Howard Hathawy Aiken

Born: 1900*; Died 1973. Designer and developer of the first 1arge-scale operating relay calculator in the US*

Education: SB, electrical engineering, University of Wisconsin, 1923; SM, physics, Harvard University, 1937; PhD, physics, Harvard University, 1939.

Professional experience: Madison Gas & Electric, Westinghouse, 1919-1932; Harvard University: instructor, associate professor of applied mathematics, 1937-1961, director, Computation Laboratory, 1946-1961; US Navy, Commander, Naval Mine Warfare School, 1941-1944, Harvard/Navy Computation Laboratory, 1944-1946; University of Miami, professor, 1961-1973; after retirement from Harvard, he created Howard Aiken Industries.

Honors and Awards: IEEE Computer Society Pioneer Award, 1980.

Aiken was the leader in developing four large-scale calculating machines (the word "computer" was never applied to his devices), but his accomplishments reached far beyond machine design and construction. His primary focus was *computation;* he built and used machines to solve problems. He directed research in switching theory, data processing, and computing components and circuits. He initiated one of the earliest graduate programs in computer science at Harvard University: fifteen doctoral degrees and many master's degrees were earned under his supervision. The publications of the Computation Laboratory are contained in 24 volumes of *Annals.* Scientists across the world were welcomed into his laboratory, and he did much to stimulate interest in computers in Europe. Truly a giant in early development of automatic computation, Aiken left perhaps his greatest legacy, the many people whom he influenced, particularly the members of his staff at the Computation Laboratory at Harvard.

Aiken's Shift from Electron Physics to Computing[1]

Although Howard Hathaway Aiken achieved world fame as a computer pioneer, when he entered Harvard's Graduate School of Arts and Sciences in 1933 as a candidate for the PhD in physics, he had no idea that he would devote his career to computing. Then 32, older than most graduate students, he had obtained his undergraduate degree in electrical engineering from the University of Wisconsin and had worked as a power engineer before coming to Harvard.

During Aiken's initial years as a Harvard graduate student, he followed the usual program of studies. He then shifted his allegiance to the field of electronics, the physics of vacuum tubes, and the properties of circuits, working directly under Professor E. Leon Chaffee, who became (and remained) his primary academic sponsor. He began teaching in his second year as a graduate student and, after receiving his PhD in 1938, was appointed a faculty instructor, the name of the rank then introduced by Harvard to replace that of assistant professor. Aiken never published any of the results of his thesis research; all of his published writings dealt with one or another aspect of computing and computers.

Aiken 's Background in Computing and Gadgetry

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[1] Much of the following essay on Aiken is extracted with permission from Cohen 1992.

In an autobiographical letter to Warren Weaver in September 1940, Aiken stated that his “chief research for the past six years has been the construction of an automatic calculating machine for scientific purposes.” This would place the beginnings of his interest in a “calculating machine” in 1935, when he had begun his thesis research.

His training as an electrical engineer and as a graduate student in physics would have exposed him to a generous amount of pure and applied mathematics. In those days, scientists advanced from slide-rule calculations to using electromechanical desktop calculations-chiefly Monroe, Burroughs, and Marchant machines. Aiken mastered this kind of calculating, as well as the mathematics of ordinary and partial differential equations, vector analysis, and matrices. In this he was in no way different from dozens of other students in pure and applied physics.

One feature of Aiken's writings shows him to have been very different from most other physicists and applied mathematicians: Aiken always had an interest in the history of his subject, and he joyfully paid tribute to his illustrious predecessors. This feature has led to a severe misunderstanding of his knowledge of the work of some predecessors, notably Charles Babbage; as a result, Aiken's originality has been seriously misjudged by assuming that he had depended heavily on Babbage's ideas.

Aiken's 1937 proposal for a calculating machine began with a series of paragraphs devoted to an account of the pioneers in machine calculation: Pascal, Moreland, Leibniz, and, above all, Babbage. This same historical homage characterizes the series of articles in *Electrical Engineering* in 1946**.** The whole of the first chapter of the *Manual of Operations for Mark I* was a historical chronicle, stressing the work of Charles Babbage; one of the illustrations even showed a set of calculating wheels from Babbage's never-completed Difference Engine. The result was that Aiken's machine was often considered to be indebted to Babbage's ideas; L.C. Comrie, the leading figure in British computing, referred to the Mark I as “Babbage's Dream Comes True.”

Planning for the Mark 1/ASCC[1]

Aiken's 1937 proposal is a fairly long document, filling twenty-three double-spaced typed pages. It opens with a brief history of “aids to calculation,” concluding in a major discussion of Babbage's engines, plus a brief statement of Hollerith's invention of punched-card “tabulating, counting, sorting, arithmetical machinery.” Aiken observed that the machines “manufactured by the International Business Machines Company” have made it possible to do “daily in the accounting offices of industrial enterprises all over the world” the very “things Babbage wished to accomplish.” Aiken then turned to the “need for more powerful calculating methods in the mathematical and physical sciences.”

The next section was crucial to the organization of a calculating machine. Aiken specified four design features that are different for punched card accounting “machinery” and “calculating machinery as required in the sciences.” First, a machine intended for mathematics must “be able to handle both positive and negative quantities,” whereas accounting machinery is designed “almost entirely” for “problems of positive numbers.” Second, calculating machinery for mathematical purposes must “be able to supply and utilize” many kinds of transcendental functions (e.g., trigonometric functions): elliptic, Bessel, and probability functions. Third, for mathematics, a calculating machine should “be fully automatic in its operation once a process is established.” In

[1] Automatic Sequence Controlled Calculator, the IBM designation for the calculator.

calculating the value of a function in its expansion in a series, the evaluation of a formula, or numerical integration (in solution of a differential equation), the process, once established, continues “indefinitely until the range of the independent variables is covered”-usually “by successive equal steps.” Fourth, calculating machinery designed for mathematics “should be capable of computing lines instead of columns,” since very often in the numerical solution of a differential equation, the computation of a value will be found to depend on preceding values. This is actually “the reverse” of the way in which “existing calculating machinery” is capable of evaluating a function by steps.

The proposal was obviously geared directly toward IBM's operative elements. But it is also clear that, at the general level of Aiken's actual text, the only demands for functional elements were that they be digital; that they be capable of performing the four fundamental operations of arithmetic; that they could be linked and controlled so as to perform their operations in a predetermined sequence; that they could store numbers (either constants or intermediate results) and to introduce them at a specified stage in the automatic sequence, and that they print out the final results in tabular form. IBM engineers could readily understand the function of each of the operative elements and could design circuits that would permit these operations to be performed in sequence according to predetermined commands entered on punched cards or perforated tape. These engineers could, and did, transform Aiken's ideas into an electromagnetic level of machine reality that allowed the calculator to be designed for construction.

A factor in the later disagreement that arose between Aiken and IBM, however, was that Aiken always discussed his machine in terms of the higher level mathematical problems he had designed it to solve. A full and comprehending reading of Aiken's proposal thus required a level of mathematical literacy that was several degrees beyond the capacity of almost everyone on the engineering staff of IBM at that time. Not many of the engineers in 1937 were even college graduates. Clair D. Lake, the engineer who was put in charge of Aiken's project, was a distinguished inventor who came to IBM in 1915 from the automotive field; his “credentials were based on performance, not education” (after the eighth grade he had gone to a manual training school rather than a high school). Francis E. (Frank) Hamilton, who directed the work on the Aiken project, had a distinguished career at IBM. He became a member of the company as a draftsman in 1923, when it was still known as CTR; in 1937, Hamilton was an assistant to Lake. The third member of the working team for Aiken's machine was Benjamin Durfee, who had been with IBM since 1917 (in the CTR days) and who had spent a year in the company training school, after which he developed “a reputation for diligence in servicing tabulators” (a job consisting “mainly of checking machine adjustments, oiling and cleaning, and replacing worn parts”).

The enormous intellectual gulf between Aiken and the IBM engineers with whom he was in contact transcended the level of mere mathematical training. Lake, Hamilton, and Durfee were from a wholly different world, and they had no understanding of Aiken's scientific and intellectual values. Aiken often tended to think of this IBM trio as mere mechanics, supergadgeteers, clever at their work but in no possible sense his peers. They, in turn, considered “their machine” to be their invention, admitting only that Aiken had supplied the initial broad outlines and the occasion for the project. Naturally, these men (and everyone else at IBM) would resent any later move by Aiken to present himself as principal inventor, on a different and more fundamental level of creativity than Lake, Hamilton, and Durfee. In retrospect we can see an inevitable head-on collision that would necessarily arise when it came time to apportion the credits for the great invention.

IBM Agrees to Build the Machine

By March 31, 1939, the final agreement had been drawn up and signed. IBM agreed (1) “to construct for Harvard an automatic computing plant comprising machines for automatically carrying out a series of mathematical computations adaptable for the solution of problems in scientific fields." Harvard agreed (2) to furnish "without charge" the structural foundation, and (3) to appoint "certain members of the faculty or staff or student body" to cooperate with "the engineering and research divisions of IBM in completing the design and testing." It was agreed (4) that all Harvard personnel assigned to this project would sign a standard "nondisclosure" agreement to protect IBM's proprietary technical and inventive rights. IBM (5) would receive no compensation, nor were any charges to be made to Harvard. The finished "plant" would become "the property of Harvard." A letter from Dean Westergaard confirmed the "understanding that the computing plant will be for the use of Harvard in scientific fields and that no commercial use will be made of it by Harvard." On May 10, 1939, about a year and a half after Aiken's first approach to IBM, James Bryce wrote Aiken that all the papers had been signed and that he was now "engaged in getting an appropriation put through." He would then "issue the shop orders" and "begin the actual work of designing and constructing the calculating machine." It may be noted that Bryce quietly shifted the language from "calculating plant" to "calculating machine." By May 12, the first appropriation had been made and the project was at last under way.

In January 1943, the Harvard machine was completed in the North Street Laboratory at Endicott, N.Y., and ran a test problem. But only in December 1943 was the machine demonstrated to members of the Harvard faculty. The machine was then disassembled and shipped to Harvard, where it was housed in a large basement room in the Physics Research Laboratory, known as the Battery Room because it then housed a giant wet-cell battery.[1]

Excitement rippled through the Physics Department on February 1, 1944, as the trucks arrived and the parts of the huge machine, many of them in large crates, were transported to the Battery Room. To record the event, the Cruft Laboratory photographer Paul Donaldson was on hand to make still photographs and to capture the entrance of the crates on 16-mm film with his newly acquired Kodak Cine Special motion picture camera.

By early spring the giant machine was in full operation, under the direction of Robert Campbell. Aiken himself was not in residence. A reserve officer in the Navy, Aiken had been called to active duty in 1941 and had been sent to the Naval Mine Warfare School in Yorktown, Va. His assignment was to prepare Navy technicians for using mines.

The Dedication of the ASCC/Mark I

When the machine had been turned over to the Navy for operation during wartime, Campbell became a lieutenant in the Navy and was joined by Lt. Richard M. Bloch and Lt. Grace Murray Hopper (who had been a professor of mathematics at Vassar College), plus other naval personnel including Lt. Comdr. Hubert A. Arnold, Ens. Ruth A. Brendel, Lt. Harry Goheen, and Lt. Brooks J. Lockhart. There was also the usual complement of naval "ratings." When Aiken himself was transferred to Cambridge, he became the first naval officer in history to command a computer.

On April 17, 1944, Harvard's president, James Bryant Conant, reported to IBM's president, Thomas J. Watson, Sr., that "the calculating machine" had been "put into operative condition." Expressing his appreciation for "the speed with which the machine has been installed" and noting that it "is already being used for special problems

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[1] As an aside, I may mention that as a very junior member of the wartime staff of the Physics Department I participated in the faculty vote to turn over the Battery Room to Aiken and IBM for the new calculator. The vote stipulated that at the end of the war the room would he restored to its original function, something that-to the regret of some members of the department-was never done. This vote was my first formal contact with Howard Aiken and his machine.—I. Bernard Cohen.

in connection with the war effort," Conant nevertheless regretted that the covering sheath was "still to be completed," thus delaying the "public announcement of the machine and its purpose." Watson replied on April 21 that he had "given orders to rush the completion of the cabinet for the machine." He concluded in an expression of the "great pleasure and inspiration" it had been for his "organization to cooperate with you and your associates in connection with this machine." He was "looking forward to being present at the dedication." On July 24 Conant wrote about the arrangements for the dedication, to take place on Monday, August 7. A luncheon at the Fogg Museum of Art would be followed by ceremonies in University Hall. Conant hoped that Watson would "say a few words."

The Harvard News Office, in close consultation with Aiken, prepared a news release. It was evidently not considered necessary to clear the release with IBM, even though what used to be called "common courtesy" might have seemed to demand such action. According to IBM's historians, "Watson [would have] assumed that he and Aiken would agree in a press release." The release was headed 'World's greatest mathematical calculator" and bore the statement: "The NAVY, which has sole use of the machine, has approved this story and set this release date [Monday papers, August 7, 1944]." The first five paragraphs (occupying almost two of the eight pages) stated that the machine would be presented to Harvard by IBM, that it would solve many types of mathematical problems, that the presentation would be made "by Mr. Thomas J. Watson, president of International Business Machines Corporation," that the machine was "new in principle," and was an "algebraic super-brain." Then followed the bold unqualified statement that "In charge of the activity...is the inventor, Commander Howard H. Aiken, U.S.N.R," who "worked out the theory which made the machine possible." It may be observed that not only was Aiken designated "the inventor," but no reason had been given thus far for IBM being the donor-it had not even been mentioned that IBM had actually constructed the machine. In fact, in the whole eight pages, the only reference to IBM's contribution was a single paragraph later on in the release.

Two years of research were required to develop the basic theory. Six years of design, construction, and testing were necessary to transform Commander Aiken's original conception into a completed machine. This work was carried on at the Engineering Laboratory of the International Business Machines Corporation at Endicott, N.Y., under the joint direction of Commander Aiken and Clair D. Lake. They were assisted in the detailed design of the machine by Frank E. Hamilton and Benjamin M. Durfee.

It is said that when Watson arrived in Boston accompanied by his wife and first saw the news story, he became so irate that he even planned to return to New York without attending either the ceremonial luncheon or the formal dedication ceremonies. When Watson arrived at his hotel, he telephoned—so the story goes—to his Harvard hosts, threatening to boycott the ceremonies on the following day. Conant and Aiken thereupon rushed from Cambridge to Boston to placate Watson, who launched into a furious tirade against Aiken and (presumably) Harvard. Evidently Conant and Aiken succeeded in calming Watson, who did attend the dedication on the following day and gave a star performance.

The Aftermath of the Dedication

About a month after the dedication, on September 20, 1944, Aiken wrote a letter of apology and explanation to Watson,[1] which was acknowledged by Watson in his reply to Aiken dated October 3, 1944. Watson thanked Aiken both for his letter and for "your kind remarks about me at the dedication of the Harvard machine." Watson mentioned a letter that Aiken had written to Lake, of which he had "just seen a copy," in which Aiken

[1] I have not been able to locate a copy.—I. Bernard Cohen

had referred "to the unpleasantness that had unfortunately occurred." Watson then restated his strong feelings about the "original press statements given out, identifying you as sole inventor of the machine" and not giving Lake, Hamilton, and Durfee credit "for their very important and untiring efforts." Watson therefore felt the need of telling Aiken that "it would have been a gracious gesture on your part" and "very much appreciated" by Lake, Hamilton, and Durfee if Aiken's "letter to Mr. Lake had contained an acknowledgment of the sincere regret over such unfortunate and erroneous publicity.[1]

Conclusion

The IBM ASCC (the Harvard Mark I) was the first of a series of four computers associated with Howard Aiken. Mark I and Mark II were electromagnetic, using relays, but Mark III and Mark IV had a variety of electronic components, including vacuum tubes and solid-state transistors. Of the four, Mark I was the most memorable because it produced such reliable results, and could run continuously for 24 hours a day, seven days a week. Thus, although it was very slow compared with any of the electronic machines, it produced a huge output—since unlike its electronic rivals, which had long "down times"—it ran continuously. Mark I also had a long life span, serving students and researchers at Harvard for more than a decade. Mark I was also notable for its very existence, proving that complex calculators or computers were feasible and could reliably follow a complex sequence of' commands.

Howard Aiken's place in the history of computers, however, is not to be measured by these four machines, interesting and important as they may have been. He recognized from the start that the computers being planned and constructed would require mathematicians to program them, and he was aware of the shortage of such mathematically trained men and women. To fill this need, Aiken convinced Harvard to establish a course of studies leading to the master's degree, and eventually also the doctorate, in what was to become computer science. Just as Aiken—by the force of his success, abetted by his ability to find outside funding for his programs—achieved tenure and rose to become the first full professor in the new domain of computer science, so he inaugurated at Harvard what appears to have been the first such academic program anywhere in the world. The roster of his students contains the names of many who became well known in this subject, including Gerrit Blaauw, Frederick Brooks, Jr., Kenneth Iverson, and Anthony Oettinger. As other later programs came into being, they drew directly or indirectly on Aiken's experience at Harvard. Aiken is sometimes held to be reactionary because he was always wary of the concept of the "stored program" and did not incorporate it into any of his later machines. This stance did put him out of step with the main lines of computer architecture in what we may call the post-Aiken era, but it must be kept in mind that there are vast fields of computer application today in which separate identity of program must be maintained, for example, in telephone technology and what is known as ROM ("read-only memory"). In fact, computers without the stored-program feature are often designated today (for instance, by Texas Instruments Corporation) as embodying "Harvard architecture," by which is meant "Aiken architecture."

In assessing Aiken's fundamental contributions to the computer, many computer scientists and historians would stress his bold pioneering achievement of introducing computers into a university environment and inaugurating an academic program in computer science. Others would give primacy of place to the Harvard Mark I (the IBM Automatic Sequence Controlled Calculator), not as a machine that set design standards for an industry, but rather as a first real demonstration that such machines were practicable. It is a fact of historical record that Mark I was the machine that first proved to the world at large that a complex calculating engine could function

[1] I have not as yet been able to find the text of the letter from Aiken to Lake.—I. Bernard Cohen

automatically, performing operations in sequence, and could follow a predetermined program from the entry of the data to the production of the final results. The worldwide publicity attendant on these achievements, aggrandized by the stark fact of its regular and continuous operation to produce reliable and accurate results, convinced any last doubters that large-scale, automatically sequenced calculators were practical and could perform a major role in the technical world. In this sense, it is certainly correct to say that when the switch on Mark I was thrown, the Computer Age began.

Aiken 's Calculators[1]

The four large-scale calculators which Aiken developed were:

Automatic Sequence Controlled Calculator (the Harvard Mark I, known within IBM as the ASCC): conceived by Aiken in 1937, designed by IBM engineers and by Aiken, built by IBM as a gift to Harvard. The Mark I was used at Harvard by a US Navy crew that included Grace Murray Hopper and Richard Bloch. Aiken was extremely conservative in his use of well-tested, well-understood elements, using electromechanical decimal rotary counters and relays, punched tape for the input of instructions, and tables of functions. Punched cards, as well as modified electric typewriters, were also used for input/output. The major purpose of this calculator was to calculate tables of values.

Mark II: Designed and built at Harvard for the Naval Proving Ground at Dahlgren, Va., for the development of ballistics tables. While this machine used basically the same components as the Mark I, it actually contained two complete identical calculators.

Mark III: Like Mark II, this machine was designed and built at Harvard for Dahlgren. Unique in utilizing separate magnetic drums for data and instructions and some vacuum tube circuitry for such components as registers, this calculator also used magnetic tape for input/output. The tapes were transferred to off-line electric typewriters for hard copy. At first the Mark III seemed to be a highly unreliable machine, but it was discovered that many of the problems were created by closing the machine down each weekend and restarting on Mondays. Once the machine was left up continually, the system became very reliable.

Mark IV: Designed, built, and operated at Harvard for the US Air Force, it incorporated the magnetic drums and tapes of the Mark III but added core memory shift registers for working data storage. For the first time this machine contained semiconductor diode circuitry as well as vacuum tubes.

Component	Mark I	Mark II	Mark III	Mark IV
Detailed Design Began	1939	1945	1948	1950
Implementation Complete	1944	1948	1950	1952
Retired from Use	1958	1956	1956	1962
Data Word[2]	23 dd+s	11 dd+s+e	16 dd+s	16 dd+s
Memory-Data-Slow Access[3]	72	96	4,000	4,000

[1] Prepared by the 1983 National Computer Conference Pioneer Day Committee.

[2] dd = decimal digit; s = sign; e = exponent in floating-point notation.

[3] words

Memory-Data-Fast Access	0	0	360	230
Memory Instructions	paper tape	paper tape	4,000	10,000
Basic Add Time[1]	300	200	4	1.2
Basic Multiply Time	6,000	1,000	12	12

QUOTATION

"The president of IBM can't tell the president of Harvard what to do."

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[1] Milliseconds (both Add and Multiply)

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UPDATES