end of the way, rocketed free of the entire mechanism, and landed in a gloomy heap on the laboratory floor. Surveying the carnage, Lynott could only sigh, "Well, back to the old drawing board." Twelve days later, on February 6, 1954, a completely redesigned servo system for the first time successfully accessed between two magnetic records on different disks. This incredibly speedy redesign was primarily the work of Lynott, Davis and Trigg Noyes. Although severe servo design problems lay ahead, this demonstration was still a cheering sight to all.<sup>17</sup> The IBM 305 was the first IBM commercial product, incidentally, to incorporate a servo, a matter of no little worry to management, since it had no prior experience with servo mechanisms.



*The first partially assembled random access file test bed as it appeared on February 2, 1954.*



*The "file-to-card" machine consisted of the RAF test bed (above), an 026 key punch modified for I/O service and the control electronics (against the wall). First operable on February 10, 1954.*

Meanwhile, Ewing had completed the design and construction of the read/write amplifier and Stone, Bowdle and Kean had at least partially debugged the File-To-Card machine circuitry. The FTCM and the Random Access Memory were quickly connected together and joint operation was attempted. On February 10, 1954 the first successful transfer of information from cards to disks and back again from disks to punch cards took place. The following messages were printed and punched out at the 026 station:





## Chapter 5. From Dream to Reality

Slowly, the weary components of the original File-to-Card Machine were coaxed and cajoled into a semblance of working order, but the machine never performed with any degree of reliability. Nevertheless, just seeing it work at all gave the staff morale a boost that carried it through the painstaking refinements that were to occupy the next two years.

*The random access file effort was supported by an outstanding group of model makers. From the left, Ed Johns, Charley Morgan, Bill Mueller, Ed Ursuny, Bud Ritts, Harry Wisdom, Ray Chadly, Chuck Blackley, Dean Hodges and Frank Maurer.*



Word of the marvelously entertaining spectacle of a pair of magnetic heads dashing pell-mell from disk to disk, and then in and out along a radius, soon spread to the east and a small trickle of visitors started to appear in San Jose. But, as Stevens has said, “The array looked like a Rube Goldberg arrangement [and still] not many people believed we would be able to make such a thing practical, and [even if we did] doubted we could be successful in pushing the business toward anything different from the batch processing scheme...but it was like a religion with us, — we were going to make the damned thing work for sure and...solve those systems and those technical problems in spite of ‘those guys’. Because if we failed in this environment, the whole San Jose experiment would fail... None of us was going to allow that to happen...”<sup>5</sup>

Nevertheless, around this time a near calamity almost did bring the entire project to a premature end. A new set of disk spacer rings was received undersize and to enable assembly of a model the rings were cut with a split, similar to piston rings. The model was put together with only a few disks plus a number of clamped spacers. This was a serious mistake for as the disks were being brought up to speed, one of the spacers flew asunder, triggering a chain reaction that disintegrated the entire stack, hurtling shrapnel in all directions. Two people

When "Desk Set," the hit comedy about computers, came to San Francisco, Laboratory people attended more or less en masse. Greeting the star, Shirley Booth, back stage are (from the right): Roy Haug, Miss Booth, Norman Sly, Morton Astrahan, Mrs. Astrahan and Mrs. Haug.



were hurt seriously enough to require hospitalization, and to this day Wes Dickinson bears a reminder in the form of a small scar across the bridge of his nose. This incident resulted in much testing at high speed with the spacers made to specification to be sure that the disk files were not a product that behaved like a hand grenade. No further incidents of the sort have occurred.

#### *The First Model is Jettisoned*

"Religion" sometimes requires confession and it soon came time to confess that neither the first model of the disk file nor the File-to-Card Machine were performing well enough to make them convincing demonstration vehicles. On March 19, 1954, an in-depth re-evaluation of every basic file design decision was undertaken and specifications for an entirely revamped entity, called Model II, were drawn up. By June all effort on the original hardware was abandoned and it was consigned to the warehouse.

Concentration was now on a more sophisticated Model II, of which five copies were to be constructed. Actually Trigg Noyes had been thinking about a new design for some months and one of his first decisions was that the shaft should be upright rather than horizontal. His reasoning was that this would: (1) provide more workable dimensional aspects for the overall machine, (2) make disk replacement easier, and (3) provide more space for a number of independent access mechanisms.<sup>18</sup>



The "new" carriage as it appeared in November, 1954, showing, detents, servo potentiometers, ways and heads. This was the first version of the multiplexing, servo-actuated access mechanism.

Meanwhile, radical rethinking of the proper product environment had followed the early pioneering systems work by Haanstra. This work was collected in a December 2, 1954 report called "Magnetic Disk Processing Machine." With remarkable clarity this document argues the great functional power that a successful random access file would open up. It also sets forth in considerable detail the basic elements on which the logic of the IBM 305 RAMAC was based. Gone forever were any thoughts of simply automating the tub file.

*Breakthrough on the Diplomatic Front*

As summer gave way to fall, progress on the Model II file provided increasing confidence in the disk concept and the San Jose Laboratory appeared to have everything going for a successful product, except for corporate acceptance. But corporate management had been sufficiently intrigued by the noises emanating from the west to assign F. J. Wesley the task of keeping tabs on it. It did not take Wesley long to become a convert, and a diplomatic breakthrough occurred via a letter he wrote dated October 8, 1954. This letter is worth quoting at some length:

"I have watched the development of Electronic Data Processing from its inception in IBM in 1948, to the present time as characterized by the announcement of the Type 705.... My purpose in writing today is to make a 'pontifical pronouncement' with respect to my personal opinion of where we should be heading now in the EDPM area. It is my opinion that we must apply the principle of tremendous storage of figure facts rather than the approaches now being taken with the 705. The entire present EDPM area is devoted to a serial storage approach in the form of magnetic tapes. We must immediately....attack accounting problems under the philosophy of handling each business transaction as it occurs, rather than under the present conditions of batching techniques, which are necessary to magnetic tape approaches....

"We must build storage and peripheral equipment which can spread out into individual accounts every business fact [random access storage] and allow operation of a new concept for handling business information concurrently with its inception.... I, for one, question the economies of spending many more millions of development dollars on the 705 type of electronic machine....

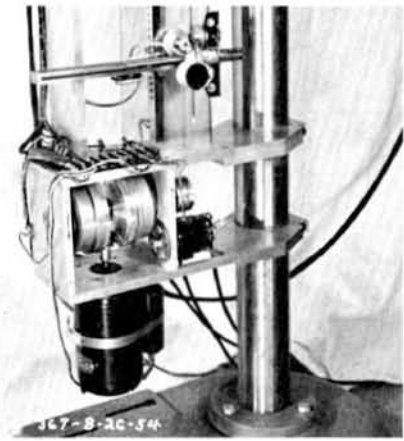
“Our present efforts in random access are good, but not sufficiently extensive to permit a real solution in time to make this new concept....a real IBM ‘first’.

“I wish to recommend for your consideration that we double or treble our efforts in this development....I am firmly convinced that [otherwise] we cannot expect to accomplish the real purpose and the real use for electronics in the business world.”

Shortly after, things truly began to hum. In November, McDowell called a meeting at WHQ at which RAMAC product development was first given official sanction. Noted Stevens, “It was decided at this meeting to build a machine utilizing a disk random access memory attached to a serial “stick” printer to provide an initial machine utilizing random access storage.” McDowell charged the San Jose Laboratory with designing, developing and building several field test models of these machines.

#### *Designing Around the Conference Table*

The logical organization and structure of the instruction set for the “Direct Reference Accounting Machine” (“DRAM” as it was then called) was first documented in detail in a report dated December 17, 1954. It was to be a two-address design with a fixed-length, ten-character instruction. Three basic arithmetic functions were to be provided for; division was not at this time included but did appear later as an optional feature. The principal input was to be a serial card reader of the type used on the IBM 475. A manual inquiry station, in the document called an “Immediate Access Unit,” was described. Outputs included the “stick” printer, capable of printing a line of eighty characters in 1.6 seconds; the IBM 523 gang punch; and, at the manual inquiry station, a typewriter. Many machine functions were to be controlled through a plugboard. Murray Lesser, one of the principal architects recalls, “Most of us in those days were plugboard men. There were a few stored program people, but not many. We decided that what we wanted was the best of both worlds.... We literally designed a lot of that system around a conference table. We asked ourselves what we could do best by stored program and what best by plugboard. We decided one could transfer data best with stored programs, — that was always a



*The test stand for the time sharing servo access mechanism for the Model II RAF.*



*By May, 1955, the first RAMAC-305A system was being assembled at 99 Notre Dame. Here is a general view of the assembly and debugging activity, which went on 24 hours a day. Identifiable participants here are Greg Toben, Jim Davis, Len Seeder, Don Johnson, Trigg Noyes, John Lynott and Hal St. Clair.*



*This press photo was taken just one month later than the above.*

nuisance with all those wires to string, –but one could make decisions a lot easier on plugboards. And that’s how we arrived at the organization of the 305 machine.”

All internal and internal/external information transfers were to proceed via a small magnetic drum having several tracks, each holding one hundred characters of information. It is interesting to recall that at this time it was thought that the rotational speed of the drum could be physically synchronized not only with the file but also with the input/output devices, thus saving the expense of a full record buffer. Notes an internal report: “In the first model of the DRAM it appears that a mechanical connection by timing belts on gears will be used to achieve the desired synchronization.” In the end, however, the designers had to add a 100-character, magnetic core buffer.<sup>19</sup>

The December 1954 document also discussed the desirability and practicability of “automatic addressing”; i.e., the automatic conversion of an external identifier, such as a name or a part number, into an internal address representing a specific physical location in the file. While it was recognized that a direct means of accomplishing automatic addressing would be of immense value, the statistics of the problem were not then well enough understood to permit a programmable solution.<sup>20</sup>

#### *Joining IBM’s Product Team*

With the decision at the November meeting to proceed officially, the San Jose Laboratory suddenly found itself a full-fledged member of the IBM product team. It came as something of a rude awakening to many who had not previously been through the product release cycle to discover just what this would entail. The trickle of visitors quickly grew into what seemed a torrent, people with strange sounding titles and functions, product planners, cost estimators, product engineers, manufacturing engineers, patent analysts, product test engineers, customer engineering planners and estimators, and industrial designers, to name a few. The first reaction of the San Jose wild ducks, now perhaps somewhat inclined to smugness over their own achievements, was to resent these intrusions, feeling that there was nothing on the horizon that the home team could not cope

with. But as the problems multiplied and the realization of inadequate resources available in San Jose grew, the resentment gradually gave way to a real appreciation for the contributions these experts had to offer.<sup>21,22</sup>

The first of the five Model II files was successfully demonstrated on January 16, 1955 and debugging of the others continued on a three-shift basis through spring under the direction of Dickinson<sup>23</sup>. By now the plan to build a number of RAMACs for internal use and for field testing in actual customer applications was well underway. The quantity was set at between fourteen and fifty but the lower number was settled upon early in 1955. Destinations of some of these were established in March – three were to stay in-house, two were to go to the Air Force, and five were consigned to commercial customer field testing – and a production schedule was established calling for the first external shipment during December 1955.

An analysis of thirty-three different applications of twenty-eight separate customers published in June 1955 concluded that:

- From a procedural standpoint only (costs excluded) the proposed RAMAC solution was more favorable than the existing solution in twenty-six applications.
- Access, processing and printing specifications were well-balanced.
- At the anticipated rental figure RAMAC would be superior in twenty-one instances.

The first half of 1955 was climaxed by the announcement to the press on May 6 of the disk technology (incidentally the same day that the Salk polio vaccine was announced). Along with the vital statistics of the new device, the press release stated, "Random access memory permits a return in principle to the accounting methods used in business houses long ago when there was no necessity for batch processing of records as today. Then, clerks on high stools adjusted all affected records each time a transaction occurred. But the 305 borrows only the old philosophy, and, using a multi-million character memory and taking instructions

from a stored program, it does the job automatically and at high speed.” (For clarity, it should be noted that the final nomenclature was yet to evolve, and “305” referred to the disk file. Later the file itself became the 350, and the entire system became the IBM 305 RAMAC.)

#### *Choosing a Manufacturing Site*

The San Jose Laboratory was now openly in the product development business and for the first time engineers were free to boast to their wives and neighbors in general terms of what they had been up to for the past three years.

Now the question inevitably arose, assuming that the field tests would be successful and would point up a significant sales potential, how should IBM go about producing the machine in quantities?

As may well be imagined this was a period of intense soul-searching for the company and many options were considered. McDowell and Jay Schnackel, then the IBM Vice President of Manufacturing, favored retaining San Jose as a development facility only. Among other plans were:

- Transfer RAMAC production to the Poughkeepsie plant after the 305 field tests.
- Construct a manufacturing facility in San Jose to build the file modules only, with the rest of the system to be constructed elsewhere.
- Construct a complete 305 manufacturing facility at an undetermined location in the Middle West.
- Construct such a facility in San Jose.

A Manufacturing Engineering Report dated June 7, 1955, prepared by E. H. Caffrey of IBM Poughkeepsie and F. E. LeBaron of Endicott, based on a production plan by Wesley, showed a buildup to quantities of ninety-four file units and eighty-three RAMAC systems per month by the end of 1957, and

estimated that 146,000 square feet of new factory space would be required. It cited a large number of reasons why West Coast manufacture would be at a severe cost disadvantage as compared to Poughkeepsie.

Stevens' notes indicate that on June 21 a "firm" decision was made to build a factory in San Jose to produce files only. Final attachment to a system was to be at a new facility in the Middle West. This proved to be another "firm" decision without much sticking power, for on Sunday, August 26 Stevens and other IBMers were surprised by the headline in the *Mercury-News*: "IBM Plans Giant New San Jose Plant" and "Firm eventually may employ more than 5,000 here." The *Mercury's* story contained considerably more detail than the IBM press release, evidence that the business writer for the paper had done some digging on his own.

Early in 1955 Rey Johnson had begun gradually to disengage himself from active leadership of the RAMAC project in order to take on advanced work at newly-leased facilities on Julian Street. Stevens took over 305 responsibilities and acquired an assistant, Perry Perrone, a veteran of the Endicott organization who became a steady second hand on the tiller and served in many important Laboratory capacities until his retirement in 1976. In November 1955 Joseph D. Fernbach transferred to San Jose as Manager of Engineering. This move reflected a corporate decision that there was not to be a continuing independent product development mission in San Jose, and Stevens now reported to General Manager Gavin A. Cullen via Fernbach. To many San Jose engineers this new organizational structure had all the earmarks of a denial of their achievements and for a time it seemed that the San Jose experiment might perish, a victim of its own success. But the decision had its opponents, Ralph Palmer chief among them, and it was set aside in December 1956 under the corporate reorganization that came out of a meeting at Williamsburg, Virginia. Under the newly formed Data Processing Division, the San Jose Product Development Laboratory regained status independent from Manufacturing. Palmer became Manager of Product Development for the new division, and he named Stevens to head the San Jose Development Laboratory. Product Engineering remained a part of Manufacturing until 1958.

## A Pioneer in Industrial Design



*Eliot Noyes*

Appearance, or industrial design, was one aspect of machine design that had traditionally been pursued only desultorily at IBM. Thus it is worth noting that the 305 was a pioneer in this area. Although IBM machines had indeed progressed from the era of lion's claw feet, they still resembled Henry Ford's automobile in that they "were available in any color the customer wanted so long as it was black or grey." Crisp squared edges, op-

tional color schemes, and attractive trim were 305 firsts. These departures came as a result of the company's engaging the late Eliot Noyes, a prominent industrial designer, as a consultant with the charge to revamp the corporate design image from bottom to top — from letterheads to the product line. The firm of Sundberg, Farrar, working under Noyes' direction, was responsible for the RAMAC industrial design.



*Salesmen students put the Education Center's 305 through its paces.*



*Marshall Freeman demonstrates the 305 capability to visitors at Family Day, June 8, 1957. Don Stephenson is visible in the foreground.*

### *Getting the Glitches Out*

Construction of the test model systems (by now called "305A") had moved to a leased location at South 10th Street which, under manufacturing coordinator Frank G. Paul, was the first manufacturing site in San Jose. Debugging then became a major operation, in Stevens' words "a gargantuan task." The basic pluggable unit circuit design had been done by people without a firm background in the discipline necessary for production equipment, and the sins of omission now began to make themselves felt. It is a fact that many designers were so innocent as to be aghast when the Product Test people sprang the notion that voltage and temperature marginal tests should be performed -- tests the hardware could not possibly sustain. To the electronics engineer, a spurious signal occurring as the result of imprecise circuit timing is known as a "glitch." There was hardly a glitch-free gate in the entire machine and some uncommonly weird and ingenious ruses were devised to get out of terrible timing predicaments on the 305A.

The December schedule for first customer shipment came and went; spring ran into summer, 1956. Some heroics during this period are worthy of mention. The building at South 10th Street was, of course, not air conditioned and as the summer sun went to work, temperatures in the debugging areas ran up over 100°F. Not only the machines, but also the engineers, were failing under these conditions. Plant Engineering was notified that something had to be done. It was, but quickly -- literally overnight an air conditioning system of adequate capacity was installed.

Also it must be recorded that the Product Test contingent on the scene was not content to merely point out design problems, but to their everlasting credit pitched in to help solve them as well.



*Even at the height of the 305 crash debugging effort there was some time for merrymaking. Left to right at the Valentine's Day Dance at Blossom Hill School, February 12, 1955: Malcolm White, (unidentified back), Mrs. White, Minnie Hodges, Dean Hodges and Anita Sullivan Criger, Cecil Criger.*

*This building on South 10th Street in San Jose was the first home of the manufacturing organization. The 305A's were assembled, product tested, final tested and shipped from this location.*

As a result of such efforts the monster gradually yielded, and by June 1956 the 305A was deemed sufficiently reliable to be shipped to the first customer, the Zellerbach Paper Corporation. First announcement of the IBM 305 RAMAC (along with three other products, including the 650 RAMAC) finally came on September 14, 1956. On the occasion T. J. Watson Jr. said, "This is the greatest



*An historic sequence of photographs documents the shipment of the first IBM 305A RAMAC to the Zellerbach Paper Co. in San Francisco. Here Lou Stevens and John Haanstra discuss the disassembly.....*



*.....the console is hoisted onto the shipping van.....*



*.....and a group of Zellerbach officials try out the controls at the machine's new home.*

new product day in the history of IBM and, I believe, in the history of the office equipment industry... . Engineers at the San Jose Laboratory deserve much of the credit for these significant advances in automation." The treatment of the story in the *San Francisco Examiner* appeared next to an ad proclaiming "At last...glamour in a trash can, \$12.95." The store placing the ad is now defunct; the disk file business is not.



## Chapter 6. Small is Beautiful

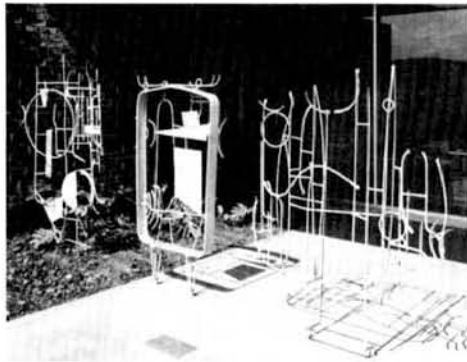


*The Hydrogyro goes up. This structure by sculptor Robert B. Howard of San Francisco still dominates the central patio scene. The legend at the base reads in part "man...cannot determine if he creates, invents, discovers, or is guided into what he thinks he knows and believes."*

In conjunction with the RAMAC announcement of September 1956, the press was invited for the first time to witness the construction nearing completion at the new plant site at Monterey and Cottle Roads. Under Gavin A. Cullen, general manager, the construction had proceeded on schedule. Thus 190 acres of the original 10,000-acre Rancho Santa Teresa of the retired Spanish soldier Joaquin Bernal, where once colorful vaqueros pursued thousands of "ganados" and, on fiesta days, performed feats of equestrian derring-do to impress dark-eyed señoritas, was gradually transformed into the most modern of industrial complexes — a transformation that won for the completed project *Factory* magazine's Factory of the Year Award for 1957. The long rectangular buildings of architect John Bolles were carefully placed in order to emphasize the site's rural setting and to lend a carefully cultivated "campus" atmosphere. Bay region artists were commissioned to execute murals and sculptures to accent that mood. (Actually 97 of the 190 acres were initially left in their original agricultural state, and in 1957 IBM revenues were augmented by \$3,200.00 from selling the alfalfa crop.)

The first building, the 200,000-square-foot Manufacturing and Administration Building 005, was occupied in December, 1956, and Building 001 came next in May. This building was originally intended to house the Supplies Division, but it was later decided that it would move to a new building in Campbell; 001 became part of DPD manufacturing. The cafeteria, boiler plant, Plant Engineering, Education, Product Engineering and Research Buildings were all in use by October 1957, and the 1,000-employee milestone was reached about the same time. To head up the new West Coast Education Center, native Californian Byron N. Luther returned to San Jose after ten years of assignments in the Middle West and New York.

The formal plant dedication came on May 27, 1958, a gala event attended by an estimated 38,000 persons, according to the *Mercury-News*. Features of the ceremony, aside from RAMAC itself, were a keynote address by San Jose State College President John T. Wahlquist, musical performances by the San Jose Municipal Band and by soprano Anna Maria Alberghetti, and brief remarks by T. J. Watson, Jr. in which he revealed that seventy RAMACs had already been shipped to customers and that 1,200 more were on order.



*One of the original sculptures which no longer stands is "The Elements", by Henri Marie-Rose. "Forms of nature represent fire, water and earth. Air is suggested by the spaces within and surrounding these forms. There is a hint of diagrammatical electric circuiting," says the dedicatory plaque.*



*Among the first plant site buildings to be completed were the manufacturing building (005) and the cafeteria (011).*



*305 RAMACs going together in Building 005, Mel Olsen identifiable in the foreground center.*

Frank Freeman's column in the *Mercury* on the following morning read in part, "Several things struck me while attending IBM's dedication.... First, that its tremendous success may be attributed to the simplest little formula — accumulate a lot of brains, give them the facilities, turn 'em loose — and they'll come up with the answers.... Next, it's so different out there in those campus surroundings, so different from the usual pell-mell workaday experiences, that it's like being in another world, a sort of Buck Rogers' world.... And two other things: The whole place is peopled by young brains, no long hairs, and they all give the impression that they're exceedingly proud and gladly would die for old IBM."



*Part of the crowd attending the dedication ceremonies. Speakers' platform at the left. Education Building and the Diablo Range in the background.*

## Lest We Forget

Easterners brought up on the tradition that Europeans first set foot on this continent at Jamestown or Plymouth Rock sometimes find it difficult to accept the fact that Santa Fe, New Mexico was a bustling pueblo by that time. Similarly it is easy to forget that the first IBMers in San Jose were not those who set up shop at Notre Dame Avenue. Nine years earlier, on August 22, 1943, two special railway cars bearing IBM people who had been selected to man the company's first West Coast card manufacturing facility eased into the San Jose railway station. They numbered 105 in all, including employees and family members. Augmented by nine locally

hired people they began manufacturing tabulating cards for West Coast wartime industry in a one-time laundry building at St. John and North 16th. Luther L. Sheppard was the resident manager and Roger R. Williams the plant superintendent.

The first IBM Sales Office in San Jose was opened in February 1946 under Byron Luther.

Rey Johnson is fond of declaring that IBM was the first non-indigenous industry in Santa Clara Valley. This is the kind of assertion that invites challenge but so far, Rey claims, no one has disproved it.

*The Temple Laundry at the corner of St. John and 16th Street in San Jose went out of business and the building became the site of the first IBM presence here when the Card Plant moved in 1943.*

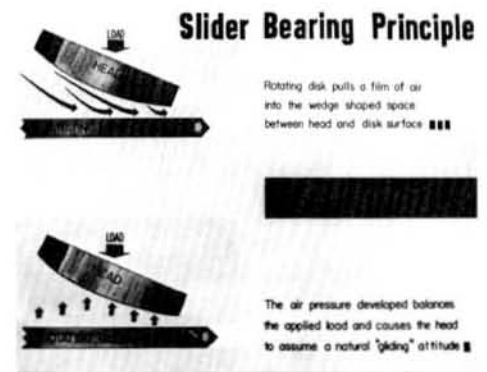


### *Replacing the Pressurized Air Head*

It is safe to say that the volume of disk products would have never reached today's heights if a replacement had not been found for the pressurized air head. The compressors for these heads were of a size that would simply prohibit servicing a multi-headed file. Thus it was fortunate that Jacob Hagopian had managed to pursue his hunch that a properly shaped piece of metal could be made to "glide" over the surface of a rapidly rotating disk. On intuitive grounds he felt that the moving surface must carry along with it the adjacent molecules of air and that this airstream might be caused to support a suitably shaped object.<sup>24</sup>

Hagopian was soon demonstrating his "gliding" head in hardware to anyone he could corral. An electrical engineer by training and experience, he foresaw and advocated the systems implications of eliminating the need for compressed air: It would now be feasible to build disk files having one or more magnetic heads to service each magnetic surface. Not only would this eliminate the need for a disk-to-disk accessing motion, thus greatly reducing average access time, it would also permit implementing the "cylinder" read-out concept. That is, with one head per surface and a suitable structuring of the data, we could envisage having available an entire "cylinder" (two tracks' worth from each disk) with electronic switching only -- no mechanical accessing motion whatsoever.

These concepts formed the basis for a major new project initiated in early 1955 at the West Julian Street Laboratory, which had been deliberately set apart to work on advanced concepts without danger of being drawn into the 305 fire-fighting exercises, and was under the direction of Rey Johnson. The new project was called the Advanced Disk File (ADF). It was to use gliding heads, a tape-actuated track-to-track access mechanism and a quintupling of storage capacity to 25 million characters (later boosted to 50 million). The work continued in the Research Laboratory until a test bed built by Jack Harker demonstrated feasibility of the gliding head concepts and the project was turned over to the Product Development Laboratory.<sup>25</sup>



## Gliding Heads: A Need For Synthesizers and Analyzers

Some of Jacob Hagopian's early successes were not consistently repeatable and most people at the time were convinced that absolute flatness was the key to stable flight. A few bearings would operate successfully but many would fail catastrophically at some arbitrary value of load by contacting the surface.

At this time there was no prior applicable experience; the knowledge that was available was based upon assumptions concerning incompressible lubricating fluids such as oil. Bill Gross in Research had begun theoretical work to consider the effects of compressibility. At the same time Russ Brunner and Ken Haughton were trying to measure and find parameters with which they could correlate successful operation or predict failure.

With the prime leadership being provided by Jack Harker, over a period of at most two months, one of the most significant pieces of technical work that has been done at IBM San Jose took place. It resulted from an active interaction between Gross and a number of others, including Bill

Michael, who provided some very imaginative programming, Russ Brunner and Ken Haughton, who provided experimental data as input and correlation, and Al Osterlund, who worked on suspension designs. This work led to an understanding of the fundamental theory of operation of gas lubricated bearings and forms much of that body of technical work today. The practical result was the discovery that a special curvature of the surface of the flying element was needed for stable gliding. The story serves as a remarkable example of the necessity for having both synthesizers and analyzers on the development team.

### *Stretching to Build Stretch*

Concurrently undergoing development in Poughkeepsie was a very large computer bearing the code name "Stretch" (a running gag was that the 702 building there would constitute the main frame for Stretch). The architects of this machine had recognized the importance of random access memory (by now called direct access storage to avoid the trademark RAM) and Haanstra was instrumental in negotiating an agreement under which San Jose Research would



*"Advanced Disk File," with ganged heads and cable actuated access mechanism, as it appeared in early 1956.*



*Ray Johnson presides over a meeting of his Research group shortly after the move to Building 025. Left to right: Johnson, Ralph Marrs, James Allen, Laverne Richard, Murray Lesser, Calvin Clauer, Roy Haug, Ed Supernowitz, unidentified, ?? Warren Christopherson, Harold Markey, Walter Johnson, Lloyd Tidball, Emil Hopner, unidentified, Frank Glass.*



*Marjorie Griffin, one of the pioneers of 1952, is held in high esteem by thousands of IBM engineers for her skillful and always helpful management of many of the local IBM libraries. She is shown here (standing) with Lucille Gardner in her Julian Street domain in 1955.*

provide the hardware. Stretch was to operate in a parallel mode on 72-bit words. This meant parallel readout from the Stretch file and, consequently, a separate full read/write amplifier associated with each head.

Thus the ADF work, originally intended to yield a commercial product, was diverted to fulfilling the Stretch requirement, although it was anticipated that a commercial derivative could result with a minimum of redesign.

Stretch faced many vicissitudes, and by early 1960 the Stretch File was still in technical difficulty. Following the recommendations of a task force Victor Witt, who had become laboratory manager in November 1959, relinquished all other

*The Advanced Disk File (ADF) test bed and its proud designers — left to right, Al Osterlund, Russ Brunner, Sam Biao, Paul Gilovich and Jack Harker.*



responsibilities to take personal charge of all file programs. Witt named Ralph Golub to head the Stretch File team and instructed him to drop the gliding head and revert to pressurized air heads "because we know they will work and satisfy Stretch commitments." The device was announced as the IBM 353 in December 1960, and while it required an air compressor system so enormous it had to be housed in a separate room, it did resolve the technical problems.

Thanks to the determination of Harker work on the gliding head technology was continued and a commercial version successfully using this technology emerged as the IBM 1301 in June, 1961. It offered 21.6 million characters capacity per 25-disk module and an average access time of only 165 milliseconds. Also of note here is the contribution of Walter Scott, assistant general manager, who in 1962 accepted a special assignment to help solve the manufacturing problems associated with production of the 1301.

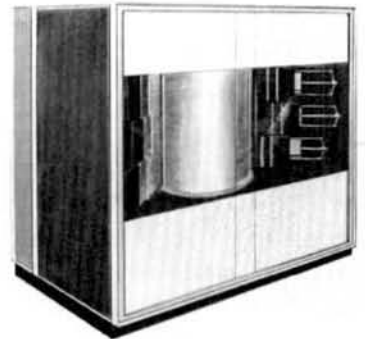
### *Once Again Doubts About Disks*

Returning now to the summer of 1957, as work on the gliding head progressed, the old qualms about disks were being reawakened. A great deal was being heard from the world of IBM competitors about differently configured direct access storage devices that would seriously impact IBM if successful. Many of these involved tape strips and loops of various dimensions. A study of the overall situation, both external and internal to IBM, was requested by Ralph Palmer. Matt Gibson, Noyes and Haanstra undertook the task and in their November 1957 report recommended a three-pronged development program "to assume a position of leadership for IBM":

- . Increase the specification for capacity of the ADF from 25 million to 50 million characters and expand the program to assure release in the last half of 1959.
- . Initiate the development of a tape strip bin file with a capacity of one billion characters, with release in 1961.
- . Formulate a program for development of a one million character file with ten millisecond average access time.

All three recommendations were adopted. The tape strip bin file underwent a seven-year metamorphosis from a rectangular array of strips accessed by a selection device not unlike that proposed by Telecomputing in 1952, to a cylindrical bin which rotated the array of strips past a stationary picking station. A succession of program managers found the specifications unusually challenging, and it was not until April 1964 that the product was announced as the IBM 2321 Data Cell Drive. It was released to manufacturing by Gerald V. Harries and offered 400 million characters of on-line data stored in interchangeable increments of 40 million characters each. The average access time was just over one-half second.

In its time, the 2321 filled a void in the cost-performance spectrum of the random access family. But the verdict is now in and disks survive while short tape strips have largely passed from the scene, probably for good. Closely packed magnetic strips, plucked from a bin and wrapped around a drum for reading and writing, seemed to both IBM and its competitors to be a very logical and economical solution to high-density rapid access, but the mechanical complexities proved just too great and expensive to overcome in comparison to disks.



*An Industrial Design conception of the Advanced Disk File circa 1959.*



*The Very Large Capacity Memory (VLCM) project responded to the task force's second recommendation. Here is the rectilinear access mechanism as it appeared in 1959.*



*A model of the "voice coil actuator" for use on the million character file. This principle found application in several later products.*

The third of the 1957 task force's recommendations, the one million character file, was based on a flexible plastic drum principle. It was later abandoned to free people when ADF problems surfaced, but the project with Ralph Marrs and Bill Tibbets did make an important contribution to later products — the first use of a voice coil actuator. It is also worth remembering that the flexible recording sleeve on this device was to be replaceable.

#### *Systems Activities at San Jose*

Although it may seem as though direct access files occupied the entire attention of the San Jose facilities in the 1957-58 period, there were several other systems activities that evolved in Stevens' Development Laboratory and which deserve a brief mention. IBM had begun pilot line production in Poughkeepsie of high quality transistors. The new circuit element promised to provide significant increases in reliability, speed and function at lower cost than vacuum tubes. Its availability in small quantities led to a corporate decision that the logic circuits for all future products (with some few dispensations) would use it. It was a disconcerting time of change for circuit designers brought up on the vacuum tube and the decision was not universally popular. It was considered at best to be premature and based on an as-yet-unproven technology. But the wisdom of it will now be debated by hardly anyone, since it forced designers to think solid state long before the normal human time constant would have preferred. At any rate, transistorization of the 305 was a natural, and a small band set about the task.<sup>26</sup> Eventually it was decided not to switch 305 production over to transistors, but to complete the design to a point that would permit switching rapidly should that prove desirable.

The other principal systems activities in late 1957 and early 1958 were the "306" and the "310." The latter was to be a transistorized system of new design and increased power to supersede the 305. The design objectives called for a completely stored program machine (no plugboards) with approximately the logical power of the 650 and specifically designed to accommodate the Advanced Disk File, but taking advantage of faster input/output devices (chiefly the 400-line-per-minute chain printer) then under development in Endicott. A stripped-down version of this machine was to form the 306, in the accounting machine class with performance about two times the 407.

Meanwhile, elsewhere in the company contending proposals were being advanced for the 306 area and pressures were building for decisions on which laboratory should do what in the systems arena. After considerable debate it was decided that the San Jose Product Development Laboratory should withdraw from this field in favor of the Endicott entry. It was a bitter pill, but the Endicott machine went on to become a pacesetter which sold in truly large quantities, the IBM 1401. To its success San Jose contributed a transistorized version of the 350 disk file (the 1405) and old timers will recall that conversion of the servo circuits to solid state took the laboratory through another period of anguish.

Work on the 310 design continued for some months. In December 1957 John Haanstra, who had been in on the start of the project, was promoted to Assistant Manager of Product Development for the Division. In this role it was naturally his duty to judge his erstwhile teammates impartially. He became convinced that the functional and cost objectives of the 310 could best be met as a follow-on to the 1401 program. Consequently, it too was ordered terminated and transferred to Endicott, to be announced later as the IBM 1410.

#### *Thinking Small: The Low Cost File*

Although the 306 and the 310 were lost, the San Jose Development Laboratory was not long without a mission. To some degree its new role was decided when it became clear that Larry Wilson would be coming to San Jose. A man who had already accomplished enough for several careers, Wilson's technical and business reputation preceded his arrival, in September, 1958.

A Texan educated at the University of Illinois, Wilson was by training a statistician who had spent his early career at the U.S. Bureau of Census. There he became familiar with IBM products and intrigued with the idea of contributing to their design. He joined IBM in 1939 as a junior salesman and shuffled between sales and engineering for several years before becoming a senior engineer at Endicott in 1951.



*San Jose's first Watson Scholars are presented their citations by Ed Quade on June 29, 1957. They are Harold Huffman (to Quade's right) and Ronald Berfors (to his left). Proud fathers Dwight Huffman and Carl Bergfors flank their sons.*

## Larry Wilson and His Wonderful New Product Machine



*Lawrence A. Wilson*

Possibly no other man in IBM history has been involved with as many new products over his career as has Larry Wilson, who ended his career back in San Jose after a tour as site manager at Boca Raton. Indeed Wilson was an exception to the norm in product development, which is that different stages in the process require different talents and, hence, different leaders. Wilson was both a technical creator and a skilled entrepreneur who was able to carry a project from its early engineering stage through to release.

The first product to emerge at San Jose from the Wilson team was the 609 transistorized electronic calculating punch, the basic design for which had been done by Roy Harper in his spare time while on assignment in Paris. Next were two I/O devices which became part of the Endicott machine called the IBM 1440. These were the 1442 serial reader-punch, the first high-speed serial card handler, developed under Don Rex, and the 1443 incremental bar printer for which E. Rae Wooding and John Schmidt were primarily responsible. Glen Nielsen's group, in conjunction with the Boeblingen Laboratory,

produced San Jose's highly successful contribution to System 360, the Model 20. Wilson's people also produced three pieces of I/O equipment which found use in many System 360 installations; the 2501 card reader; the 2560 parallel punch; and a longstanding dream of Wilson's — the 2520 multifunction card machine.

Next came the 1130 Computer, developed under Roy Harper's (and later Brian Utley's) direction, which also found use as the processor for the 1800 process control system. The 1130 featured a printer of interesting concept, since it was designed to make use of reconditioned parts from the 407. Alfred E. Stone, one of the 1952 pioneers, was instrumental here. Another important feature of the 1130 was Walter Buslik's single removable disk file known as "Ramkit."

In 1964, Wilson was appointed an IBM Fellow. In this role he was free to pursue another old passion, the notion that advancing technology should by all rights have obsoleted the standard eighty-column card; he developed a functional replacement about one-third the size. This permitted the design and demonstration of a

line of equipment which added up to truly low-cost data processing system for very small businesses, which, transferred to Rochester, became the IBM System/3.

Still Wilson was not ready to quit. Several later projects did not materialize, but one, a matrix line printer, developed by Al Brown, Al Chou and Dick Darling, was transferred to Endicott and emerged as the IBM 2213.

In those days most computer people were thinking big: They wanted larger capacity files and more powerful processors -- it was a badge of honor then to be working on the largest computer ever conceived. Wilson, however, was thinking small. His sales background and his intuition led him to conclude that there was a vast marketplace ready and eager to enter the age of data processing at the right price. His engineering experience led him to believe that it could be done profitably.

In June 1958, prior to but clearly anticipating the announcement of the Wilson mission, Palmer, who was manager of product development for the Data Processing Division, defined the Laboratory's responsibility as "being the development of a line of compatible data processing and/or accounting machines that are below the RAMAC 305 in both function and cost." He stressed that this would require a great deal of ingenuity in both system organization and input/output equipment design. Thus the Laboratory milieu in early 1958 was a peculiar admixture of "bigger is better" and "low cost is best." On the one hand there were the 310 proposal, the ADF and the Stretch file projects; on the other hand, the San Jose systems future had been clearly directed toward low cost.

Stevens assigned Jack Harker, H. K. St. Clair and D. L. Stephenson to define a "Low Cost RAMAC System," which he described as having half the size, half the capacity, half the performance and half the cost of the 305. Obviously one important component of the machine would have to be a low-cost file. Stevens recalls that during a cross-country flight with Haanstra the latter remarked that IBM would have to learn to build files as General Motors builds Chevrolets, that is to say, mass production on a highly-automated assembly line. This indicated his vision of the future of direct access storage and had important implications for the engineering of the low-cost file.

Meanwhile, A. S. Hoagland, who had made significant contributions as a consultant to early magnetic head designs and was by now a full-time IBM Research employee, had undertaken the development of a "single disk file," pushing the magnetic recording technology to its density limits and incorporating a track-following servo. <sup>27</sup> The idea was to make the single disk easily removable, like a phonograph record, and interchangeable by use of the track locating servo.



*John M. Harker*

## The Khrushchev Visit

No account of IBM in San Jose would be complete without the telling of one of the most colorful events in American industrial history. The San Jose Plant site was selected to be shown to Nikita S. Khrushchev as an example (not necessarily typical) of how our country goes about its business. The Soviet Premier arrived on September 21, 1959 and if you think plant security is tight now, well, you should have been here then. Armed guards lined the roofs of all buildings and infiltrated the crowds, as vigilant helicopters hovered overhead.

Khrushchev had just come from Los Angeles where he had thrown something of a tantrum because he was denied his request to see Disneyland, and local managers were consequently a little edgy, worried about what sort of mood this mercurial leader would bring with him.

But all went well, the tour of manufacturing impressed him and he was most gracious as he dined in the cafeteria along with several hundred employees randomly selected for the occasion. After lunch Thomas J. Watson, Jr. delivered an official welcoming speech, broadcast over the plant public address system, and Khrushchev responded with a seventeen-minute expression of appreciation.

One item connected with that day sticks in some minds. The press reported that Khrushchev was immensely impressed on his drive down Bayshore from San Francisco to San Jose, first by the size of the automobiles and, second, by the fact that most of them had but a single occupant. "You foolish Americans," he is quoted as saying, "Don't you realize that you will soon burn up all of your petroleum? Then what will you do?"

*Khrushchev, sporting a visor cap given him earlier in the day by a San Francisco longshoreman, converses with Watson earlier in the day as they stroll the grounds. Henry Cabot Lodge, U. S. Ambassador to the United Nations, is seen behind the Soviet Leader. Many other dignitaries were present, including Russian Foreign Minister Andrei Gromyko.*



Jack Harker recalls saying something like, "You know, if we really mean 'small' and 'low cost' then we're talking about simple and light weight. I believe that by pushing recording technology we could get perhaps a couple of million characters on half a dozen disks about the size of phonograph records. Furthermore, this stack of disks could be light enough, and could be designed, to be easily lifted from the spindle and stored in a closet." Several people recall being intrigued and impressed by the idea but few could foresee the full significance.

Neither, apparently, did Harker, at least at first. Early in June 1958 he traveled with St. Clair and Stephenson to Poughkeepsie, Endicott and Lexington to learn all he could about the small business requirements. Their report reached several important conclusions, but most significantly, for the purposes of the present saga, it reads: "A rotating file could be designed so that part of the record surface could be easily replaced, permitting introduction and removal of larger quantities of data. (It is unlikely that it would be desirable to change the entire memory)." This appears to have been the first written mention of disk removability, a concept which, together with the gliding head, would ultimately cause disk technology to win out over competing approaches.

Despite the advancement of removability as one of the criteria, the first test bed for the Low Cost File reverted to the horizontal shaft orientation, which was incompatible with removability. Indeed, one might be forgiven if at first glance he mistook it for the first RAMAC mockup of five years earlier.

Work on the Low Cost File continued throughout 1959, now as part of the Wilson organization developing it into engineering model hardware (the Low Cost RAMAC system was discontinued earlier that year).<sup>28</sup>

## Vic Witt: Driving Force to a New Industry



*V. R. Witt.*

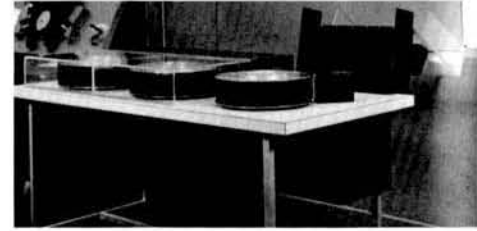
For the decade of the 1960's Victor Witt's name was synonymous with IBM's disk storage development. Through his leadership, the fragile concepts and technologies became the basis of a new industry. Although his imprint is on many other products, his determination to exploit the removable disk in a compatible family of products can be identified as the true turning point toward the wide acceptance and application of disk storage and the creation of an industry standard. The impressive improvements in density and cost that were accomplished under his direction can be attributed to a management stress on excellence which nurtured a strong technology effort with close working relationship to manufacturing.

Vic joined IBM in 1951 in Poughkeepsie after working for Western Electric and Sperry Gyroscope Company (where he obtained a BSEE from NYU while holding down a full-time job.) He was involved in early magnetic tape media and drive development and managed that effort before

becoming Development Laboratory Manager in San Jose in late 1959. He was appointed an IBM Fellow in 1970 and maintains an active interest in Direct Access Storage.

The record does not make clear the steps through which the replaceable and interchangeable disk pack gained respectability. However, the feature was included in a report on program objectives published by Harker on February 9, 1959, although its usefulness was still seen as being limited to an alternative to periodic file dumps and protection of continuity (since disk packs could be transferred to other drive modules in case of a machine failure). The real economic advantages of the disk pack's shelf storage potential were to become clear somewhat later and were championed by planner Ken Foulger. The official design objectives, authored by W. M. Masline, came out a year later and spelled out in greater detail what interchangeability would mean.

And so the low-cost file became the 1311 and proceeded down the glory road, the first disk file designed for a specific system (1440) and to make use of both the gliding head and the replaceable disk pack; the forerunner of so many variants that have made IBM history. The story cannot be closed without giving final tribute to the outstanding work of David Montgomery who carried the machine through Development Test and of James Carothers and Robert Pattison who led the production design and took the machine through Product Test and into production.



*The low cost file went through a number of transitions before its final design. This three spindle version was photographed in January, 1959, and in a sense anticipates the multi-drive products of much later vintage.*



*Closer to the IBM 1311 as it eventually emerged is this October, 1959 model.*

## Chapter 7. Other Members of the Product Team

The story to this point has concentrated on product development activities. It will surprise no one to be told that innovation does not cease when the prototype product design exits the doors of the Development Laboratory; the story of innovation in San Jose is only one-third told until the roles of Manufacturing and Programming Systems are included.

Mike Hall, a member of the manufacturing team since 1961, has steadfastly maintained that development is dedicated to the design of products that are intrinsically impossible to manufacture. Indeed it is one thing to produce a prototype and quite another to replicate it in quantity, and most development people would be willing to concede that manufacturing has been handed more than one very hot potato.

During the period of product transition from laboratory to production, it is inevitable that many system and technical problems will arise, and frequently the result is heated debate as development tries to push manufacturing into accepting new challenges beyond the realm of their existing capabilities and, conversely, the plant argues in favor of "more realistic" specifications.<sup>29</sup> The outcome is a compromise but the relationship proves to be synergistic, with manufacturing winding up agreeing to accept much more risk than it really deems prudent and going on from there to pioneer the needed process improvements. Most old hands in the Development Laboratory harbor a deep admiration for the ability of San Jose Manufacturing to come up with innovation on demand. After the dust has cleared, the protagonists recognize that they are all players on the same team.

### *Setting Up Shop*

Now IBM's third largest manufacturing location -- the largest outside New York State -- San Jose manufactures more computer-related storage products than all other company locations combined. The General Products Division has the greatest installed leased inventory of any IBM product division thanks to San Jose's prolific output and Endicott's printer products. That inventory now includes tape drives and magnetically recorded mass storage systems (transferred from Boulder), impact printers and the IBM 3800 Printing Subsystem, whose new

and complex electrophotographic, non-impact printing technologies required years of development and conversion to manufacturing techniques at San Jose. <sup>8</sup>

It all began, following the November 1954 decision to go ahead with the construction of several test models of RAMAC, when Frank Paul arrived in July 1955 to supervise their construction, with the aid of a special manufacturing team, at IBM's first "plant" on South 10th Street. He had scarcely got himself settled when it was announced that San Jose was to be the site of a full-fledged manufacturing facility. Gavin Cullen was appointed General Manager in February, 1956 and the manufacturing organization quickly outgrew the South 10th Street building, overflowing into at least four other leased locations spread around the city from Lenzen Avenue on the north to Monterey Road on the south.

Cullen's initial set of top managers (in addition to Paul as manager of manufacturing and Fernbach as engineering manager) included: Ernie Friedli, product engineering; Phil Taylor, manufacturing engineering; Bud Sherriff, purchasing; Bob Muller, production control; Bill Hall, quality assurance; Paul Richards, plant engineering; and Bob Simmons, personnel. In early 1957, Clarence Frizzell joined the team as Assistant General Manager. This basically functional organization grew and persisted until May 1967 when the "product manager" concept was introduced.

At that time Jeff Thwaite became responsible for all aspects of disk and cell manufacture; Mike Hall for magnetic heads; Joe Sheredy for file products; and Bill Hall for systems. With temporary perturbations, this organizational structure has persisted to this day, and many consider it one of the most important contributions to the Plant's ability to handle a variety of product and technical challenges.

#### *Pushing the State of the Manufacturing Art*

When the first RAMAC was shipped in 1957, disks were still fabricated from aluminum recording stock, with the coating still poured by hand from paper cups. But process automation came at an amazing rate once manufacturing had the opportunity to settle down to the serious business of producing machines in volume in permanent quarters. By 1959 automatic coating systems operating in controlled environments had replaced the paper cup. As recording densities

increased, ever greater demands were placed on disk surface smoothness. Standard recording disk aluminum was no longer adequate for 1405 use and an automatic sanding operation was added. When the head flying height was reduced to 250 microinches and less in later products, the smoothness specifications surpassed the capability of the state of the manufacturing art not only to produce but also to measure. An extensive survey of the field by Bob Ryon and Art Tollkuhn indicated that no vendor was capable of doing the job and so an internally designed system was placed on line. Sophisticated test instrumentation was also developed.

The IBM Plant in Sindelfingen, Germany was designated to be the World Trade Corporation source of disks and disk products and a very close working relationship developed between San Jose and the German sister plant. Engineers in Sindelfingen first came up with the precision diamond turning lathe which eventually set the standard for disk surface finishing. Sindelfingen engineers also developed a sophisticated optical runout tester for measuring surface quality.

Comparable progress has taken place in the production of magnetic heads and slider bearings. The first 350 heads consisted of stacked laminations around which the read-write coils were wound by hand. This assembly was then bonded to the aluminum slider with epoxy. Most operations had to be performed under a microscope and many tedious hours of assembler training were required. Since then automated procedures have taken over most of the work. Ferrite cores have replaced the laminations and the slider material has progressed through stainless steel, plastics, alumina and ceramics.

Later glass bonding of head to slider was used. Some appreciation for the innovative techniques introduced in head manufacturing can be gleaned from the figures showing the exponential buildup of production quantities and the number of people required to meet them. At one point there were 240 people making magnetic heads for the 2314 disk file, on two full shifts. Today there are 24 people in the same area making more heads than before, and with infinitely tighter tolerances.<sup>8</sup> It was not until December 1968 that the millionth head came off the line (an event that was appropriately celebrated). The next million were produced in the following two years and by May 1977 the seven millionth head was assembled.



*Handling magnetic head laminations in the 1963 era.*

### *Not By Disks Alone*

But the San Jose manufacturing story, of course, is by no means limited to RAMAC and its offspring. Nor does it necessarily run parallel to the San Jose development output; for various financial and personnel utilization reasons it has often been necessary to switch product manufacture from one plant location to another within IBM and San Jose's mission was broadened constantly from the earliest days. In 1957 the West Coast Reconditioning Center, under Owen Humphrey, became an integral part of the Plant. Then came the 604 family of electronic calculators from Poughkeepsie, followed by the 2821 printer control unit, the 1440 system, the 360 Model 20 system, one-half inch tape products and the 3850 Library System. In 1975 the San Jose facility added the capability of circuit card manufacture, easing the workload in Endicott and freeing the home team from reliance on a source 3,000 miles distant.

But, of course, the San Jose Development Laboratory has provided its manufacturing neighbor with the bulk of its "impossible" production challenges including and going beyond the disk storage field. Unquestionably one of the most difficult was the 2321 Data Cell Drive. From the manufacturing viewpoint, the engineering model of this product appeared at first to be unproducible. Dimensional tolerances on both metal and plastic parts were unheard of in the manufacturing world of the day and it took a long-term task force of engineers from both development and manufacturing to get the schedule and costs under control. One component in particular, the data cell itself, required a broaching operation that was thought to be impossible, but under Gavin Struthers it, too, eventually yielded.

San Jose Manufacturing has pioneered a number of organizational and procedural changes which, because of clear advantages in enhancing product quality and reducing costs, have been adopted on a company-wide basis. An example of this is the concept of "purchasing engineering," initially advocated by Arthur W. Brown who believed that the procurement manager should be held responsible and accountable not only for the price and scheduling of purchased components but also for their quality. Acting on this notion the San Jose Plant over the period from May 1970 to June 1972 transferred a number of technical functions, traditionally found elsewhere on organization charts, to the jurisdiction of the purchasing manager. These included supplier quality engineering,



*The 2321 bin, cell and strips*

receiving inspection, and manufacturing and test engineering. These changes have proved their worth in reducing manpower and paper work while greatly improving vendor relationships and reducing costs. Another example was the formation of the “new-products” organization. First set up in San Jose in June of 1961 to coordinate the work of all functions related to the development and manufacturing of a new product. The idea has been adopted by all other manufacturing locations. <sup>30</sup>

To illustrate the Plant – Laboratory synergism that has characterized the San Jose experience, it will be useful to recount the histories of two products in particular — the Process Control Systems mission and the IBM 3800 Printing Subsystem. From an organizational and record-keeping standpoint, possibly no product has had a greater impact on an IBM manufacturing facility than the 1800 Control Systems family. From the standpoint of the newness and complexity of the technologies involved, the 3800 holds a similar position.

#### *Controlling Industrial Processes*

The Control Systems mission had its genesis in some case studies done by the old Special Engineering Products Division in 1958. Cuthbert C. Hurd of the Advanced Systems Development Division’s Mohansic Laboratory undertook some hardware designs to meet the needs that SEPD had stated. The emphasis then was on large continuous-flow industrial processes, such as those found in oil refineries. Not only was the necessary sensor instrumentation already installed, but it was clear that small improvements in process efficiency could yield handsome dollar returns to the customer. The initial approach was simply to convert analog signals from the instrumentation into digital data which could be punched into cards. The cards were then batch processed and the results verbally communicated to process operators who would then make appropriate set point adjustments manually.

In 1959, the Mohansic group launched the design of a more sophisticated system, incorporating the 1620 processing unit. Since, as befits an “advanced laboratory,” Mohansic had no release or production facilities, the entire project was transferred to San Jose in 1960. Howard Mussell was sent out to head the receiving team and Hurd himself followed later.

Three special 1720 contract systems, as they were called, were successfully installed for customers and provided valuable information for follow-ons. A more modest system, the 1710, was announced in 1961 and first installed a year later.

In 1963, Norman Wilson headed a group of engineers who transferred to Rochester, Minnesota to set up a satellite process control program. Although the 1710 had provided an entry into the sensor-based field, it was not effective in a broad range of applications and the two laboratories, San Jose and Rochester, began a collaboration to satisfy three of them: (1) high speed data acquisition (reminiscent of the 1952 activity in San Jose); (2) direct digital control of process actuators; and (3) process optimization tasks. The outcome was the 1800 system which incorporated a central processing unit similar to the 1130 computer.

Under Don Stephenson's management, development of the 1800 proceeded on a "crash" basis, first customer shipment occurring a scant two years after receipt of the corporate "go" signal in March 1964. In the heat of battle, many of those who had transferred to Rochester found themselves back in San Jose. The 1800 was a functional and financial success (one half of those produced are still in service and the system is still in limited production here) but its release to manufacturing presented a unique challenge. It is the nature of the process control business that virtually no two customer installations are alike. In fact, the number of optional and special features available for the 1800 was so large that they could not all be accommodated simultaneously in any reasonable size electronics frame. This led to the creation of the "floating feature" concept; the circuitry for a given feature might appear in one location in a given machine and in quite a different place in another. This required an entirely new dimension of discipline and cooperation from the entire gamut of IBM organizations, from sales through engineering, manufacturing and purchasing to field engineering, but the most severe impact was on manufacturing.

Many functions that had previously been readily accomplished by routine manual procedures had to be computerized in a hurry. That it was carried off so successfully is testimonial to the dedication of those involved.



*An 1800 system going together in Bldg. 005. Keeping track of "floating features" was a major methods headache.*

Also, in contrast to the usual computer situation -- where the operating system always commands system resources -- the utilization of computer resources for process control must necessarily be subject to change in the face of external events. Therefore a separate multi-programming executive software system had to be developed along with the hardware.

#### *IBM's Kind of Product*

Joe Sheredy has held key positions in both the laboratory and manufacturing, and has served as the interface between the two organizations in connection with many products. Sheredy describes the printer subsystem, the 3800, as "IBM's kind of product — tough to design and tough to build." It is certainly true that it combines a number of new and complex technologies. Significant innovation has been required in both development and manufacturing to achieve a successful product.

The development of the IBM 3800 Printing Subsystem began in October 1967, when Chuck Branscomb, SDD President, asked Laboratory Managers Ira Lohman from San Jose and Jim Troy from Endicott to undertake the development of a high performance non-impact printer. The development began in San Jose even though the printer mission was in Endicott at that time. This decision was based upon the fact that extensive technical capability in the relevant technologies existed in San Jose in research and product development. Moving this talent to Endicott was not practical.

When the IBM 3800 Printing Subsystem was announced on April 15, 1975, Carmin Rosato, who had taken over project management from Jack Hildebrand, paid special tribute to Hildebrand's early accomplishments. "We would not be announcing this product today," he said, "were it not for the fact of Jack's early guidance through extremely tough technological problems in the advanced development phases."

Larry Wilson at one time advocated a “sunset law” for product development — any development that has gone on for five years without entering Product Test would automatically be terminated on the grounds that the product was very likely unmanufacturable. The 3800, which had a development history of at least eight years, may be a notable exception to Wilson’s Law. However, acting on the essence of Wilson’s message, Manufacturing became deeply involved with the development team as early as March 1973, four years before first customer shipment. It is probably fair to say that the 3800, more than any other product, has benefited from this early participation of plant personnel. Sheredy and Steve Ramsey were among the first who contributed heavily to assuring manufacturability as the design proceeded. Over the years since, there has been continuous interplay between plant and laboratory personnel.

An important component of the 3800 Printer Subsystem is the organic photoconductor, which was developed in the early 1960’s at San Jose Research by David Shattuck and Ulo Vahtra. This photoconductor is flexible and can, therefore, be wound around a drum. It is also easily replaceable. There will be more said about this material in the next chapter. Another 3800 innovation is the use of a modulated laser light source to expose the photoconductor.<sup>31</sup>

Most parameters connected with the 3800 are impressive, but one in particular is revealing of the nature of the challenge that manufacturing was to face. The machine is capable of printing at the rate of 20,400 lines per minute and at top speed consumes 1.7 miles of paper per hour. A partial listing of the highly interactive technologies, many of them new, that make this sort of performance possible includes: laser beam character generation using a piezoelectric crystal modulator, an 18-faceted precision rotating sweep mirror and other precision optics; ultra-high speed paper handling including bursting and stacking; new levels of performance requirements from the organic photoconductor material (two months of usage in the 3800 is equivalent to a lifetime of usage in the IBM office copier); fusion of toner particles to paper traveling at over two feet per second, and so on.

It is safe to say that this is IBM’s most complex product and the opportunity cannot be passed to pay tribute to Chris Coolures and his development teams as well as to Dick Mattern and his group of business planners for the introduction of a new era of high function computer printing capability.<sup>32</sup>



*Development engineers take a final look at the 3800 Printing subsystem with the Burster-Trimmed-Stacker feature before it is shipped. Larry Derrington and Les Morris, front, Stan Moss, left rear, John Wright, John Graham and Fred Arrasmith*

Finally, it should be noted that Manufacturing Engineering's Bill Cathcart designed and constructed the precision test equipment for fine tuning the machine's optical system –equipment that has since become the project standard.

#### *The World of Programming Systems*

In 1957, when the Laboratory was celebrating its fifth anniversary, Robert C. Miller came to San Jose, transferring from his post as System Science representative in Sacramento. His assignment was to bring the programmer's viewpoint to Charlie Earley's product planning team, which was even then considering 305 follow-on products. Miller can claim to be the first full-time programming specialist in the San Jose complex.<sup>33</sup> In those days, computers were still for the most part instructed in machine language and the advent of FORTRAN and other high, level languages lay still beyond the horizon. Thus, if anyone had told the engineers then working on the 305 that one day there would be in San Jose a 585,000 square foot building complex housing 2,000 IBM professional programmers, they would have been regarded as a prime candidate for protective custody. Hans Jeans and Quentin Correll soon joined Miller and the trio contributed some customer routines for the 305 in addition to assisting the product planners. When the Control Systems mission came to San Jose in 1960, Miller became part of its product planning team and Jeans took over responsibility for 1620 programming.

By 1961, Earley, then in ASDD, had launched a major new pioneering programming effort known as Multiple Business System (MBS). It was directed at providing computer facilities to small businesses through shared access to a large central machine. This idea was a precursor to today's time sharing. The service was never available from IBM domestically but was announced by the World Trade Corporation in 1970 and is in use today. In addition the application program "customizer" concept pioneered by MBS has found wide usage in the General Systems Division product line.<sup>34</sup>

Another pioneering time sharing system developed in ASDD was announced in the fall of 1964 for the 1440. This system, known as the Administrative Terminal System (ATS), was directed at providing computer assistance for the preparation of text and other administrative documents. The project was led by Roy Haug and Michael Nekora.<sup>35</sup>

In 1961, Wallis Bolton, Development Laboratory Manager, got general acceptance of his concept of a unified Computation Center to bring together the various small programming activities that had sprung up and he selected Eugene Lindstrom to head it. The Computation Center encompassed both technical support programming, such as design automation for the 1301 project, and programming product work. Jeans and his group working on the 1620 Assembler, FORTRAN and Monitor packages, became a part of the Center, as did the Control Systems Executive programs.

By the fall of 1964, when the true magnitude of the programming task in support of the System/360 was beginning to be fully appreciated, the San Jose Computation Center's External Commitments Department was assigned the task of developing the Report Program Generator (RPG) and the Assembler language portions. A year later, when the Systems Development Division was created and Carl Reynolds was named divisional director of programming, work on System/360 programming was severed from the Computation Center to form the nucleus of the first semi-autonomous Programming Center here. Gene Lindstrom was named manager in July, 1965 and Roger Simons came over from ASDD to assume leadership of the Computation Center.

The truly significant role that disk products would play in System 360 was apparent by late 1966. In order to provide a better environment for considering trade-offs between disk file control hardware and data management software, a decision was made in early 1967 to move the Data Management elements of the operating system from Poughkeepsie to San Jose. Tom Apple came along with the move to become manager of the San Jose Programming Center. Programming focused on data management, device support, access method design and key system facilities such as Input/Output Supervisor (IOS) and System Generation



*Eugene Lindstrom*

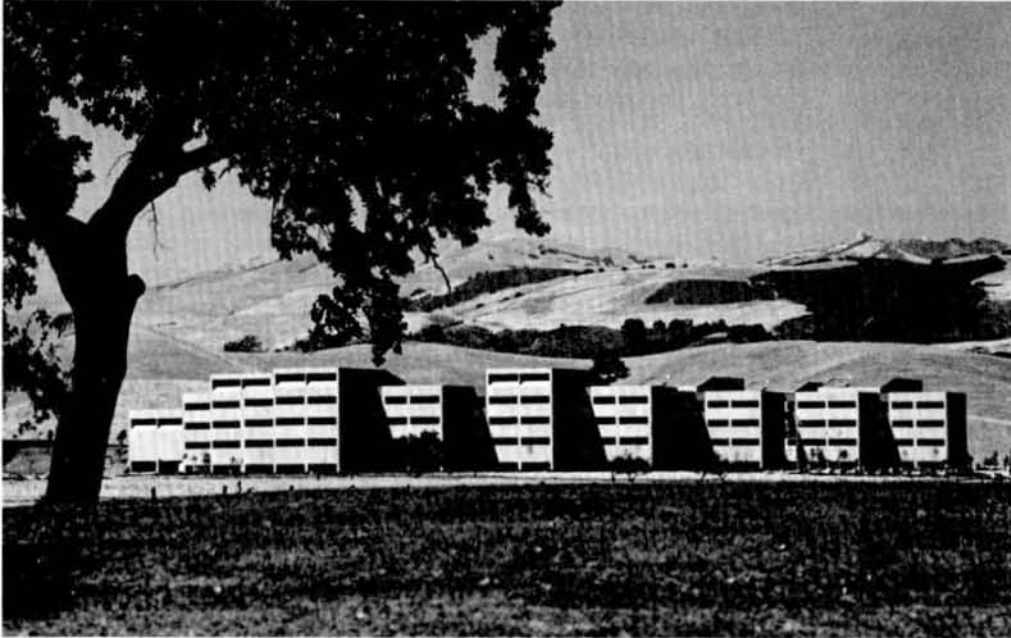
(SYSGEN). Apple initiated the first serious effort in the development of data base software which led to a new Virtual Storage Access Method (VSAM), an important innovation announced in 1972.<sup>36</sup>

The Data Processing Division, meanwhile, had noticed a sharply rising customer interest in data base management program products in specific applications. To satisfy this interest, DPD in 1970 established a Data Base/Data Communications Center in Palo Alto. The three major products of this organization were: the Information Management System (IMS), Customer Information Control System (CICS) and a Generalized Information System (GIS). Burt Whipple brought these early priced program products together under this DB/DC product mission.

In January 1972, the importance of data base systems to IBM products was fully recognized when the DB/DC center was absorbed into the SDD Programming Center under the direction of Frank Carnella. This era was one of significant expansion of product and programming location responsibilities and was highlighted by: significant component design and development for three major virtual storage operating systems - OS/VI, SVS, and MVS, a quantum jump in increased device support activities; and the design and development of VSAM.

The responsibility of the San Jose Programming Center manager encompassed work going on at other locations: Palo Alto, Boulder, New York City and several European Laboratories. When Jim Frame took over this position in March 1973, he undertook the consolidation and integration of this diverse and far-flung activity and began structuring the current Language and Data Facilities mission. The mission was transferred to the General Products Division in 1975.

With the opening of its new Santa Teresa facility in 1977, programming center personnel from seven different buildings spread around Santa Clara County, from Palo Alto to Campbell, are at last brought together. The Santa Teresa Laboratory complex consists of eight four-story cruciform-shaped buildings which occupy only 50 acres of the 1,180 that IBM holds there.



The Santa Teresa Laboratory provides world-wide leadership in four important areas:

- GPD device, subsystem, data management and mass storage support.
- Data Base/Data Communications program products.
- Interactive problem solving languages: Virtual Storage Personal Computing (VSPC), APL and BASIC.
- Application development languages: COBOL, PL/1, and FORTRAN.

## Chapter 8. A Little Bit About a Lot of Things

The preceding chapters have focused on the evolution of some of San Jose's most important products. Yet, the story would be incomplete without recalling highlights of other less dramatic innovations that had their roots in San Jose.

### *Six from Research*

The San Jose Research Laboratory is one of three laboratories of the IBM Research Division, the others being in Yorktown, New York and Zurich, Switzerland. At the outset under Johnson, the focus of the Laboratory was more nearly advanced product development and the turn toward research as the term is generally understood came with Gardner Tucker.<sup>37</sup> From the first, San Jose researchers have made substantial contributions to the world of basic science, as well as to the technologies of IBM products. Research in San Jose has been distinguished by contributions in two fields in particular — materials science, especially organic materials, and the analysis and application of large computing systems. Six areas of work will be used to highlight innovation at San Jose Research.

*Organic Photoconductors:* The organic photoconductor, which is key to the success of both the IBM office copier and the 3800 Printing Subsystem, grew from work done here. Because of the Laboratory's strength in organic chemistry it was in 1961 assigned corporate responsibility for coordinating the company's needs in this field, with emphasis on light-sensitive organic materials for electrophotography. The work was under the direction of Art Anderson and later Cliff Herrick. It was already known that polyvinylcarbazole exhibited photoconductive changes when exposed to ultraviolet radiation. It was also known that the addition of 'transfer' molecules could shift the effect into the visible spectrum, but unfortunately the best sensitivity that could be obtained was only one-tenth that of commercial inorganic photoconductors. The breakthrough came when Dave Shattuck and Ulo Vahtra began testing the effects of a sensitizer known as trinitrofluorenone (TNF). The literature had reported that TNF could enhance the sensitivity of polyvinylcarbazole in concentrations of 2 to 3 percent. Shattuck and Vahtra discovered, however, that higher concentrations produced a marked increase in sensitivity without introducing any of the common degrading



*The IBM San Jose Research Laboratory was completed in 1970.*

effects. In fact, they increased the concentration to nearly one molecule of TNF for every molecule of carbazole and observed that a truly new material was formed. It was a polymer with different physical and electrical properties from any reported in the literature. Indeed, its light sensitivity is equal to that of the inorganic materials then in commercial use for document copying, and unlike the latter it is flexible. The technology was transferred to the Office Products Division Laboratory in Lexington.

*An Electron Beam Resist:* Traditionally, ultra-small circuits have been produced through a lithographic process in which the desired patterns are exposed onto a plastic resist material by visible light and then etched. These techniques are limited because the lines cannot be made narrower than the wavelength of the energy used to expose them.

To overcome this, and thus to pack more components into a given area, it is desirable to be able to use energy sources of very short wavelengths. Researchers at San Jose and elsewhere have pioneered the use of finely focused beams of electrons to 'draw' circuits on resist materials under computer control, but a fully successful system required the development of a resist material that is highly sensitive to electron beam radiation. After testing literally hundreds of different candidate materials, the experimenters discovered that two polymeric molecules — methyl-methacrylate and methacrylic acid — would combine chemically to form a copolymer with the desired characteristics. In the end, they achieved a deep understanding of the interaction between polymeric resists and electron beams. The practical outcome has been the narrowing of microcircuit lines by a factor of five.

*A Superconducting Polymer:* It was once thought that the phenomenon of superconductivity (the complete absence of electrical resistance) was unique to metals. It was first observed in a polymer during an investigation conducted by Richard L. Greene and G. Bryan Street of San Jose Research in conjunction with Laurence J. Suter of Stanford University. They found that polysulfur nitride reached a superconductive state at one-half degree Fahrenheit above absolute zero. Although this is a prime example of a research result that has no immediate practical application, it does suggest that further study might lead to an improved understanding of the phenomenon and eventually to the structuring of a material that is superconductive at substantially higher temperatures. Every technologist in the field dreams of the discovery of a material that superconducts at room temperature; the practical applications would then be limitless. The work at San Jose Research gives new hope that this may be more than just a fantasy.

*Scientific Computation:* Computer scientists at the San Jose Research Laboratory have focused on a range of theoretical problems that lend themselves to solution by large, high-speed computers and the Laboratory has, for many in the scientific world, become synonymous with "large scale scientific computation." From these studies, IBM has gained much valuable information, not only about the physical phenomena under scrutiny, but also of the programming requirements and operating characteristics of very large machines.

The field of quantum chemistry has been a particularly productive one from the viewpoint of both basic science and advanced computer applications. Enrico Clementi, Paul Bagus, Bowen Liu, Megumu Yoshimine and Douglas McLean developed a set of programs called ALCHEMY which allow the fundamental chemistry of small molecules to be examined by computer. The algorithms developed by them have had effects on computing practice well beyond the original application.

*Laboratory Automation:* Researchers in San Jose have contributed significantly to the use of computers in laboratory environments by developing a software system which enables the IBM System/7 computers to respond in real time to fast occurring events in lab experiments. The system enables data to be passed back and forth between a number of System/7's and a more powerful central computer. In San Jose, for example, the system is currently used to control 125 laboratory operations and process control applications on nineteen different System/7 computers.

In April 1976, this software package, developed by Bob Martin and Don Raimondi, was made available to IBM customers under the name Event Driven Executive and has become one of the most successful software products ever offered for use with the System/7.

*Relational Data Base:* In 1970, IBM Fellow Ted Codd of the San Jose Research Laboratory proposed an alternative to the conventional structures for handling computer data bases. Building on his idea, other computer scientists in the Laboratory have developed a system of programs to test its feasibility in real life business applications. If the tests are successful, the complex business of manipulating and extracting information from computer data bases could be reduced to learning a few simple English-like instructions. Thus a person with little inclination to become a computer expert might be able to accomplish what it now takes an expert to do.

#### *New Product Probes From ASDD*

The Advanced Systems Development Division was created in May 1959, and ASDD Laboratories were spun off from Research in San Jose and Yorktown. For several months, Johnson headed both the San Jose ASDD and Research Laboratories, but, in August, Gardner Tucker arrived to take over the Research Laboratory leadership.

Consistent with a new corporate policy requiring each new division to find a permanent location for its buildings, ASDD selected a bucolic setting on Guadalupe Mines Road in Los Gatos. There, a most attractive redwood building complex was erected which for a decade was the home of ASDD, Los Gatos.

ASDD existed as a part of the IBM development team for fourteen years. Its mission was to explore potential new business and application opportunities through a prototype phase. Any efforts which matured were transferred to an appropriate product division for development and manufacturing. ASDD was combined with Industry and Custom Systems in 1973 and absorbed into SDD. The Los Gatos facility became a part of the General Products Division Development Laboratory in 1976.

ASDD San Jose/Los Gatos had a wide variety of interesting projects including pioneering work by Emil Hopner in data communications and ultra high density magnetic recording, library automation by Marjorie Griffin and custom LSI design by Larry Warren. In addition, the early work of Ernie Nassimbene and Tom O'Rourke on delta distance codes deserves note. These and other technologies pioneered at the Los Gatos Laboratory have found their way into products released by IBM Laboratories around the world.



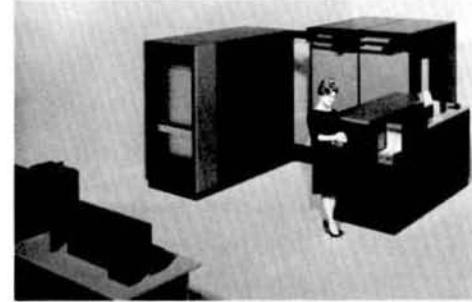
*Louis D. Stevens*

*Photographic Storage:* One of the important activities at ASDD had to do with systems that store information on light-sensitive emulsions in either digital or graphic form. Both applications were being worked on in Johnson's laboratory as far back as 1955, one (digital) being called "direct access photo memory," and the other (graphic) emerging under the code name "Walnut." The latter was a massive image retrieval system contracted for by a government agency. This system was installed in December, 1962 under and is still operational. Work on photographic storage continued in ASDD, aimed originally at the engineering drawing field. In 1961 Stevens returned from a two year assignment in the east to take over responsibility for this technology known as "Cypress". Working with Stevens were Jack Kuehler and Jack Harker and as the work became increasingly product oriented it was transferred to the Product Development Laboratory in December 1964, the three principals going along with it. The next summer it was announced publicly that IBM was working on two massive digital photographic memory systems for the Lawrence and Berkeley Laboratories of the Atomic Energy Commission. Each of these machines could store an

unprecedented one trillion bits of information on film chips. Under contracts amounting to \$2.1 million, the two machines were installed in September 1967 (Livermore) and March 1968 (Berkeley) as the "IBM 1360 Photo Digital Storage and Retrieval System." Three additional systems were built under special contracts, two for the National Security Agency and one for the Los Alamos laboratory of the AEC. Three of the five are still in operation. In addition an "IBM 1350 Photo Image Storage and Retrieval System" for engineering drawings received a limited announcement in May, 1966 but was withdrawn later in the year. Although they were not marketed further, the engineering accomplishments on these products were monumental, and many technical advances in the photographic sciences and mechanical arts were made. The experience gained was useful in early versions of the IBM 3850 Mass Storage System designed in Boulder.

*Application Terminals:* From 1965 until 1972 ASDD Los Gatos had a program directed at financial terminal systems for electronic funds transfer. From this effort the magnetic stripe credit card and several terminals for its use were developed. The first of these was the 2730 Credit Authorization Terminal done jointly with Custom Systems. Another was an automatic ticket vendor for use by airlines. This was a joint field test effort with American Airlines and American Express. Jerry Svigals, who contributed to these two efforts, also led the work with various standards groups to establish international standards for magnetic stripe credit cards.

In 1968 a prototype of a computer-controlled cash-dispensing terminal activated by a magnetic stripe credit card was constructed. This prototype was transferred to SDD Custom Systems in Raleigh. It provided the base for a successful bid to Lloyds Bank and 500 were produced as the IBM 2984. This product was the predecessor of the IBM 3614 Consumer Transaction Facility, which made a full circle when it became a Los Gatos project upon integration of Custom Systems and ASDD into SDD Industry Systems.



*Industrial Design mock-up of the Cypress Photo Digital File system.*

One other product of interest was started in ASDD using the magnetic stripe technology, this time on card stock used as stored fare tickets for Bay Area Rapid Transit (BART).

Whenever you ride BART you are surely made aware all over again that the fare collection system is a product of IBM San Jose. What may not be appreciated, though, is the complexity of the engineering and, most especially, the human factors problems that were encountered. What would happen if cards containing monetary information recorded on magnetic stripes were loosed to the general public? How would a mother with six children get them all through the entry gate when the ticket return chute had to be on the far side? How do you design an admittance gate so that you accept a ticket holder but exclude the next in line without dismembering him?

A prototype was constructed by ASDD in 1967 by Bob Schneider and Frank Glass and when bids were requested by BART in 1968 FSD Huntsville decided to respond, based upon this ASDD work. They were awarded the contract in May 1968 and went to work. By March of 1970 fears were surfacing that the

*Bill McDonnal, Art Guldenschuh, Lou Stevens and Ralph Golub were passengers on an early BART train.*



scheduled installation date would be missed. It was decided that San Jose proximity to the customer was of overriding importance and the project was assigned to the San Jose SDD Development Laboratory. W. J. McDonnal, DPD branch manager in Seattle, was assigned to lead the effort and Ralph Golub returned from a two-year assignment in Paris to be manager of engineering. Together they assembled a team of highly talented people from Los Gatos, Huntsville and San Jose, and completed the contract on time, with major contributions from Manufacturing and Joe Sheredy.<sup>38</sup>

*Display Terminals, Disk Buffers, and Education Systems:* ASDD built many new display prototypes and two of them had an effect on IBM products. The first, built by Jim Allen in 1964, formed the starting point for the development of the IBM 2260 display by the Kingston Laboratory. And the work done in 1967 by J. T. Ma and H. F. Martin on magnetic disk video buffering gave Allen, by then in the Development Laboratory, the basis for his ARIES buffer.

One of the most intriguing projects of the ASDD Laboratory was an outgrowth of Rey Johnson's life-long interest in education. By the time Johnson was appointed an IBM Fellow in 1965 (being replaced as ASDD Lab Manager by Stevens) he had been successful in stimulating IBM to probe into computer-assisted instruction through a contract with Patrick Suppes at Stanford University. This contract was an important ingredient in the development of the IBM 1500. As an IBM Fellow, Johnson turned his full attention developing aids to teaching and learning, an interest which he pursues after "retirement" at his own laboratory in Palo Alto.

#### *Unsung Heroes in Custom Systems*

The ASDD work on credit card terminals was picked up and expanded by a group of people who are among the unsung heroes of the IBM San Jose team. Various known as Custom Systems, Special Systems, or Industry and Custom Systems, in the early days they tended to work off stage-center, on customer Requests for Price Quotation (RPQ's). However their role was expanded in 1963 when it was recognized how much IBM sales revenue was made possible through their

contribution. To better focus these efforts a separate organization was established reporting to Bob Nern. That organization was the forerunner of the current SCD Industry Systems, a major unit of the IBM development team.

In San Jose it all started with the original San Jose product, the 305 RAMAC. Ray Bowdle estimates that 20 percent by weight of all RAMAC's shipped can be attributed to special features and RPQ's designed by Custom Systems. It may not be far off target to assert that 95 percent of all RAMACS had at least one special feature.<sup>39</sup>

In 1958 the groups working on special features for the 305 and the 604 were merged into a Special Engineering Department.<sup>40</sup> At one stage the department had as many as 150 employees. A number of important projects involved the design of remote data collection terminals and the communication links between them and a central processing unit.

Perhaps the most significant of these was a \$13 million system that entailed specially designed terminals installed at each of the 1,500 offices of the Household Finance Corporation and connected with a central computer system in Chicago. The success of this system can be traced to the leadership provided by Ralph Golub and Ed Murphy, as can a number of banking terminals such as the 2972/2980 which was done for First National City Bank in 1966. This effort was precursor to the subsequent IBM 3600 banking system in which San Jose Custom Systems was destined to play a part through the development of the 3614 Customer Transaction Facility. This product was defined in November 1971 and announced two years later. It encountered many new and unique requirements because of its direct interface between a bank customer and his money. San Jose Custom Systems also pioneered computer typesetting for newspapers and supermarket customer checkout terminal which subsequently became a Raleigh product.

The work on magnetic striped credit cards culminated in the announcement of the IBM 2730 in early 1971. Two other unique products that used the Magnetic Stripe Card were pioneered by Custom Systems. They were the Controlled Access System (CAS), and the Slot Scanner. The CAS was developed to an early

prototype in 1971 and then taken over by GSD Boca Raton and announced on the System/7 in 1972. The slot readers were developed from ASDD prototypes as a common subassembly and have found use in the 3600 and 3270 and other systems.

### *Floppy Disks and How They Grew*

It is appropriate to close this chapter with a return to disks, but of another variety. The "floppy disk" project started off in San Jose modestly, giving little evidence of the industry-wide repercussions it was eventually to produce. Systems architects in the 1967 era were calling for a simple, highly reliable and inexpensive device for storing the microcode used for initial loading of control programs and diagnostic routines.<sup>41</sup> In November, David Noble was assigned the development responsibility. He investigated a number of possible technologies and concluded that the principle employed in the flexible recording disk used on a German dictating machine, combined with a direct access capability, offered the most promising approach to meeting the specifications, an unusual aspect of which was that the medium had to be transportable via the U.S. mails. Noble proposed a "read-only" device based on a variant of the audio disk and the concept was accepted.

The original disks, eight inches in diameter, were stamped from commercial computer tape stock and backed with one-eighth inch of foam rubber for compliance. Early in the program, the compliance material was transferred to the head-arm assembly as a pressure pad on the reverse side of the disk, and the disk itself became a thin plastic substrate coated on both sides (to avoid curling as well as to permit discharge of static electricity). The disk was permanently sealed in a protective envelope which was lined with a wiping material to keep the recording surface clean. The envelope had a central aperture to expose a portion of the disk surface to the magnetic head. The head access mechanism was based on a lead screw rotated by a simple stepping motor.

The so-called "Minnow" file and its successors became the initial control program and diagnostic program loading device for the 370 family of IBM processors as well as for the storage control units of San Jose direct access file products. Usage was great, and the next generation flexible disk drive called "Igar" incorporated writing capabilities with increased speed and capacity as well as an interchange architecture. <sup>42</sup> Prospective users appeared in droves.

In December 1972, the flexible disk responsibility was transferred to Rochester (Lou Blendermann's effort was important here) and since then its commercial importance has continued to expand spectacularly. Within IBM, flexible disks (now called Diskettes) have found use in processors, control units, key entry stations, terminal devices, word processing units, printers, input/output devices and others. Other manufacturers around the world have picked up the idea, manufactured compatible flexible disks and drives, and applied the usage of flexible disks in large numbers for use with low cost microprocessors.



*Hal Hester and Russ Rogers with the Diskette and using equipment which they helped develop.*



## Chapter 9. The Score at the End of the First Quarter

So what has it all added up to, this quarter century of innovation in San Jose? How big has the impact been on IBM? On the data processing industry? On the world of commerce and industry?

In order fully to appreciate the magnitude of it, one must understand a little of what happened following the introduction of the concept of disk pack replaceability. When the 1311 was announced for use with several smaller IBM computers in 1962, "invention once again became the mother of necessity". As Haanstra, and perhaps he alone, had foreseen, hitherto undreamed of customer applications for data processing surfaced which, in turn, created the necessity for still further improvements in direct access hardware. When the 2311 came along a year later, the capacity of the replaceable pack was more than doubled and the access time halved (see Appendix G). Perhaps even more important now was the introduction of the "common file control unit," the 2841, which added so significantly to operational flexibility and error control. Systems designers, recognized the advantages of development of the storage units and their control electronics jointly at San Jose and Martin Kelly came to San Jose to head up the talented team that developed the remarkable 2841.<sup>43</sup>

The company now began to think in terms of "storage subsystems," semi-autonomous storage hierarchies incorporating rather extensive data manipulative powers. Customer appetite for storage appeared insatiable as acres of filing cabinets across the land began to be emptied, their contents transferred to magnetic disks. In 1964, Haanstra pressed a concept he had investigated a few years earlier, the idea of increasing storage subsystem flexibility, reliability and capacity another notch by incorporating in one physical entity a number of disk drives and an "intelligent" file controller. New technology had been demonstrated in the laboratory by Rudy Lorenz and his crew which would permit a quadrupling of storage capacity as well as improved access times. At Haanstra's urging, Witt convened a meeting that included Kelly, Shugart, Lorenz and Peter Lazarus; the outcome was the basic concepts for the 2314 File Facility, the "wall-to-wall" storage subsystem comprising eight active and one spare drives.

So eagerly was it accepted by the data processing world that sales of the 2314 outstripped the announcement level forecasts by a factor of more than ten.

It was inevitable that the proliferation and profitability of disk storage should attract competition. Investment capital was readily available during the sixties for starting up any organization associated with the computer industry. The new companies often recruited development people from the established mainframe manufacturers, including a number from San Jose development. But the shocker to management was when trade secrets of the company's follow-on disk file technology were stolen. Additional new security procedures became essential to protect company technological assets. <sup>8</sup>

And IBM indeed had accumulated an impressive store of technology. In 1969 Witt organized a separate function under Harker to assemble the "critical mass" required for achieving progress in the increasingly process-oriented technologies that future files would require. The group, then known as Technology and Advanced Development, today called Product Technology, established a close working relationship with manufacturing on process-intensive product elements to provide early assurance of manufacturability. <sup>44</sup>

The new product pace quickened. A full recitation by name and type number is not warranted here, but it will be useful to briefly mention the most interesting.

In 1970 came "Merlin," the IBM 3330, with its three and one-half times increase in capacity over the 2314. It incorporated a new voice coil actuator with improved access times, a track-following servo for increased track density and a new flexible controller. Also in 1970, "Zeus" (the IBM 2305) became a member of the storage subsystem line up. For by now the cost of producing the magnetic read/write heads had been reduced to such an extent that it became economically feasible to offer a product having a separate head for each recording track, 768 in all, thus providing the extremely high data rates and short access times required by larger processors. The control units for Merlin and Zeus (the IBM 3830 and 2835) also contained innovative new features. Designed around a common microprogrammed processor and a writable control store loaded from a Minnow disk they provided a new level of flexibility. <sup>45</sup>

With the 1973 announcement of “Winchester” (IBM 3340), came the concept of “data modules,” replaceable cartridges containing not only the recording surfaces but also the read/write heads with their access mechanisms. The advantage of this configuration is that the head that writes the data is always the head that reads it back; this permits further recording density increase and eliminates any need for adjustment of heads in the field. <sup>46</sup>

Then a funny thing happened. A growing number of customers were no longer making use of the replaceability feature of their storage units. What had happened was that the capacity per disk pack or data module had been increased, and the cost of the drives decreased, to such an extent that, for many installations, the on-line capacity and reliability of a single pack per drive was adequate. The response to this trend completed the full circle back to the fixed disk concepts commenced twenty years earlier. If replaceability was not required, then still further recording density increases and reduced storage cost could be achieved. And so in July 1975 “Madrid,” (the IBM 3350), made its appearance, offering an incredible storage capacity of up to 317 megabytes per spindle at a density of three million bits per square inch of recording surface, a factor of 1,500 increase over the 2,000 bits per square inch of the original RAMAC disk file. Each “Madrid” contains the same amount of data as sixty-three much larger RAMAC files. And the customer cost per million bytes has been reduced by a factor of seventy. <sup>47</sup>

If the group at 99 Notre Dame had not persisted with its “baloney slicer” one can assert with full assurance that someone somewhere else would sooner or later (and probably sooner than later) have come up with the same or a similar idea. For when the time is ripe for a technological breakthrough there are likely to be several independent groups with roughly equivalent competencies engaged in the attempt to satisfy a need. Yet it remains a fact that direct access data storage was pioneered and carried forward by IBM in San Jose, and this history has been an attempt, in part, to describe why it was so.

Each reader will decide for himself the larger philosophical implications of it all, but the significance is evident in the outcome as of today. At present there are many disk drive spindles installed, and widely in use around the world. They can



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4. *IBM Record*, Vol. 36, No. 2, April, 1953, p.4.
5. Michael F. Wolff, "The R & D 'Bootleggers': Inventing Against Odds," *IEEE Spectrum*, July, 1975, p. 38.
6. Jean Ford Brennan, *The IBM Watson Laboratory at Columbia University: A History*; IBM Corp. Armonk, 1971.
7. J. Rabinow, "The Notched-Disk Memory," *Electrical Engineering*. Vol. 71 August, 1952, p. 745-9,
8. *Think*, Vol. 43, No. 3, May-June 1977, pp. 12-16.
9. IBM San Jose Research and Engineering Laboratory is the name that appeared on the Laboratory's front door at 99 Notre Dame Avenue. But the usage was a bit loose and in other places and other times it was referred to as the IBM Laboratory for Advanced Development and the IBM Research and Advanced Development Laboratory.
10. When after a year it became necessary to add onto the building, the expansion was constructed on what had been the parking area. An empty lot across St. James Street was leased as a replacement. This lot had been the original homestead of the legendary Santa Clara County figure, Mountain Charley McKiernan, the first American to settle in the Santa Cruz mountains, where, fending off grizzlies with one hand, he built many of the roads that now wind through the mountains.
11. Haddad's original acronym referred to the complete 305 system and was coined from Random access memory Accounting MACHine. In later usage the word became generic and was applied to any machine with a disk file. Sales literature changed the meaning to the more general (and sensible) Random Access Method of Accounting and Control.

12. The Zellerbach Paper Company's tub file billing and inventory control operations provided the touch stone application study, and the interest, assistance and cooperation of principals and employees of this company were vital inputs to the specifications of the disk file, the file-to-card machine and the 305 RAMAC.
13. During his Endicott days Johnson had designed and built prototypes of several random access files of sorts, including one that accessed punched cards for reading.
14. Although the idea did not catch on at the time, a similar scheme turned up years later in the IBM product line as the 2321.
15. The table below compares Critchlow's February 2, 1953, Design Objectives with the 350 specifications.

	<b>2/2/53 Design Objectives</b>	<b>Final 350</b>
Disk diameter, inches	16	24
Recording band, inches	4.25	5
Tracks per inch (tpi)	20	20
Tracks per disk side	82	100
Bits per inch, max (bpi)	200	100
Characters (7 bit) per track	200-inside band (64) 400-outside band (18)	500
Characters (7 bit) per disk	80,000	100,000
Number of disks	50	50
Capacity (7 bit characters)	4,000,000	5,000,000
Disk spacing, inches	.313	.4
Rotational period, milliseconds	62.5	50
Seek time (max), seconds	<1	.6

16. In addition to Haanstra, the early system study group consisted of Kean, Critchlow, Melvin E. Maron, Larry H. Bixby, and Thomas G. Leary.
17. For example, a tendency of the system to "creep" around null position was corrected by introducing an integrating network to increase the zero frequency gain of the amplifier. But this led to the tendency to overshoot, thus a tachometer to provide velocity damping was also incorporated.
18. Other key personnel assignments during the summer of 1954 were: Wes Dickinson, servo and electronics; Norm Vogel, airhead and arm; John Lynott, carriage and ways; Jack Harker, clutches, capstan and drive; Don Johnson, disks and coatings. Significant improvements to the design of the magnetic read/write element were contributed during this period by Quade and A. S. Hoagland, then a professor at U. C. Berkeley, serving IBM in a consultant role.
19. When, in March, 1955 the decision was made to incorporate a 100-character magnetic core buffer (Williams tubes were also serious contenders) into the system design, J. M. Taylor and H. K. St. Clair spent several months in Poughkeepsie to coordinate the work there.
20. John Nolan did some pioneering work on means to "randomize" part numbers to provide useful disk addresses. This work led to the invention of a practical "hash" algorithm. The feature did not appear on the IBM 305 product, but the subject of automatic address translation was to occupy the attention of many minds over the ensuing years, and is a principal task of modern access method software.
21. Some of these visitors came, gave of their knowledge and departed; others either immediately or subsequently became permanent transfers. Among the latter were John Nolan, Lesser and William Woodbury who participated heavily in the basic system organization of the RAMAC; H. S. Gifford, the first permanent Product Planning representative here, Ernest Friedli, who supervised construction of the first field test machines with the assistance of Dean T. Hodges; S. H. Bailey and Jon Wiseman, who established the Product Test operation; and Jacob E. Bell who set up the Customer Engineering organization. F. J. Wesley, whose memo had given the project such important impetus, was officially appointed WHQ coordinator for RAMAC.

22. Product Planning in those days reported independently to William Simmons at World Headquarters and it was a source of some irritation to local engineering managers that they did not have direct control over what it was they were to develop. Not until the creation of the original General Products Division in 1959 did the product planning function become an integral part of laboratory operations.
23. Jon Wiseman and Jake Bell, on loan from Endicott Product Test and Customer Engineering respectively, participated actively in this intensive debugging effort.
24. Goddard had in a sense anticipated Hagopian. His engineering notebook shows an air head design, the windward edge of which was opened to the breeze. The idea was that this would scoop up air molecules as the disks rotated, thus building up a pressure in the manifold to be exhausted through the Bernoulli ports. This at least exhibited an appreciation for the importance of doing away with clumsy compressors.
25. Others besides Harker engaged in this project were Hoagland, St. Clair, Russell Brunner, A. Osterlund, John Beck and Sam Baio. Upon transfer of the project to the development laboratory in July 1957, Beck, St. Clair and Harker went along with it and the effort was consolidated with work of similar objectives going on under T. Noyes.
26. Actually, transistorization of the RAMAC had been considered two years earlier, when Heywood's group undertook the major redesign of the original 305A circuitry. The conclusion at that time was that the supply of transistors with uniform characteristics was not sufficiently dependable.
27. Working with Hoagland were K. E. Haughton, J. O. Hildebrand and G. C. Bacon.
28. In the 1958 development report of the Data Processing Division, the following are among the projects listed for San Jose: Million Character File, Billion Character File, Mechanical Tub File (!), 305TX Studies, 310 Proposal, Advanced Disk File, Double Density 350, Advanced Card Development, File Indexing Studies, Single Disk File, Portable Disk File and Small RAMAC (the Low Cost RAMAC System).
29. Perhaps this conflict was never more intense than during the introduction of System 360, when the company for the first time introduced a completely new product line from top to bottom in one massive step. During this period a "troika," with representatives from

Product Test, Manufacturing and Engineering, met on a weekly basis to iron out disputes as to how technical problems would be approached and who would be responsible for doing what.

30. The first new products department consisted of Walter E. Hoppes, Manager and Program Administrators Bernard J. Barden, Donald E. Brooks, Peter J. Ficalora, and Edward R. Sanet.
31. Laser beam accessing and modulation technology was started by Mel Rabedeau and Milt Latta in the late 1960's and converted into an operating prototype device by Jim Belleson and Bob Treseder. Jack Fleischer invented the optical system that made the rotating mirror practical.
32. Other key engineers included Allen Slutman, Roy Jensen and Howard Smith. The product planning was handled by a team under Ken Foulger. First customer shipment came in the spring of 1976.
33. A year earlier the fledgling Research Laboratory had installed an IBM 650 to be used for analytical support of its technical programs (it was on this machine that the pioneering work on compressible fluids was done). Charles Hoppel, Roger Simons and Bill Michaels were the nucleus of the Research computation center, but they were more accurately mathematicians than programmers.
34. Originally conceived and demonstrated by Joyce Wrenn and Bryce Ella for MBS the "customizer" concept was later developed in GSD by Jack Mumford.
35. The inadequacies of existing terminals in the office environment became apparent and stimulated the development of an improved typewriter-like terminal. Fifteen prototypes of this terminal developed by Jack Masterson were installed in ASDD for testing. They provided the starting point for the development of the 2740/41 Terminal System by OPD Lexington.
36. This project, known as AM/1, was redirected to a simplified system known as AM/0 and finally reoriented to the access method approach. VSAM was developed under the leadership of Luke Little.

37. The San Jose Research Laboratory was established in 1956 under the leadership of Rey Johnson. In 1959 Gardner Tucker arrived to assume the Research responsibilities, and by the time he left to become director of the World Trade Corporation Laboratories, in March 1961, San Jose had a fully functioning research organization. Tucker was succeeded by Arthur Anderson, who had been with IBM since 1951, starting at the Watson Laboratories at Columbia University. Anderson had been a member of the San Jose research team essentially since its inception. Following Anderson in the post were J. D. Swalen (1963), Andrew Eschenfelder (1967) and D. E. Rosenheim (1973). Construction of the Research building began in June, 1969, and in 1971 the group moved into its new quarters from Building 025, to which it had moved after leaving Julian Street in 1956. (Julian Street was later occupied by Development Engineering.)
38. Also notable is the effort by Duncan Lagoe in producing the initial 11 million magnetic stripe tickets. He designed the production equipment, set it up in the Campbell plant and supervised the production.
39. In the early days the key engineers involved in these designs included Hal Preece, Robert Bennett, Don Fiehmman, Ralph Sherman, T. C. Bailie and Bowdle.
40. Roland Shaw was the first manager of this versatile organization and was followed by E. Rae Wooding, Howard A. Mussell, Ralph Golub and Ed Murphy.
41. The low cost/low performance characteristics of a "stretched membrane" disk prototype built by Bob Treseder and Fran Underwood as a part of a tutorial computer project were considered in 1966 for this requirement.
42. The next generation was initially code named after the opera Figaro. It did not meet the cost requirement and its successor was named Igar. Taking away the first and last letter was symbolic of the cost reduction effort.
43. Other key members of the 2841 design team were Hal Eden, Don Frush and John Harmon.
44. Key contributors to the original Technology and Advanced Development (TAD) group were Lou Blendermann, Ken Haughton, Dennis Mee, George Santana, Lou Taft and Marco Padillino.

45. The original Zeus development was led by Carmin Rosato and George Ahearn. The early Merlin development effort was headed by Marty Kelly and later by Jack Clemens, assisted by Bob Pattison, Woody Glueck, Dick Wilmer and Les Adams. When Clemens resigned shortly after B Test, his place was taken by Rosato who saw the product into production. Control unit development was under the leadership of Saul Miano with key contributions from Ahearn, Adams, Don Frush, Duane Walker, and Bob Osborne.
46. Spearheading the Winchester program was Ken Haughton, with large assists from Chris Coolures, Bob Friesen, Jim Gilmore, Dick Mulvany, Ko Nishimura, Hal Peterson, Wes Peterson, Erik Solyst, Perrin Smith and Jack Swartz.
47. Key contributors under Madrid engineering manager Chris Coolures and later Bob Friesen included Al Rizzi, Tom Patel, Ed Kramer, Jim Gilmore, Jim Makiyama, Dick Oswald, Hal Peterson, Paul Wilson, Jim Riley, Jack Swartz, Shel Ellis, and Matt Gibson (the latter a veteran of the RAMAC days).



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**Appendix A. First Two Years' Employees**

*1 librarian*

*44 mg.  
5 sec.  
1 janitor*

*2 mg. Hood, John*

*3 admin Jack Poole  
Art Robinson  
Ellich Hadad*

*8 node  
5 technician  
2 Patent attorney*

**1952**

- Feb. Rey Johnson \*<sup>v</sup>
- Jim Hood \*<sup>v</sup>
- Mar. 3 Hale Zimmerman<sup>-1</sup>
- 3 Anita Sullivan (Crieger)<sup>d</sup>
- 3 Gloria Doolittle
- 15 Hal Martin \*<sup>2</sup>
- 17 Bill Sprinkle
- 18 Jack Poole \*
- Apr. 1 Bill Crooks<sup>3</sup>
- 1 Warren Christopherson<sup>41</sup>
- 1 Wes Holman<sup>5</sup>
- 1 Joe Price
- 21 Art Critchlow<sup>6</sup>
- May 5 John Lynott<sup>7</sup>
- 12 Paul Pecchenino<sup>87</sup>
- 12 Vic Westerfield
- 12 Harry Wisdom \*
- 19 Jack Harker<sup>9</sup>
- 23 Lou Stevens \*<sup>10</sup>
- June 1 John Haanstra \*<sup>11</sup>
- 2 Jim Beaumont<sup>12</sup>
- 2 Ray Bowdle<sup>13</sup>

- 9 Dave Kean<sup>14</sup>
- 23 Lloyd Allen<sup>15</sup>
- 30 Frank Mauer<sup>16</sup>
- 30 Al Lutus
- 30 Jim Welsh<sup>17</sup>
- July 1 Doug Dethlefsen<sup>18</sup>
- 1 Jake Hagopian<sup>19</sup>
- 1 Bill Maron<sup>20</sup>
- 1 Len Meyer<sup>21</sup>
- 1 Dean Hodges
- 7 Dick Weeks<sup>22</sup>
- 9 Ed Quade<sup>23</sup>
- Sept. 1 Howard Singhaus<sup>24</sup>
- 8 Wes Dickinson<sup>25</sup>
- 8 Virginia Slamcik (Chadly)
- 15 Tino Gonzales
- 15 Joe Gloria
- 29 Jim Moore
- Oct. 1 Fred Wood<sup>26</sup>
- 13 Larry Bixby<sup>27</sup>
- 13 Keith Tremelling \*<sup>28</sup>
- 15 S. C. Chao<sup>29</sup>
- 20 Lloyd Tidball<sup>30</sup>
- Nov. 3 Henry Hendricks<sup>31</sup>
- 3 Al Stone \*<sup>32</sup>
- 17 Don Cronquist<sup>33</sup>
- 17 Charlie Morgan

- Dec. 15 Al Ewing<sup>34</sup>
- 15 Bill Goddard<sup>35</sup>
- 15 Marjorie Griffin
- 15 Jack Masterson<sup>36</sup>
- 22 Geoff Hotham<sup>37</sup>
- 27 Dick Hadad \*
- 27 Art Robinson \*<sup>56</sup>

**1953**

- Jan. 4 Curt Erickson
- 5 Trig Noyes<sup>38</sup>
- 29 Don Johnson<sup>39</sup>
- 31 Herb Gibbins
- Apr. 13 Tom Leary<sup>40</sup>
- 24 Manning Hermes<sup>41</sup>
- 27 Jim Davis<sup>42</sup>
- 27 Warren Gonder<sup>43</sup>
- 27 Wally Westfall
- May 11 Lois Bogue (Rondoni)<sup>-</sup>
- July 20 Norma Daley
- Aug. 24 Perrin Smith<sup>44</sup>
- 31 Bob Laybourn
- Oct. 1 Carl Bergfors \*
- Nov. 1 John Spensler \*

\* transferred from other IBM locations



## Appendix B. San Jose Divisional Affiliations

1952-56	Electric Accounting Machine Division
1956-59	Data Processing Division Research
1959-65	General Products Division Data Systems Division Data Processing Division Supplies Division Advanced Systems Development Division Research
1965-72	Systems Development Division System Manufacturing Division Data Processing Division Field Engineering Division Information Records Division Advanced Systems Development Division Research
1972-Present	General Products Division Data Processing Division Field Engineering Division Information Records Division Systems Development/Communications Division Research



## Appendix C. Chronology of San Jose Managers/Directors

### Research Laboratory

R. B. Johnson	2/52—6/59
G. L. Tucker	7/59—2/61
A. G. Anderson	3/61—10/63
J. D. Swalen	11/63—12/66
A. G. Anderson	2/67—6/67
A. H. Eschenfelder	6/67—6/73
D. E. Rosenheim	7/73—present

### Advanced Systems Development Laboratory

R. B. Johnson	6/59—3/65
L. D. Stevens	3/65—3/73

### Development Laboratory

L. D. Stevens	12/56—10/59
V. R. Witt	11/59—7/60
W. D. Bolton	8/60—1/64
I. H. Lohman	2/64—8/68
V. R. Witt	8/68—6/70
J. D. Kuehler	7/70—9/72
J. M. Harker	9/72—7/74
G. V. Harries	8/74—present

### Programming Center

E. E. Lindstrom	6/65—5/67
C. T. Apple	6/67—1/72
F. Carnella	1/72—2/73
J. H. Frame	3/73—present

**Manufacturing**

F. G. Paul	6/55—3/56 (Mfg. Coordinator)
G. A. Cullen	3/56—6/64
R. B. Morris	6/64—1/67
C. E. Frizzell	1/67—1/72
J. R. Cook	1/72—1/77
W. F. Meyercord	1/77—present

**Product Test Laboratory**

S. H. Bailey	3/55—2/57
R. B. Keeney	2/57—12/61
J. R. Wiseman	12/61—6/73
R. M. Furman	6/73—present

**Patent Operations**

J. B. Sponsler	3/53—1/54
J. B. Clark	1/54—6/60
J. B. Taphorn	6/60—1/62
R. E. Cummins	1/62—6/76
P. R. Leal	6/76—present

**Field Engineering**

J. E. Bell	3/55—1/72
H. L. Howard	1/72—7/73
W. T. Dreyer	7/73—present

**DPD Education Center**

B. N. Luther	7/56—8/60
D. L. Beeman	9/60—3/71
M. J. Mullin	4/71—1/72
T. E. Hobbs	2/72—8/76
J. P. Curie	9/76—Present

### **Direct Access Storage Devices**

1957	L. D. Stevens	Manager, Product Development Area Manager RAMAC
1958	J. M. Taylor	Area Manager, RAMAC File Development
1960	V. R. Witt	Technical Program Manager, Random Access Memory Programs (RAMP)
1964	A. F. Shugart	Technical Program Manager RAMP
1966	V. R. Witt	Manager, Storage Products
	J. D. Carothers	Technical Program Manager RAMP
1967	V. R. Witt	SDD Director of Storage Products
1967	G. V. Harries	Manager, RAMP
1968	V. R. Witt	Director of Storage Products, and Location Manager, San Jose/Boulder
	A. F. Shugart	Product Manager DASD
1969	M. J. Kelly	Product Manager DASD
1970	J. M. Harker	Product Manager DASD
1972	W. J. McDonnal	Product Manager DASD
	to present	



## Appendix D. IBM Fellows in San Jose

### Appointed from the San Jose Area

L. A. Wilson***	1964
R. B. Johnson*	1965
W. S. Buslik*	1968
L. R. Harper*	1968
E. A. Brown*	1969
H. G. Kolsky	1969
E. Clementi**	1970
V. R. Witt	1970
R. G. Brewer	1973
J. M. Harker	1974
E. F. Codd	1976

### Appointed at Another Location

J. W. Backus	1963
G. M. Amdahl**	1965
D. DeWitt	1970
A. R. Heller	1975

\* Retired

\*\* Resigned

\*\*\* Deceased



## Appendix E. Some Important Patents from San Jose

San Jose Patent Operations selected the following patents as some of the most important from the over 1,000 that have been issued to San Jose inventors.

<b>3 058 844</b>	Composition of Epoxide Resin, Methylol Phenol Ether, Polyvinyl Methyl Ether, and Acid Anhydride Catalyst, and Metal Substrate Coated Therewith, Especially a Magnetic Signal Storage Device.	D. D. Johnson R. Flores M. J. Vogel
------------------	--	---

Every rigid magnetic disk produced by IBM, and much of the industry, employs the invention of this patent, an aluminum disk with a specific magnetic coating thereon.

<b>3 176 281</b>	Portable Memory for Data Processing Machine	R. E. Pattison
------------------	---	----------------

<b>3 206 214</b>	Transporting and Protecting Cases for Drum and Disk Records	T. G. Leary
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These two patents form the basic coverage for all of the IBM interchangeable disk packs and have been licensed extensively throughout the world.

<b>3 207 505</b>	Record Card Processing Machine	G. Nielson D. Rex L. A. Wilson
------------------	--------------------------------	--------------------------------------

This patent relates to the high-speed transporting mechanism of the 1442 card processing system.

<b>3 411 906</b>	Diazo Development Process	J. W. Boone H. S. Todd
------------------	---------------------------	---------------------------

This invention is a process for developing diazo film utilizing pressurized ammonia which reduced conventional prior art development times from about 80 seconds to 0.1 second.



**3 750 189**      Light Scanning and Printing System      J. M. Fleischer  
The laser printing mechanism of the IBM 3800 printing system was made possible by the light beam scanning concept taught and claimed in the patent.

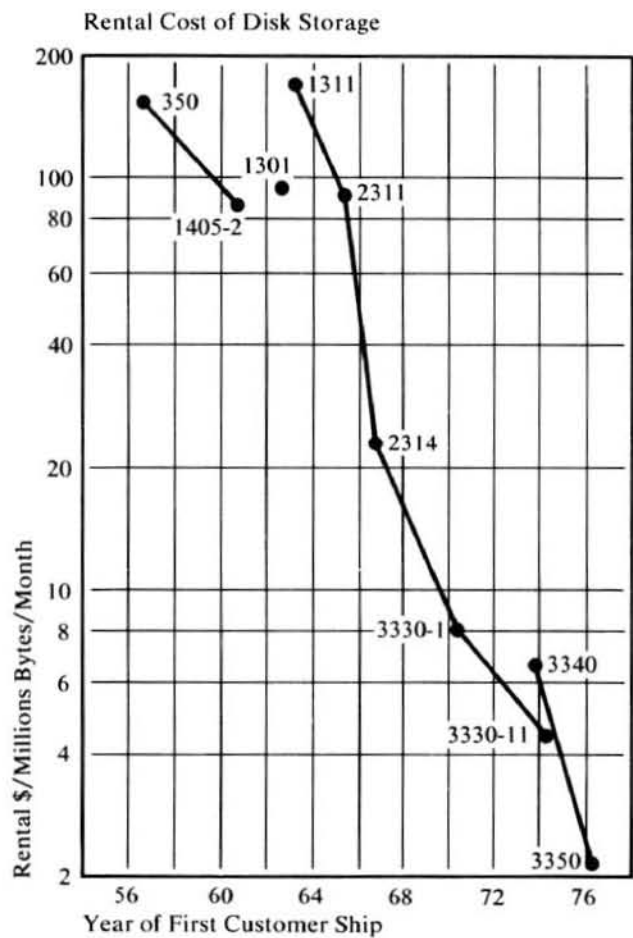
**3 786 454**      Magnetic Disk Storage Apparatus      R. W. Lissner  
R. B. Mulvany  
This invention was the basis for the implementation of the IBM 3340 drive and the IBM 3340 data module.

**3 823 416**      Flying Magnetic Transducer Assembly      M. W. Warner  
Having Three Rails  
The 3340 and 3550 magnetic recording head, consisting of an integrated air bearing slider and magnetic element, designed to start and stop in contact is claimed in this patent.

**3 997 876**      Apparatus and Method for Avoiding      D. I. Frush  
Defects in the Recording Medium Within  
a Peripheral Storage System  
The invention covered by this patent provides the method and apparatus employed by the IBM 3340 family of products to automatically skip any defect in the magnetic disk.



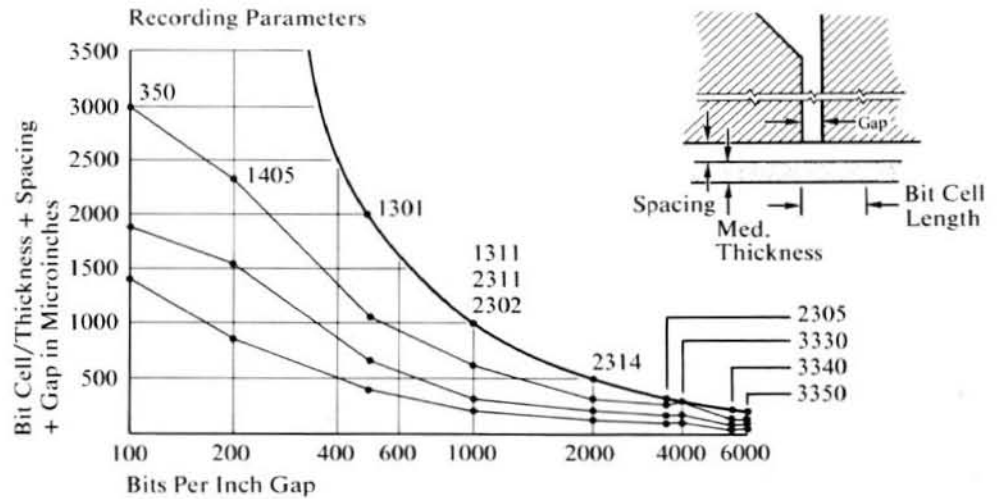
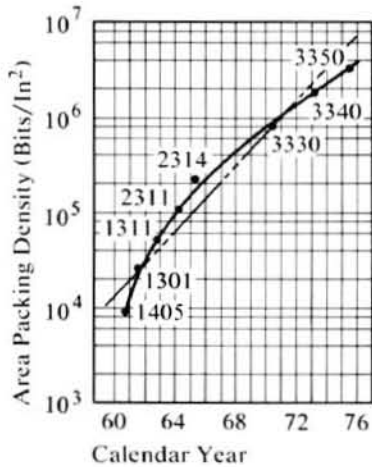
### Appendix F. Disk Storage Cost History





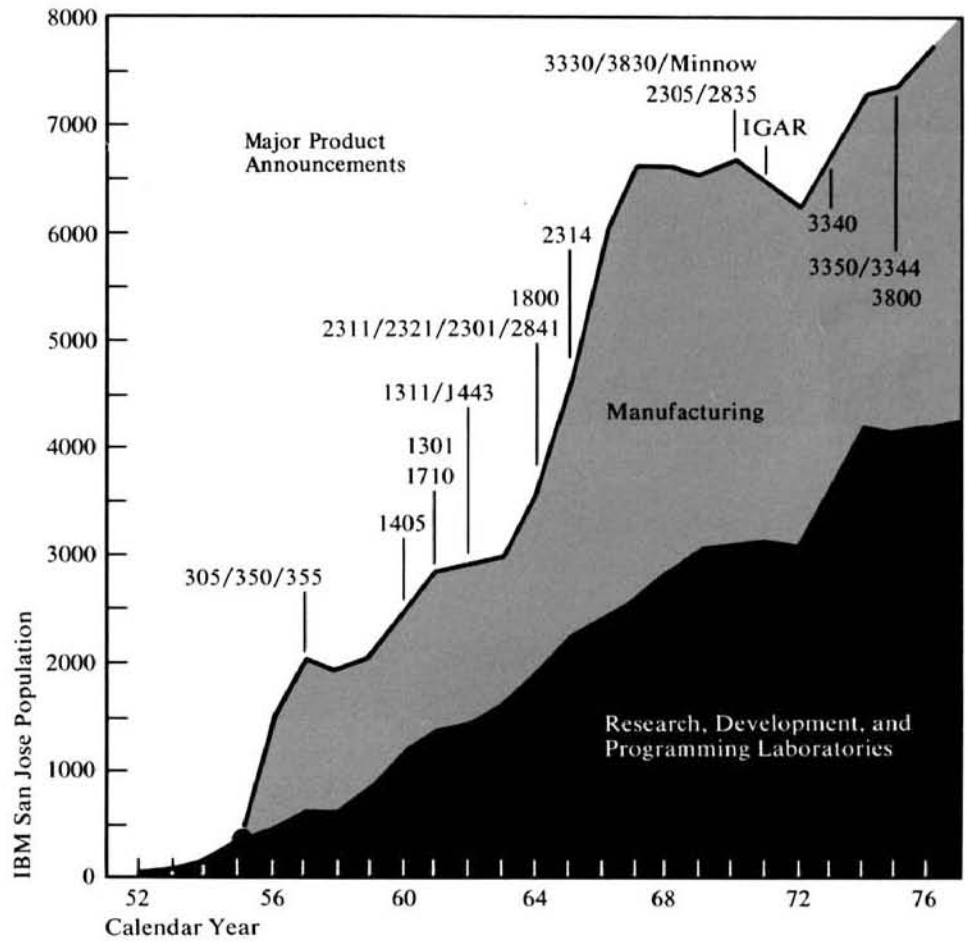
### Appendix G. Chronology of Progress of Some Disk Storage Technical Parameters

Announcement Year	Product Number	Bits per inch	Tracks per inch	Average Access Time	Flying Height, $\mu$ ins.
1956	350	100	20	600 ms	800
1961	1301	525	50	165	250
1962	1311	1020	50	150	125
1964	2311	1100	100	75	125
1965	2314	2200	100	60	80
1971	3330-1	4040	192	30	50
1973	3330-11	4040	370	30	35
1973	3340	5600	300	25	18
1975	3350	6425	476	25	18





## Appendix H. IBM Population Growth in San Jose



Arthur G. Anderson

*IBMers and Friends*

*This history has been compiled to help us all appreciate the richness of our technological heritage here at IBM San Jose. Our growth from a very small beginning twenty five years ago has been one of the most remarkable success stories of U.S. industry and I hope that this review of the basis for it can help us all, oldtimer and newcomer alike, to understand how we got to where we are and perhaps to contemplate constructively where it is possible for us to go from here.*

*In any event, I'm sure that you will find it a fascinating story worthy of a permanent place in your reference library.*

*Art Anderson*

6/9/80

Hal Martin  
Windsor  
Jack Hanks

Tom Stum

Jim Braumont

Ray Brudde

John Hagopian

Mer Dickson

Larry Pitkin

Keith Tremblay

A. L. Ewing

Art Robinson

Trig. Woy

Jim Martin

Perin Smith

Bob Layburn

27  
22  
22  
71

16/71 =  $\frac{22.5\%}{27}$

**IBM**

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General Products Division  
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San Jose, California 95193