An Wang

Born February 7, 1920, Shanghai, China; died March 24, 1990, Boston, Mass.; developer of the basic concept of the ferrite core memory, and founder of Wang Laboratories, which developed the first desktop computer.

Education: BS, engineering, Chiao Tung University, Shanghai, China, 1940*;* MS, applied physics, Harvard University, 1946*;* PhD, applied physics, Harvard University, 1948.

Professional Experience: research fellow, Harvard Computation Laboratory, 1948-1950; founder, president, Wang Laboratories, 1950-1987.

Honors and Awards: 23 honorary degrees; Medal of Liberty, 1986*;* National Inventors Hall of Fame, 1988.

Early life in China[1]

Wang was born in Shanghai, China, on February 7, 1920, the second child and eldest son of the five children of Yin Lu Wang, a teacher of English and a practitioner of traditional Chinese medicine, and Z.W. Chien, his wife. His name, An Wang, means "peaceful king." Until he was 6 he lived in the Shanghai compound of his mother's family. Then his family moved to his father's ancestral city, Kun San (Kunshan), about 30 miles west of Shanghai. Here Wang started his formal education in the private elementary school where his father taught. Because the school lacked the first two grades, he had to start in the third. As a consequence, for the rest of his education in China, he was always two years younger than his classmates, a situation which he said put him at a great disadvantage but from which, in the long run, he benefited because he found that he could quickly learn to swim when faced with the alternative of sinking.

He discovered early that he was good at mathematics but had difficulty with subjects requiring rote memorization, and he always had a hard time concentrating on subjects, such as political doctrine, that did not interest him. His father started teaching him English at home when he was 4. His paternal grandmother diligently tutored him in Confucianism, which he later called "the practical philosophy that has profoundly influenced Chinese character," and which embodied the principles of moderation, patience, balance, and simplicity that he later concluded were important to success in business. Wang also ascribed to Confucianism his belief that a sense of satisfaction comes from service to one's community.

During these school years he found that, although he did poorly during the term in the nonscientific subjects that did not interest him, by concentrating at the term-end he could always perform well enough on the final exams to get by. This success added to his confidence that he could rise to the occasion when the situation demanded it.

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[1] This material is drawn largely from Wang's 1986 didactic autobiography (Wang 1986), which is also a triumphant recounting of the founder's view of the history of Wang Laboratories, and in turn from Weiss 1993. To avoid clutter, the autobiography will not be referenced again.

By the time Wang was 11 the bloody struggle with the Communists had left the Nationalist Government barely in control of China. In 1931 the Japanese seized Manchuria and repeatedly bombed Nationalist-held Shanghai. The Nationalists directed an overwhelming program of relentless propaganda at its school children between the ages of 8 and 12. Wang remembered being forced to join in at least five political mass rallies a year. This experience turned him against political activism, an attitude that he retained all his life.

When he was 13 he enrolled at Shanghai Provincial High School, about 10 miles outside the city, where he boarded and where he was taught entirely from American textbooks. Wang's two-year age disadvantage kept him out of team sports but he found that he had a talent for table tennis. At the age of 16 he entered the university his father had attended for one year, Chiao Tung University in Shanghai, then the MIT of China. He had the highest entrance examination scores of his class. Here for the next four years he studied electrical engineering with an emphasis on communications. The subject, again taught from American textbooks, was easy for him. He later said that he spent more time at table tennis (he was on the university team) than he did studying engineering.

In late 1936, during Wang's first year at Chiao Tung, his mother, broken by years of fear and conflict, died in Kun San. After the Japanese invasion of China, the university was moved into the French concession of the Shanghai International Settlement. This gave protection from the devastation, because for the first few years of the war the invaders respected the territorial integrity of the foreign concessions. In the midst of this chaos Wang's family made its way from Kun San to temporary safety in the concession.

After graduation in 1940 Wang spent a year in Chiao Tung as a teaching assistant. In the summer of 1941 he joined a small project to provide radios for the Nationalist troops. His group of eight went by boat from occupied Shanghai to still-British Hong Kong, and then to Kuan Chou Wan, an isolated French concession on the Lui-Chow peninsula between the South China Sea and the Gulf of Tonkin. From here they slipped through the Japanese line and marched for three nights to a river where they took a boat and then a train to Nationalist-held Kweilin (now Guilin), 300 miles inside China.

In Kweilin, 21-year-old Wang was put in charge of a group scrounging and scavenging parts and improvising the designs to build radios for military use. In late 1944 Wang and his group were evacuated to Chungking just before the Japanese took Kweilin. Wang did not hear until much later that, in this period, both his father and his older sister Hsu had died as a result of the war. His younger sister Yu and his two brothers Ping and Ge survived, although he did not see them for 40 years.

Going to Harvard

In March 1945, with Japan in retreat, Wang placed second in a competitive examination to enter a Nationalist government program to give two years of advanced training in the US to several hundred young engineers. In April he was flown “over the Hump” in a US DC-3 to Ledo in India, went by train to Calcutta and, after a wait of a month, made a month-long voyage to Newport News, Virginia, where he arrived in June. By this time, he writes, “the notion that there were things I could not or should not attempt to accomplish was utterly foreign to me.”

Because, Wang says, he looked for cultural similarities, not differences, he claims that he suffered no culture shock. The US was exciting but not strange, and to him seemed a lot like China. Wang's group was housed temporarily at Georgetown University in Washington, D.C. Its campus struck Wang as “not unlike that of Chiao Tung.” While some in the group immediately accepted offers to serve their two-year apprenticeships as technical observers with firms such as Westinghouse and RCA, Wang conceived the novel idea of applying for admission to Harvard. By luck, he applied at the only time that Harvard would have considered a case like his. In the early summer of 1945, although Germany had surrendered, at least a year of further war with Japan seemed certain. Most American young men were still in uniform, and even Harvard had more openings than potential students. It turned out that getting into Harvard was easier for several in the group of Chiao Tung graduates than finding an apprenticeship in industry. In September 1945 Wang entered Harvard as a graduate student in applied physics.

Here, although his spoken English was poor, he felt comfortable. He could read and write English well. The university setting suited him, there were a number of other Chinese associated with Harvard, and a laboratory seemed a second home to him. He found the work relatively easy and in two semesters he satisfied the requirements for a master's degree in applied physics, getting two A+'s and two A's in his first term-Wang always had a clear and proud recollection of his in any academic successes.

After the summer of 1946, Wang's monthly $100 stipend from the Chinese government ended as the Nationalists turned all their resources to the civil war with Mao Tse-tung. At first Wang took a clerical job with the Chinese purchasing mission in Ottawa. This was a mistake. The work was routine and boring, and the fall weather was extremely cold with worse to come in the winter. Wang applied to Harvard for admission to the PhD program in applied physics. He was accepted and given a $1,000 a year teaching fellowship and, later, a Benrus Time Fellowship. By February 1947 he was back in Cambridge determined to get his degree as promptly as possible.

In May he chose his thesis topic not for its importance but because he knew he could do it quickly and it would satisfy his PhD committee. It was in nonlinear mechanics, and involved the determination of the effects on a mass with a nonlinear response of two forces simultaneously oscillating at different frequencies. He later said it was one of the few problems he ever approached without concern for its practical application-although its practical purpose was to enable him to get a PhD. He did some experimentation in the summer, started to write up his results in September, finished his thesis in December, submitted it in February, defended it at the oral exam in the spring, and obtained his degree at the ceremony in June 1948.

After seeing the pile of security forms that Hughes Aircraft sent to him in reply to his job inquiry, he walked across the Harvard campus to see if he could get a job in the Harvard Computation Laboratory, then consisting of Howard Aiken, five or six research fellows, and a few assistants in a new but undistinguished two-story brick building that still housed the glass-enclosed Mark I on the ground floor. Aiken was working on the Mark IV for the US Air Force, his first purely electronic computer, which turned out to be the last computer that he, and Harvard, built. Wang applied to the Computation Laboratory not because he was eager to work on computers but because it was nearby. While his graduate education had nothing to do with computers, he had taken courses in digital electronic circuitry and this, as well as his newly minted PhD and his personality, appeared to qualify him, for soon after being interviewed by Aiken he started work as a research fellow, although his appointment was delayed until July 1.

Invention of Magnetic Core Storage

On May 18, 1948, within a day or two of starting work, Aiken gave him the problem of finding a way to record and read magnetically stored information without mechanical motion. Later Wang wrote, “After struggling with the question for about 3 weeks, the solution presented itself to me.” He agreed with many others in the then small computer community who were considering the same problem, that the best way to store information magnetically was by magnetizing a toroid or core of magnetic material which had a strong residual magnetic flux. The problem was how to read the stored information out without destroying it by demagnetizing the core. One day, while he was walking through Harvard Yard, the idea came to him in a flash, that the destruction did not matter if, immediately after reading the information, it was rewritten back into the magnetic toroid. His June 29, 1948, notebook entry reads, “. . . It is very possible that the information can stay there [in the core in the form of a particular magnetic direction] and be transferred many times before the information [is lost or muddied]. . . .” As Wang later put it, “The idea is that by destroying the information-I know it.”(Pugh 1984)

This simple, novel, and elegant concept, applied to all the magnetic core memories that followed, which were, as Pugh (1984) said, these “memories that shaped an industry,” was Wang's greatest technical achievement. Although these devices are now fast becoming only a memory, their importance to the development of computers in the period from 1950 to 1970 was second only to that of transistors. Indeed Pugh (1984) goes further, saying, “Development of reliable, high-speed ferrite core memories that could be mass-produced at low cost was probably the most important innovation that made stored-program computers a practical, commercial reality.” It was Wang's concept that set this development in motion.

This conceptual breakthrough left him with the practical problem of finding the right materials and implementing his design. He found a Navy publication that described a suitable magnetic material developed by the Germans during the war, Permanorm 5000-Z (the US copy of this material was called Deltamax, made by Arnold Engineering, a subsidiary of Allegheny-Ludlum). To put the toroids into a memory system, he linked them in series so they became the magnetic core delay line used in the Mark IV, but in almost no other computer.

In June 1949 Wang first discussed the idea of patenting his device with his fiancée, Lorraine Chiu, whom he had been courting for a year and whom he married the following month. Wang had met Lorraine in 1948 at a Boston area get-together for Chinese students and academics. She was distantly related to Yung Wing, the first Chinese to study at and graduate from Yale (1854). Her parents had been born in Hawaii before its annexation but had moved back to Shanghai, where Lorraine was born and where she had her undergraduate education at St. John's College. She had come to the US to study Shakespeare at Wellesley, where the civil war in China marooned her. The conflict also prevented the couple from following the traditional procedure of seeking her parents' approval of their marriage.

Chiu saw the value of a patent based on the concept and encouraged Wang to get it. No one else at the Computation Laboratory had taken any patents and at that time there was a feeling at some universities that patents were evil and should not be taken out on inventions made by academics.[1]

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[1] At this time only a few universities, chiefly those with strong departments of engineering, had established policies about the patent rights of their staff members. Just a few years earlier the acrimonious split between the University of Pennsylvania and the inventors of the ENIAC had been caused by a difference of opinion about valuable academic patents. MIT, on the other hand, had a policy of turning such patents over to the closely linked Research Corporation which made arrangements to reward the inventors, exploit the patents, and pass the resulting funds to MIT It is interesting that Harvard and Pennsylvania, two universities that denigrated staff patents, quickly lost and never regained their original computing eminence, while MIT, with the opposite patent policy, has always been at the forefront of computing research. (Editor)

Wang wanted to avoid Aiken's legendary wrath, although he had never personally encountered it, so he first explored the question of patents with the Harvard administration. At that time Harvard only reserved patent rights to itself for those inventions that applied to public health. The Harvard administrator he consulted advised Wang to file for it himself at his own expense, and recommended Harvard's own firm of patent attorneys, Fish, Richardson, and Neave. Within a month, on October 21, 1949, Wang filed his patent application, titled “Pulse Transfer Controlling Devices,” with 34 claims, most of which are directed toward “an information delay line.” The application resulted in Patent 2,708,722, issued May 17, 1955 (Wang 1955). The most important claim, number 24, stating Wang's concept in the arcane language of the Patent Office, allowed the patent owner, ultimately IBM, to demand and usually obtain royalties from all who made core memories, that is to say, the entire computer industry.

This monopoly existed for the patent's 17-year life, that is, until 1972, after which Wang's invention entered the public domain and could be freely used by anyone. Since Wang's work at Harvard had been funded by the Air Force, the US government always had a non-exclusive license to use what the patent claimed.

Here is the claim:

> *24. A pulse transfer controlling device including a core of magnetic material in which the residual magnetic flux density is a large fraction of the saturation flux density, winding means on said core, current Pulse generator means operatively connected to said winding, means to apply current Pulses of opposite polarity to said winding means, said pulses of one polarity acting to saturate said core in one direction to read in information, and of the opposite polarity acting to read out said information by inducing voltage in said winding means as controlled by the state of residual magnetic flux density of said core and to reset said core.*

After filing his patent application Wang suffered a rare sleepless night as he braced himself to inform Aiken, who, to his surprise, while not overjoyed, did not react at all. Aiken later gave Wang another substantial raise in pay and in the year and a half that Wang stayed at the lab he noticed no difference in his relationship with Aiken, which had always been correct but never close or cordial.

On September 29, 1949, just before filing his application, Wang described his invention at a Harvard computing symposium and later wrote technical papers about it for the *Journal of Applied Physics* and the *Proceedings of the Institute of Radio Engineers*, making his concept well known to those in the computer memory field. Others already working on the problem (notably Ralph E. Meager, Munro K. Haynes, Jan Rajachman, and Jay W. Forrester) devised and sometimes patented improvements, releasing a storm of patent litigation out of which Wang's patent emerged virtually unscathed as controlling over all later patents in the field, because of its priority and breadth.

Jay W. Forrester at MIT devised a different way of organizing the cores. His scheme, which Wang called “brilliant” and always regretted not thinking of himself, was to arrange the cores not in a line but in a matrix with wires strung so each one could be individually selected (Forrester 1951). This system, combining the concepts of Wang and Forrester and ascribed by some to Haynes, dominated computer memories until cores were replaced by solid-state devices.

It is remarkable that while Pugh (1984) in his description of these times gives full credit to Wang, writers about Forrester's Whirlwind, which used magnetic core storage (Redmond and Smith 1980), and the MIT Institute

Archives Staff (1990), manage to ignore Wang and his controlling patent completely, giving full credit for the core memory to Forrester.

It was clear to Wang in 1950 that Harvard was soon going to deemphasize basic computer research in line with its policy of staying out of fields that had commercial applications. He later wrote that Harvard was ill-advised to abandon its eminence in computer development.

Since Harvard was not going to do basic computer research it was easy for him to decide to leave the Computation Laboratory. He treasured independence and did not want to work for someone else's company. What he really wanted to do was to try something on his own.

Start of Wang Laboratories

His innovations with memory cores had given him the status of an expert in digital electronics, a status which he thought he might exploit by starting his own business to make and sell memory cores, a business for which little capital would be needed. He had been making $5,400 a year; he hoped to earn $8,000 or so in his first year on his own. He did not anticipate great wealth. He discussed the plan with his wife, but she later said that she had been so preoccupied with the birth complications of their first son, Frederick, that she did not appreciate the importance of the step that Wang was taking. In April 1951 he gave his notice to the Computation Laboratory and in June he set up Wang Laboratories as a sole proprietorship with his six hundred dollars of savings as capital, no orders, no contracts, and no office furniture.

An Wang's life was so intimately intertwined with his creation, Wang Laboratories, that their histories must be considered as one. Thus what follows is as much about Wang Laboratories as about Wang himself. It is plain that in his mind, there was no clear distinction.

His Chinese friends, sensitive to anti-Asian discrimination, did not think it wise to start a business in an area dominated by the Caucasian establishment. His success encouraged other Chinese in academia to follow his example.

Wang began methodically telephoning or writing to everyone in universities, government, and industry whom he thought might be interested in buying memory cores. Within three weeks he began to get responses to his offer of cores at $4 each. The lump sum payment to him of his Harvard pension fund gave him a year's cushion, but even so, his finances were precarious. To supplement his income he taught an electrical engineering evening course at Northeastern University. In the last six months of 1951 he earned $3,253.60, somewhat more than the $2,700 he would have earned at Harvard. In the fall of 1952 the Laboratory for Electronics gave him a contract to develop a pulse synchronizer and counter. He got more and more consulting contracts to design specialized digital equipment, which developed his facility with digital electronics. The contracts also taught him about the marketplace and the essentials of running a business. His approach was to be concerned with innovation only insofar as it served the marketplace, an approach which he said characterized his company as long as he lived.

Bargaining with IBM

One of the first steps he took after starting Wang Laboratories was to ask IBM if they were interested in buying a license to his pending patent. Over a period of a year IBM corresponded, sent visitors, and asked for detailed information, which Wang, on the advice of his lawyer, declined to furnish without an agreement. Then Wang proposed doing some consulting work for IBM, and after another year of dickering, an agreement was reached in November 1953 under which he agreed both to consult for IBM and to grant them a three-year option to buy a nonexclusive license to his as yet unissued patent. The resultant thousand-dollar-a-month income gave Wang Laboratories financial stability.

It was Wang's impression that IBM was much less interested in the specific project they gave him than in their option and their access to his thinking about the applications of magnetic cores. At that time he was surprised by IBM's slowness to grasp the importance of magnetic core storage and it occurred to him that this characteristic slowness of the giant might make it possible for a smaller, quicker company to compete against them.

There was intense activity at IBM in the development of ferrite core memories and by mid-1954 IBM was developing such memories for commercial computers (Pugh 1984). In May 1955, when Wang's patent was issued, IBM opened negotiations about royalties. They flatly declined to confirm an earlier oral suggestion of a royalty of one cent per bit. Wang offered to sell them the patent for $2.5 million, to be told that “even half of $2.5 million is too high.” In October 1955, IBM offered $500,000 plus 70% of all royalties from the licensing to third parties. Wang was prepared to accept but objected to clauses regarding the validity of the patent and the consequences of any patent interferences. After Wang replied to a list of 58 questions attacking his patent from every conceivable angle, IBM unleashed its thunderbolt. They had discovered an inventor, Frederick W. Viehe, a Los Angeles public works inspector, who had been in several patent interference battles with large companies in the past, who had a pending 1947 patent application that IBM believed would “certainly lead to an interference.” IBM would not reveal the content of the application which, as usual, the Patent Office held secret. Now IBM wanted to move immediately to an agreement with Wang. He later wrote, “Later events suggested that IBM knew more about Mr. Viehe's patent application than they were telling at the time.”

In spite of these feelings, in March 1956 Wang assigned his patent to IBM under the October terms but with the provision of certain conditions under which the final $100,000 payment might be withheld. One of the conditions was “the declaration of interference of the patent or any of its claims.” Two weeks before the deadline for an interference, in May 1956, the Patent Office declared an interference with the Viehe patent. In November 1957, while the patent interference hearings were going on, IBM bought the Viehe patent application, reputedly for a million dollars, and hired the inventor as a consultant. In spite of the fact that the opposing parties in the interference case were now IBM vs. IBM, it went to a decision a year later. The decision gave Viehe only one of Wang's claims, a minor one. The decision could not be further argued or appealed since IBM now owned both patents. Wang forfeited the $100,000 and stored in his memory a lifelong grudge against IBM.

When Viehe died in 1960 he left an estate of $625,000. His widow's attorney said he made his fortune through the sale of an invention about which he was sworn to secrecy but Viehe's son identified IBM as the buyer. It was Wang's belief that IBM decided that buying both patents might be cheaper than buying one of them should one patent emerge as dominant. Before buying, IBM used each patent to drive down the price of the other and to force both inventors to an early agreement.

In 1975 the continuing legal struggles over the various patents on a matrix magnetic core memory brought to light an internal memo by the late J. William Hinkley of the Research Corporation recounting a 1962 meeting involving IBM, MIT, and the Research Corporation, during which James W. Birkenstock, an IBM vice president, was said to have commented “that they had probably underpaid Wang or Viehe for their patents ... in view of the tremendous increase in the size of the computer industry. Birkenstock apparently put this forward as an example of how good a negotiator he was, but was severely taken to task by Watson” (Gardner 1976). It is interesting that Fish, Richardson, and Neave, the Boston law firm recommended to Wang in 1949, was patent counsel to IBM in these 1962 negotiations.

Wang later wrote: “I am sure that much of what my lawyers and I perceived as attempts at intimidation, IBM would argue was merely the exercise of due diligence in determining the worth of the property they sought to buy. Nonetheless, timing and bluff played an important role in our negotiations, and they were affected at the eleventh hour by an event totally unanticipated by me or my lawyers, and which to this day I remain convinced was instigated by IBM.”

After the settlement, Wang put his energies into developing new ideas and new directions for his company rather than becoming obsessed with any injustices concerning the patent. In spite of this surface appearance of forbearance, he took pride in the fact that tiny Wang Laboratories later competed directly against IBM's greatest strength, remarking that he had frequent encounters with IBM's no-holds-barred style of competition, and often won.

On April 18, 1955, just before the patent was issued, Lorraine and Wang gave up their Chinese citizenship and became naturalized US citizens.

Wang Laboratories Grows

During the following years Wang Laboratories gradually changed from a consulting firm into a company that developed and sold its own products. It was in this period that Wang's associates started to refer to him as “the Doctor,” a title which his own family came to use.[1]

In 1954 Wang Laboratories moved to Cambridge. In the next year, in the midst of the negotiations with IBM, the Doctor incorporated Wang Laboratories. Its assets were $25,000 and all the stock was held by Wang, some of which he gave to his wife and family. In 1958, when he employed 10 people, he bought land along Route 128 for expansion, land which the Commonwealth soon took for road widening, causing him to expand into Natick instead.

At first Wang vigorously pursued government contracts. Some of these led to commercial products such as transistor logic cards called Logiblocs, and control units for machine tools, called Weditrol. In 1959, for financial reasons, he sold 25% of his company for $50,000 to Warner and Swasey, a much larger company and one of his Weditrol customers. He regretted the deal almost at once. The alliance caused problems of management and financing far in excess of any benefits. In short, for the first time Wang was not in full and unquestioned control of his creation.

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[1] Informal titles for the leader were not unusual in small technical organizations. Howard Aiken was first known as “the Commander” and later as “the Boss.”

Compugraphic, a small Cambridge firm, proposed that Wang design and build a photo-typesetting machine, which Compugraphic would market. In one year Wang Laboratories, then 20 people strong, designed, patented, and built a semi-automated justifying typesetter called Linasec, for each of which Compugraphic paid Wang $30,000. Sales soared through the early 1960s, reaching the million-dollar mark in 1964. At this point Compugraphic took advantage of its right to manufacture the machine itself, putting Wang out of the typesetting business.

From these two mistakes, neither fatal and both educational and profitable, Wang learned not to release control of his company to anyone else and not to design and manufacture a product for another company to market.

In the mid-1970s, the Wang stock carried on the Warner and Swasey books at cost, a hidden asset worth scores of millions, attracted that aggressive acquirer of companies, William Agee, then president of Bendix. He saw that he could buy Warner and Swasey and pay for the acquisition by selling the Wang stock. Wang declined to play white knight, and the famous old machine tool company fell to the raider and into oblivion.

While Wang Laboratories was flourishing with Linasec, Wang devised a factor—combining method for finding logarithms using logic circuits requiring fewer than 300 transistors. In 1964 he applied for a patent and designed a desktop calculator, LOCI, using the principle and selling for a base price of $6,500. The user had to have some familiarity with logarithms and programming but LOCI was vastly easier to use than a computer. It could be programmed from its console or with punched cards or with a teletypewriter, which could be both terminal and printer. It could serve several keyboards. By 1966 Wang was selling about 10 a month through manufacturers' representatives, and LOCI was becoming his major source of revenue. Although Wang was ultimately issued more than 40 patents, LOCI appears to be the last commercial product based on one of them.

In 1964 Wang purchased an 85-acre site in Tewksbury and moved his total work force of 35 there from Natick.

LOCI was a transitional product that led to the Wang 300 calculator, the first Wang product that could be used by everybody. It was priced with the principal competition, Friden, at $1,695, yielding a gross profit margin of 65-70 percent. It had a small desktop unit with a numerical keyboard and a 10-digit electronic display. It performed the arithmetic functions now expected of a pocket calculator. The larger electronic unit sat on the floor and could be multiplexed to several keyboards. The Wang 300 reached the market 10 months after LOCI. Sales rose from $2.5 million in 1965 to $3.8 million in 1966 and $6.9 million in the next year when the laboratories had grown to 400 people.

With the Wang 300 the laboratories had moved from serving the scientific world into the open marketplace in which marketing, sales, and service were more important than inventions. At this time the firm also went international, selling in the UK, Belgium, and Taiwan. Some of the labor-intensive aspects of manufacturing were moved to Taiwan.

Wang developed a network of salesmen to take the place of independent manufacturers' representatives, and by mid-1967 he had 80 of his own people selling in 40 cities. He established a sales commission curve that grew according to the square root of the increase in sales, a curve later modified when his firm no longer owned the calculator market as it did when the Wang 300 was new and without real competition.

Although Wang liked to take his own risks and be in full control, he decided to take his company public, raising the money to retire his short-term debt without diluting the stock to the point where he would lose control. The firm had good earnings and had had rapid growth. Furthermore it was well known on Wall Street because of the wide use of the Wang 300 in brokerage houses. The Wang 300 had gained a legendary reputation there when it was used to reveal an error in the Salomon Brothers' bond trading tables that had been in unquestioned use for 30 years. Furthermore, in the summer of 1967 the hot new issues market was receptive to computer stocks at relatively high prices. The issuance of the stock changed Wang Laboratories from a company which had a net worth of about one million dollars to one with a market capitalization of about seventy million. Wang's own holdings rose to a paper value of about fifty million. Wang claimed no credit for going public at exactly the right time; he said it was just luck.

Wang was happy to have shown to be wrong those who warned him that a Chinese name would impede him.

While the Wang 300 and its improvements which permitted some programming were selling well, it became clear that Wang would have to replace it with something more than a mere improvement. The advent of BASIC, the first computer language that Wang considered user-friendly, convinced him that he should consider making a general-purpose computer.

When, in the spring of 1968, he saw the first proposed design, the Wang 4000, using the electronics of his more sophisticated calculators and bulk storage based on magnetic cassettes, he saw that it could not compete with DEC's PDP-8 and rejected it. Now Wang went outside his company to get the needed design expertise in computer hardware and software. In the late summer of 1968 he simultaneously launched two new efforts to develop a general-purpose computer, the Wang 700 and the Wang 3300 BASIC.

The Wang 700 was, at first, to be a computer with an architecture like that of the IBM 360 using microcoding. When Hewlett-Packard announced their new calculator, the HP 9100, with a CRT display and individual magnetic cards, Wang's sales of his top-of-the-line calculators, the Wang 370 and the Wang 380, were hurt. To protect Wang's share of the calculator market the development of the Wang 700 was changed to make it a calculator to directly challenge the HP 9100. Those were the days of “paper machines” that were announced at conception rather than birth. The Wang 700 was announced in December 1968, promised for delivery in June 1969, and reached the market a few months later. This calculator was Wang's last successful product to use magnetic core memory.

Although the Wang 3300 BASIC reached the market as a computer, it too was a false start. It was to be a true minicomputer with the capabilities of the PDP-8 but specialized for BASIC. Programs were loaded with paper tape, which often took 40 minutes per program. Furthermore it used a teletypewriter as a terminal instead of a CRT. Not many were sold.

By 1971 market price pressure had pushed the base price of the low end of the Wang 300 series to $600. Semiconductor chips, using large-scale integration (LSI) that contained all the circuits of a calculator, came to the commercial market from the laboratories that had developed them with military contracts. At Christmas Bowmar introduced the first LSI-based pocket calculator for $250 and soon afterwards a host of other similar products appeared. At that time Wang made the much too conservative estimate that their prices would soon drop to $100. Although 70% of Wang's revenues came from calculators, he decided to get out of that market, first leaving the lowest priced field. Wang claimed that this decision to move out of the calculator business was a product of reasoning and decisiveness, not luck.

His first general-purpose computer was the Wang 2200, although it was actually called a “computing calculator” to keep from frightening customers. It was first shipped in late 1972. BASIC and its interpreter were stored in ROM. The Wang 2200 continued to evolve and was still being sold in 1986 when more were sold than in 1973, although by then it accounted for only a small fraction of Wang's sales.

Word Processing

In November 1971 Wang announced the Wang 1200, his entry into the word processing market. He was deliberately attacking IBM's MTST (Magnetic Tape Selectric Typewriter). The Wang 1200 was based on the Wang 700 calculator, with rewritten firmware.

In use, a letter would be typed on a terminal and recorded on a tape cassette. Editing involved command codes. Printing was at 175 words per minute. By today's standards the Wang 1200 was extremely primitive but it was vastly superior to an electric typewriter, cutting the cost of a business letter in half. Although IBM controlled 80% of the market, MTST was only a tiny part of their business. Wang was attacking their little finger, not their right arm. As he anticipated, IBM was slow to react. It took Wang several years to develop a product that was clearly superior to IBM's and in that time, 1972 to 1975, IBM might have ended the threat altogether but, by not developing their own word processing technology they gave Wang time to learn, grow, correct his mistakes, and acquire some market share.

Although the Wang 1200 never really fulfilled the Doctor's expectations, one of its significant limitations being the lack of a CRT display, by 1975 Wang was well positioned in the word processing market. At this time Xerox came out with the 800, no easier to use than the Wang 1200 but with a Diablo printer, twice as fast as Wang's. To meet this threat the Doctor ordered the design of a word processor that did not simply copy existing automatic typewriters but offered features that reflected the desires and limitations of the user. Its specifications were drawn not from what could be done with electronics but from what secretaries, then almost all women, wanted in their machines. It would be CRT- rather than typewriter-based, and it would be driven by a series of user-guiding menus. It was called the WCS (Wang Computer System).

It was introduced in June 1976 at the New York Syntopican trade show by demonstrating the only model, so much a prototype that it even lacked a printer. People lined up ten deep to see text editing done on a screen for the first time on a commercial product. The list price was $30,000 and one customer ordered a million dollars worth on the basis of an advance look. Wang separated the sale of word processing from the rest of the sales department and, to indicate how seriously he took the new product, appointed his older son Frederick A. Wang, then 26, to head the new department.

In the midst of these events the oil crisis stopped automobile sales in 1975 and pushed Wang's earnings, which were greatly dependent on sales of his calculators to automobile dealers, down by one third. Wang had to lay off 40 people, his first layoff ever. By 1976 Wang's characteristic unusual growth started again, stimulated by sales of the Wang 2200 and the WCS, both of which represented Wang's timely move into the office market.

Wang, now the 32nd largest computer company in the country, undertook to confront IBM directly with an advertisement. IBM was the only computer company that advertised on TV. To establish Wang as a well-known name, a firm from which it would be prudent for cautious managers to buy office products, Wang doubled its yearly advertising budget to mount a three-month TV campaign based on a single advertisement.

The advertisement was a David vs. Goliath motif set in a corporate board meeting. It raised Wang's name recognition from 4.5 to 16 percent among businessmen. The Doctor recalled that following his example DEC, Data General, Prime, and Apple later turned to TV with similar anti-IBM themes, but “not always as successfully.”

Having outgrown the space in Tewksbury, in 1976 Wang bought land and a building in Lowell and moved his headquarters there, leaving manufacturing in Tewksbury. Growth and building in Lowell were by leaps and bounds, and Wang quickly became the largest employer in this previously severely depressed area. In the following few years, this move was said to have sparked the “Massachusetts Miracle” of the 1980s, rejuvenating Lowell.

By 1978 Wang was the largest worldwide supplier of CRT word processing systems, with fifty thousand users. In a few years 80% of the 2,000 largest US firms had bought Wang equipment. At one time, it was said, every secretary in America swore by Wang products.

In 1975 the financial state of the company had become as critical as when it had gone public. It had a great deal of debt and needed a lot more cash to exploit the projected WCS. The market value of its stock had dropped close to its issuing price. If Wang was to seize the opportunity he saw in word processing he would have to return to the capital market, but he wanted to retain his personal and exclusive voting control. To do this he recapitalized, issuing a class B common stock with a higher dividend but only one-tenth the voting power of class A common stock. The New York Stock Exchange would not stretch its rules to allow this (they have since changed their rules), so Wang delisted his firm from the New York Exchange and moved it to the American Exchange, where the rules would stretch. Trading was heavy in class A but light in class B, just the opposite of what the Doctor wanted. He concluded that orders to brokers to “Buy Wang” were being executed on the first Wang in the list. By changing the name of class A to class C and thus getting it listed in the newspapers below class B, the Doctor solved that problem.

Wang had also solved the problem of personal control. With 52% of the votes, Wang Laboratories remained all his. At this time the value of the Wang family trust which the Doctor had established in 1957 was $1.6 billion.

The Wang Institute of Graduate Studies was established in 1979 in Tyngsboro. Wang gave $6 million. Classes started in 1981 with five students and high hopes. It was to demonstrate how enlightened industry could advance education. Its program was for a master's degree in software engineering. It attracted an excellent staff, put a good program in place that addressed the needs of the software development industry, grew, and achieved a good reputation in a short time among practitioners and educators. Its program addressed the entirety of the systems development life cycle and acknowledged the difficult human aspects of systems analysis and project management (Fairley 1989). The institute also supported Chinese studies with graduate fellowships.

In late 1982 Wang tried to remove himself from the details of day-to-day operations, and in 1983 designated John Cunningham, a Wang sales veteran, as president. This move didn't work, for the Doctor never really let go and in late 1984 he took back the reins and Cunningham left. Wang stock peaked in 1984 at $42.5, a level never reached again. At about the same time, realizing that Wang Laboratories had missed the start of the personal computer revolution, Frederick Wang, then in charge of product development, announced a series of 14 dazzlingly innovative products. Most of them did not exist. As customers realized this, they started switching to IBM in droves.

Wang saw that an important company problem was communications, chiefly with him, so he set out on a program of traveling, which he hated, throughout the company to listen and talk to employees and customers. His talking was legendary, but some employees questioned the effectiveness of his listening.

In the decade before 1983, Wang Laboratories' annual growth had been 40%. By 1986, when Wang's autobiography ends, his company did more business in two weeks than it had done in all of 1976. It was a $3 billion dollar enterprise employing 30,000 people. The Doctor considered Wang Laboratories to be not only an example of a phenomenal success but one well situated for the future.

As the company developed in the 1980s it both confronted IBM in some areas and adapted to it in others. It was careful to stay out of the battle between corporate MIS departments, usually in IBM's pocket, and departmental decision makers who buy word processors and PCs. Toward the end of his autobiography Wang points out that when he negotiated the sale of his patent to IBM, it was ten thousand times his size but in 1986 it was only twenty times.

Wang recognized an even more formidable competitor than IBM: Japan. In his autobiography he says, “Having both observed and experienced Japan's economic aggressiveness, I am led to the conclusion that they learned little from their experiences in World War II, and instead of tempering their imperial ambitions, they are merely pursuing their goal in the economic arena rather than the military one.”

Wang Laboratories Stumbles

Just before 1986, although its revenues climbed, reaching a peak in 1988 of $3.07 billion, the earnings went into a decline from which they have not recovered. Wang had moved too slowly in product development and had gradually bogged down his company with short-term debt. Wang's word processors, built around expensive minicomputers, became dinosaurs as smaller, cheaper, more capable personal computers took over office functions. Wang's own PCs were priced too high and were not compatible with industry standards, notably IBM's dominant products. Service was poor and expensive. Almost half Wang's orders were delivered late and more than half those entered at the factory were wrong. The company had developed the reputation with its customers of being hard to do business with. Of 800 R&D projects under way only 72 had been subjected to feasibility studies.

Now with sharply reduced earnings Wang had to cut back on his contributions. In 1987, after fewer than 10 years of life, the Wang Institute of Graduate Studies closed as its funding was abruptly cut off (Fairley 1989).

In 1987 Wang made Frederick, now 38, president and chief operating officer. Frederick moved too slowly to cut costs and shift product strategy. After a modest rebound, sales stalled and losses mounted. His father rated his performance as president at 75%. In the fall of 1989, at the end of his first day back at work after undergoing surgery for esophageal cancer, and after his firm reported a $424 million loss for the previous fiscal year, An Wang, in a last ditch effort to save his company, fired his son. The firing was done in a stoical and businesslike fashion, Fred Wang, like a true Chinese son, accepting from his dying father his public humiliation with grace and dignity.

After a hectic 10-day search Wang replaced his son with 48-year-old Richard W. Miller, a Harvard MBA from General Electric with no computer industry experience. Miller faced a debt of $900 million. He ended cash dividends, sold some operations, cut staff by 27%, but still lost $715.9 million in his first year. In the next year he stabilized the firm but it has still not recovered. Its stock, which had fallen below $4 in 1990, remains at about that level today.

While the first of these wrenching changes were being made in Wang Laboratories, its founder, father, and alter ego died in Boston's Metropolitan General Hospital.

The decline in the fortunes of Wang Laboratories, especially its staff reductions, was disastrous to Lowell, where the unemployment rate, 4.3% in 1984, rose to 12.5% in 1991.

Why? Just as the Doctor must be given full credit for the astonishing and unprecedented success of his firm, it is natural to look to him and his actions for the reasons for the decline of Wang Laboratories while he was still in charge, for even while the son was president, the father continued to exercise control. He could not let go.

One author who has studied Wang's decline, Charles C. Kenney (1991), lists what he considers the following major reasons:

1. Wang was determined to pass his personal control of his company to his older son in keeping with Chinese tradition. He groomed Frederick for this from the time he was 26 and ignored the evidence that his son was not equal to the tasks he was assigned. Wang Laboratories' serious problems started with Frederick's move to the top. When directors objected, pointing out he had made a botch of his last job, product development, the Doctor replied, “He is my son.”

2. Wang was convinced that his products were so good that customers would always wait months for them and he simply refused to listen to the entreaties of his staff to develop a personal computer early. When he did, it was too expensive, too late.

3. Today, customers recognize paper machines as signs of weakness and incompetence. Product announcements must be supported by existing products. Frederick's brazen 1982 announcement of imaginary machines, unlike his father's similar 1968 ploy, backfired.

4. An Wang's personality had changed. He describes himself in his autobiography, and those who knew him before 1986 confirm this, as always avoiding the slightest hint of pomp, having only two suits, both gray, accepting a chauffeur only because he caught himself thinking while driving, and generally avoiding pomp and ceremony. In the last years of his life these things changed. He surrounded himself with security guards, bought corporate jets, and moved into a 3,000-square-foot office with a marble fireplace and whirlpool bath. In the words of deposed president Cunningham, “The Doctor had become a humble egomaniac.”

Contributions

An Wang, his family, his family trust, and Wang Laboratories gave generously in time and money to education and charity. Wang himself served as a member of the Massachusetts Board of Higher Education and the Massachusetts Board of Regents, as trustee of Northeastern University and of Boston College, and as an overseer of Harvard, to which he gave $4 million. In 1983 the Wangs donated $4 million to save the Boston Metropolitan Center, renamed the Wang Center for the Performing Arts. The Wangs were major funders of the nine-story Ambulatory Care Center of the Massachusetts General Hospital, giving it $4 million. Wang was a major funder of the Fairbanks Center for Asian Studies at Harvard. He supported China scholars and studies at MIT, Harvard, and the Chinese Cultural Institute.

Honors

Wang was awarded 23 honorary degrees. Those he prized most were from Harvard and Chiao Tung, now in Taiwan. In 1986 he received the US Medal of Liberty; in 1987 *Datamation* entered him in its Hall of Fame; and in 1988 he was entered into the National Inventors' Hall of Fame.

QUOTATION

Four years before his death, An Wang ended his autobiography with his own epilogue:

> My days are spent doing the things I really want to do. The satisfaction of turning an idea into something real never diminishes, and the great gift of change is that it continually replenishes the stock of new ideas that might be brought to life. The thrill of this challenge more than compensates for the setbacks that are the price of learning and growth. There are still many lessons to be learned.

Some may be learned from the Doctor's life.

BIBLIOGRAPHY

Biographical

Fairley, Richard E., “A Post-Mortem Analysis of the Software Engineering Programs at Wang Institute of Graduate Studies,” in Fairley, R., and P. Freeman, eds., *Issues in Software Engineering Education*, Springer-Verlag, New York, *1989, pp. 19-35.*

Forrester, JW., “Multicoordinate Digital Information Storage Device,” US Patent *2,736,880*, filed May *11, 1951*, issued Feb. *28, 1956.*

Gardner, W.D., “An Wang's Early Work in Core Memories,” *Datamation*, Mar. 1976, pp. 161-164.

Kenney, Charles *C., Riding the Runaway Horse*, Little-Brown, Boston, Mass., 1991.

MIT Institute Archives Staff, “The Magnetic Core Memory Collection at the MIT Institute Archives and Special Collections,” *IEEE Center for the History of Electrical Engineering Newsletter*, No. 23, Spring 1990, pp. 6-7.

Pugh, Emerson W., *Memories That Shaped an Industry*, MIT Press, Cambridge, Mass., 1984.

Redmond, Kent C., and Thomas M. Smith, *Project Whirlwind, The History of a Pioneer Computer*, Digital Press, Bedford, Mass., 1980.

Salton, Gerard, “Howard Aiken's Children: The Harvard Computation Laboratory and Its Students,” *Abacus*, Vol. 1, No. 3, Spring 1964, p. 28.

Wang, An, and Eugene Linden, *Lessons*, Addison-Wesley, Reading, Mass., 1986.

Weiss, Eric, “An Wang, Obituary,” *Ann. Hist. Comp.*, Vol. 15, No. 1, 1993, pp. 60-69.

Significant Publications

Wang, An, “Pulse Transfer Controlling Devices,” US Patent 2,708,722, filed Oct. 21, 1949, issued May 17, 1955.

UPDATES

Wang Laboratories filed for bankruptcy protection in August 1992. After emerging from bankruptcy, the company eventually changed its name to Wang Global. In 1999, Wang Global was acquired by Getronics of The Netherlands. (Wikipedia, 2012)

Portrait replaced (MRW, 2013)