Making business of a revolutionary new technology:

The Eckert-Mauchly company, 1945-1951

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***Abstract**: The paper analyzes John Presper Eckert and John William Mauchly's endeavours to design, sell, and build the revolutionary new technology of the first large, commercial computers. It discusses how Eckert and Mauchly's conceptualization of the computer grew out of their ENIAC and EDVAC projects at University of Pennsylvania. They incorporated their own business to gain profit from production and attain the freedom needed to develop their revolutionary new computer technology through a series of small, separate computer projects with private and government customers. The paper approaches innovation as a chaotic process and uses uncertainty to conceptualize the basic relations between actors and organizations.*

Introduction

> *"… did you ever think it was going to turn out like this? … my colleague Mr. Eckert and I, independently I think, have developed about the same answer: that, yes, we felt it was going to turn out to be a big thing. It was just to our disappointment that it took so long. But then it always takes a long time to change people's minds, and it takes even longer for us to change an institution."*[1]

This was how John W. Mauchly, in 1973, recalled the development of the first UNIVAC computer, completed in 1951. He acknowledged that he and John Presper Eckert did not know where the development would end, when it started in the mid 1940s. In contrasts, the histories of the

[1] John Mauchly, talk to UNIVAC meeting in Rome in 1973, p.1, interview OH 44, Charles Babbage Institute, University of Minnesota.

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computer industry subscribed to a linear narrative from the ENIAC project during the Second World War to the IBM System/360 mainframe computer closure in the mid 1960s, and to personal computers and beyond.[2] They discuss either engineering (hardware and software) or business aspects of the development and they, therefore, miss the shaping interaction between markets and engineering, and the crucial role of government in both funding projects and acquiring computers.

An integrated analysis of business, technology, private market, and government market is essential in order to understand how mainframe computers emerged. Further, the linear narrative ignores the size of the endeavor that Eckert and Mauchly faced in the mid 1940s of designing and building a revolutionary new technology, and it ignores the complexity of subsequent development, until IBM established the mainframe computer closure by introducing its System 360 in 1964. The development of revolutionary new technology and establishing its production was never a simple rational process. It was revolutionary because it reached beyond incremental improvement. In the mid 1940s, designing and producing mainframe computers required revolutionary new design and basic elements, like adders, memory, storage, and input and output media. John Presper Eckert and John Mauchly's journey of designing and building a computer went beyond rational engineering, which rendered estimation of expenses difficult.

The paper analyzes Eckert and Mauchly's endeavours between 1945 and 1951 to design, build, and sell the revolutionary new technology of the first large, commercial computers in interaction with private and government customers. It approaches innovation as being a chaotic process and uses uncertainty to conceptualize the basic relations between actors and organizations.

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[2] The exception is JoAnne Yates, *Structuring the Information Age: Life Insurance and Technology in the Twentieth Century*, Baltimore: Johns Hopkins University Press, 2005. Examples of linear engineering perspective histories: Emerson W. Pugh, *Building IBM: Shaping an Industry and Its Technology Cambridge*, Massachusetts: MIT Press, 1995; Paul E. Ceruzzi, *A History of Modern Computing*, Cambridge, Massachusetts: MIT Press, 1998; Arthur L. Norberg, *Computers and Commerce: A Study of Technology and Management at Eckert-Mauchly Computer Company, Engineering Research Associates, and Remington Rand, 1946-1957*, Cambridge, Massachusetts: MIT Press, 2005; William Asprey and Martin Campbell-Kelly, *Compute: A History of the Information Machine*, New York, Basic Books, 1996. Examples of linear business perspective histories: Richard Thomas DeLamarter. *Big Blue: IBM's Use and Abuse of Power, New York:* Dodd. Mead & Co., 1986; Franklin M. Fisher, James W. McKie and Richard B. Mancke, *IBM and the U.S. Data Processing Industry. An Economic History*, New York: Praeger Publishers, 1983; Franklin M. Fisher, John J. McGowan, and Joen E. Greenwood, *Folded, Spindled, and Mutilated: Economic Analysis and U.S. v. IBM,* Cambridge, MA: The MIT Press, 1983; Robert Sobel, *IBM. Colossus in Transition*, New York, 1981.

ENIAC and EDVAC: Technical Feasibility and Design of an Operational Computer

In late 1945, John William Mauchly and John Presper Eckert started exploring what a computer should be. This was based upon the ENIAC project's proof of the feasibility of building a large electronic calculator, and the EDVAC pre-project, which had produced a feasible rapid-access memory, the stored program design. Now it was feasible to imagine more complex use than calculating the third root of 2589 raised to the 16th power, the most advanced application according to US Army in 1946.[3]

John William Mauchly studied engineering and physics at Johns Hopkins University in Baltimore, Maryland, where he received a Ph.D. in physics in 1932. After receiving his doctorate, he was employed and became associate professor of physics at a small college where he had no research time. Anyhow, Mauchly was interested in meteorology and applied statistical methods to weather forecasting, and he started a project on the effects of solar activity on the earth's weather in 1936. For this end, he applied desk calculators, which was slow, and he began thinking about electronic means of calculation to make more complex calculations and to attain greater speed. Between 1937 and 1941, he designed and built electronic analogue and digital devises to reduce calculating time.[4]

The Second World War provided Mauchly with an opportunity to advance his carrier. In 1941, he enrolled as an instructor at a summer war-training course at the Moore School of Electrical Engineering at University of Pennsylvania. After that, Mauchly was offered a position as assistant professor, which he accepted,[5] and building an electronic calculator became his main research objective, replacing weather forecasting. Shortly after arriving at the Mores School, Mauchly met Electrical Engineer John Presper Eckert. At that time, Eckert was a graduate student. Mauchly discussed his idea of an electronic calculator with Eckert, who agreed that it was feasible.

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[3] US Army advertisement in *Popular Science*, October 1946, p.121

[4] John Mauchly, "On the Trials of building ENIAC", *IEEE Spectrum*, 12.4 (1975): 70-77; Mauchly, talk to UNIVAC meeting in Rome in 1973, 4-11; Nancy Stern, *From ENIC to UNIVAC. Appraisal of the Eckert-Mauchly Computers*, Bedford, MA: Digital Press, 1981; Alice R. Burks and Arthur W. Burks, *The First Electronic Computer, The Atanasoff Story*, Ann Arbor, Michigan: The University of Michigan Press, 1988, 73-104.

[5] Mauchly interviewed by Nancy Stern in 1978, Stern, *From ENIAC*, 9.

In August 1942, John Mauchly wrote a memorandum on a large high-speed vacuum-tube calculator for the Army Ordnance Department.[6] The proposal outlined the main features of a digital vacuum-tube calculator and focused on its technical feasibility. The proposed calculator intended to solve differential equations numerically, as was done at that time on desk calculators. He planned to make the arithmetic operations with electronic counters, in the manner of a desk calculator's decimal dials. This became the technical basis for a contract on a large electronic calculator, which the Army awarded to the Moore School in the spring of 1943.[7] Eckert and Mauchly's project team designed new electronic circuits and built a reasonably reliable machine. By June 1944, the formal design of the calculator was completed and it was dedicated in February 1946 as the Electronic Numerical Integrator and Computer (ENIAC).

ENIAC proved the feasibility of building a large electronic calculator, but it did not have reliability, size, moderate energy consumption, and user friendliness needed in order to make it attractive for a wider range of public and private organizations. Eckert and Mauchly's subsequent calculator and computer development focused on more compact design, less energy consumption, and three facilities, which they found essential to improve its use: a substantial memory, better programming means, and improved input and output feature. It was tedious and complex to program ENIAC. Its design did not focus on programming and it did not have a substantial memory essential for this facility. ENIAC had a tiny memory of 20 numbers, each of 10 digits and a sign. Improved programming facilities would need a substantial memory based on a design requiring less electronic components and consuming a smaller amount of power. ENIAC used an IBM card reader for input and an IBM card punch for output, which was reliable technology, but operated at speed several magnitudes slower than ENIAC's electronics calculation operations. This made input and output a bottleneck, but it was not a big problem for the envisioned scientific calculations with few input and output.

Based on discussions between Moore School and Army Ballistics Research Laboratory, in October 1944, the Army granted a supplement to the ENlAC contract to develop a computer,

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[6] John W. Mauchly, The Use of High Speed Vacuum Tube Devices for Calculating, August 1942, folder: ENIAC proposal, box 4a, series 1, acc. 1825, (Sperry Corporation Records), Hagley Museum and Library, Wilmington, Delaware.
[7] Report on an Electronic Diff. Analyzer," 8 April 1943, folder: ENIAC proposal, box 4a, series 1, acc. 1825 (Sperry Corporation Records), Hagley.

which was easier to use.[8] During 1945, this project ran in parallel with the completion of ENIAC, which had priority. John Eckert and his group focused on the development on mercury delay line memory, while a group headed by Mathematician John von Neumann designed the mathematical-logical structure of the new computer, later called Electronic Discrete Variable Automatic Computer (EDVAC). Eckert had experimented with delay lines when he was working on a Moore School subcontract for MIT's Radiation Laboratory in 1942.[9] In the summer of 1945, Eckert had design and experimental experience, which convinced him of the feasibility of delay line memory, and Eckert and Mauchly expected to use magnetic wire or tape for input and output.[10] No record was detected of reasons for replacing punched cards and punch stripes as input and output medium with magnet tape or wire, which was faster and required less space, but it needed substantial innovation to become a reliable medium. Simultaneously, the von Neumann group – interacting with Eckert, Mauchly, and others – devised the stored program computer design, which used a central processing unit and a single separate storage structure to hold both instructions and data. Based upon this work, in June 1945, von Neumann wrote a report describing this design, which he subsequently successfully marketed as exclusively his idea.[11]

Shaping a computer

In the summer of 1945, the building of large computers became technically feasible. ENIAC was being completed and had proven the feasibility of large electronic caculators. The EDVAC pre-project had provided a feasible overall design and a feasible fast-access memory. This indicated that the Moore School would get a contract to build the EDVAC computer. Simultaneously, the end of the Second World War, in August 1945, reduced the possibilities of military funding of building a new computer and it opened for new possibilities of Eckert and Mauchly pursuing computer business. Eckert and Machly decided to focus the commercial promise.

In December 1945 – while completing the ENIAC – Eckert and Mauchly started envisioning commercial possibilities. They approached the Bureau of the Census in order to sell the idea of a

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[8] Supplement No, 4 to Contract W-670-0RDA926, 27 October 1944; "PY Summary Report No" 1," 31 March 1945; box 23, series 1, acc. 1825, Hagley.

[9] Testimony by Eckert, Brainerd, and Mauchly, *Honeywell* v. *Sperry Rand,* according to Stern, *From ENIAC*, 60

[10] A Progress Report on the EDVAC, 30 September 1945, box 23, series 1, acc. 1825, Hagley.

[11] He never completed the report, which for many years circulated as manuscript, Stern, *From ENIAC*, 71-81. “First Report on the EDVAC” was first published in Stern, *From ENIAC*, 177-246.

large-scale electronic digital computer as an efficient tool for census work.[12] For this end Mauchly and Eckert studied census data processing, and probably magnetic tape was a significant sales argument. In the summer of 1945, the EDVAC design applied magnetic tape or wire for input and output. Probably the selection of magnetic tape for wire for the Census Bureau contacts in late 1945 was based on new information about German introduction of plastic recording tape coated with iron oxide during the Second World War. Plastic recording tape provided better audio recordings, it was far less expensive than steel wire or steel tape, and it had much longer life.[13]

However, it was not simple to accommodate commercial production at University of Pennsylvania, a non-profit organization. It was more difficult than accommodating government funded projects, like the ENIAC project, which was contested at many universities. They were skeptical about effect of government funding on academic freedom and feared that the type of research undertaken would be greatly influenced by the government's military needs. MIT and Johns Hopkins University had already established ways to accommodate extensive government contracts, and University of Pennsylvania worked to find a similar accommodation, since January 1946. A key element of this endeavor was establishing a policy of assigning patents to the university so that individual researchers would not be permitted to derive financial benefits from inventions developed while they were university employees. In March 1946, all Moore School staff was asked to sign a patent release form, which Eckert, Mauchly, and several colleagues refused. Instead, Eckert and Mauchly resigned from the Moore School by the end of March 1946.[14]

Historian Nancy Stern saw this patent conflict as the reason that Eckert and Mauchly went commercial.[15] True, this conflict reflected incompatibility of industrial production and academic standards at University of Pennsylvania at that time, but Mauchly's firm belief that he and Eckert could produce and market their own computers at substantial profits was also a key reason for the breakaway. In the end, Eckert was persuaded to attempt an independent commercial venture.

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[12] E. W. Cannon, History of the National Bureau of Standards Program for the Development and Construction of Large-Scale Electronic Computing machines, 1950, p.1, folder 32, box 6, Margaret R. Fox Papers (CBI 45), Charles Babbage Institute, University of Minnesota; Role of the National Bureau of Standards in the UNIVAC Program, ca. 1951, p.2, box 45, series 1, Acc. 1825, Hagley.

[13] "German Magnetic-Tape Recorder", *Electronics*, November 1945, 402-403.

[14] Stern, *From ENIAC*, 87-91.

[15] See previous note.

This was the outcome, even though Eckert and Mauchly had received an offer from IBM to establish their own computing laboratory.[16]

The ENIAC and EDVAC projects had been classified because of the Second World War. The end of hostilities facilitated declassification, which enabled Eckert and Mauchly to use their expertise for business. In addition, war-funding disappeared and public funding would again have to be based upon Congressional appropriations. The new funding structure was probably a major reason that Eckert and Mauchly since December 1945 worked to attain a contract to build a computer for the Bureau of the Census, which had run the decennial national censuses since 1902.[17] Such a contract appeared a simple access to funds. By the spring of 1946 the Census Bureau was definitely interested in Mauchly's proposal.

At their resignation from the University of Pennsylvania in March 1946, the possible census deal was the only contract, which they found was at hand. They started to work for establishing a company “to design and develop a multi-purpose rapid computing machine of moderate cost”.[18] Though they only were negotiating a contract with the Bureau of the Census, they optimistically envisioned many business opportunities in scientific computations, bookkeeping, and record management. They cited scientific calculations at universities, government agencies, and industries, bookkeeping in large companies, particularly insurance and railroad, and record management in insurance companies and libraries. This scope of application encompassed all punched card applications and the complex calculations facilities of the planned EDVAC computer. It was a revolutionary new way to see computers compared to ENIAC, EDVAC, and simultaneous work at Engineering Research Associates and Raytheon Manufacturing Company. Their original plan was to develop one or two computer models, which they estimated would be completed by the spring of 1949 and cost about $ 420,000.[19] The subsequent development would show that they underestimated the endeavor of designing and building the new computer.

However, the end of the Second World War caused a fundamental change to public funding of projects. During the war, funds were amble for war-related projects like ENIAC and the EDVAC

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[16] Nancy Stern’s interviews with Mauchly and Eckert in 1977, Stern, *From ENIAC*, 91-92.

[17] Lars Heide, *Punched-Card Systems and the Early Information Explosion, 1880-1945*, Baltimore, MD: Johns Hopkins University Press, 2009, 54-55.

[18] Immediate development plans (Electronic Calculator Co), probably March-April 1946, folder: Secretary’s Annual Papers, box 4, series 1, acc. 1825, Hagley.

[19] Immediate development plans, probably March-April 1946.

pre-project and the trust needed for funding by Army Ordnance was accomplished quite informally, when the project was located at a high standard institution like the Moore School. Now, peace-time appropriation made it essential for the Bureau of the Census to establish the trust needed to award a project to an organization. Was the project feasible? Was the price reasonable? Did the organization have the technological and financial capabilities needed to complete the contract in due time? It was not simple answering these questions for funding a project with Eckert and Mauchly of building a computer for the Census Bureau. They had substantial technological expertise, but did this suffice to build a revolutionary new device? And Eckert and Mauchly's business was not yet incorporated and had little assets. It was essential to find a way to establish the needed trust, which required assessment by experts, public or private, acting as intermediaries between the Census Bureau and Eckert and Mauchly. The National Bureau of Standards (NBS) rose to become intermediary for civilian and military government computer projects. It had been established in 1901 as an agency of the Commerce Department to give aid to manufacturing, commerce, colleges and universities.[20]

By June 1946, the National Bureau of Standards had decided to award a study contract to Eckert and Mauchly. The two inventors then formed a partnership, called the Electronic Control Company. But for bureaucratic reasons, the study contract only became effective in October 1946.[21] Eckert and Mauchly would provide specifications and a prototype of a mercury delay line memory at a fixed fee of $75,000.[22] It was originally anticipated that the research and study phase would last six months, and the design phase was expected to be completed within another six months. This schedule proved to be overly optimistic. The research and study phase itself lasted a full year. Moreover, it was not until June 1948, that the actual design contract was concluded at a fixed fee of $169,600.[23]

The Census Bureau was prepared to spend $300,000 on the Eckert-Mauchly computer. This figure included $75,000 for the original study contract and $169,600 for building the computer. The balance of $ 55,400 went to the National Bureau of Standards for services as intermediary. In

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[20] Rexmond Canning Cochrane, *Measures of Progress: A History of the National Bureau of Standards*, Washington, DC: US Department of Commerce, 1966; Stern, *From ENIAC*, 101-104.

[21] NBS Contract DA-2, box 36, series 1, acc. 1825, Hagley.

[22] DA-2 Progress Report, 21 November 1946, box 45, series 1, acc. 1825, Hagley.

[23] Mauchly to NBS, 13 March, 6 June, 1946, same location.

June 1946, Eckert and Mauchly's had estimated the development cost at $400,000.[24] Anyhow, despite their limited assets, the two men were willing to absorb the anticipated loss, because they believed that if they were successful, additional machines could be sold to both government and industry at substantial profit. But they never acquired the financial strength needed. The prolonged granting procedure caused problems to their weakly financed company, which was aggravated by their underestimation of the innovation work involved with the Census Bureau contract.

The Census Bureau needed a different computer than the sophisticated calculator, which was the objective of building ENIAC and EDVAC. Census processing required facilities for producing double entry tables and it took advantage of the plan to use magnetic tape in the EDVAC project. It needed fast and reliable sorting, which Eckert and Mauchly suggested could be achieved through transmission of data between two magnet tapes operating at separate stations. This made construction of tape stations and fast exchange of data between tape and the computer a key element of the Census Bureau contract.[25] Tape was an input and output medium and an extended storage like punched cards. The computer was changing from a fast calculator into a smart punched card machine. This transformation was more complicated and time consuming than Eckert and Mauchly anticipated.

The situation of late assignment of government contracts, which were smaller than expected, and more work in designing and building the computer than projected made Eckert and Mauchly open for approaches for additional contracts from A. C. Nielsen Company, Prudential Insurance Company, and Northrop Aircraft. Of these prospective customers, a contract with Prudential Insurance Company would imply substantial additional redesign of the computer system.

The A. C. Nielsen Company was founded in 1923 in Chicago, Illinois, by Arthur C. Nielsen, Sr., in order to give marketers reliable statistics on impact of marketing and sales programs. In the mid 1940s, A. C. Nielsen Company used large punched card installations to process the data for their market statistics. They were running into problems, because of the growing volume of

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[24] "Background and current situation relating to the formation of an Electronic Calculator Company," 14 June 1946, folder EMCC Misc papers, box 4a, series 1, Acc. 1825, Hagley.

[25] Eckert-Mauchly Board of Directors meeting minutes, 20 October 1948, Series 1, box 2: volume 2: acc. 1910 ((Sperry-Rand Corporation Administrative Records), Hagley.

business. As major users of IBM equipment, A. C. Nielsen Company had expressed an interest in acquiring more sophisticated machines from IBM but was disappointed by its unresponsiveness. Nielsen surveyed alternatives and started negotiations with Eckert and Mauchly in December 1946.[26]

In January 1947, Eckert and Mauchly offered to sell A. C. Nielsen Company a computer system equipped with a key-to-tape recorder and a printer for $100,000, all units to be completed within a year.[27] This implied changing the basis for Nielsen's data processing from punched cards to magnetic tape, which they accepted. Punched cards were only a processing tool at Nielsen, which was discarded once processing was completed. But A. C. Nielsen Company was reluctant to sign a purchase agreement with Eckert and Mauchly's company because of its precarious financial position. Nielsen wanted Eckert and Mauchly to develop their equipment and gain more business in order to establish the trust, which it needed for awarding a contract for a computer system.

Over the next year, Eckert and Mauchly reshaped their computer system and particularly its peripherals based upon their discussions with Prudential Insurance Company (see below). The A. C. Nielsen Company only needed a computer similar to that already promised to the Bureau of the Census. In April 1948, Nielsen signed a contract for a computer system with several peripheral devices at a cost of $151,400. The system included one computer, six tape units, six key-to-tape units, and one printer.[28] The following year, Nielsen contracted for a second computer with similar specifications. However, before the initial contract could be executed, Nielsen required the Eckert and Mauchly's company to have $240,000 in working capital and at least two other customers. In September 1948, John Mauchly informed A. C. Nielsen Company, that his company had contract for two contracts: Bureau of the Census and Watson Laboratories of the US Army Signal Corps.[29] But Eckert and Mauchly's company did not yet fulfill the working capital requirement.

Simultaneously with the negotiations with A. C. Nielsen Company, Eckert and Mauchly negotiated with the Prudential Insurance Company of Newark, New Jersey. One of its actuaries, Edmund Calis Berkeley, had been studying alternatives to IBM punch-card equipment as far back

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[26] Stern, *From IBM,* 142-143, which is based upon the personal archive of an A. C. Nielsen staff.

[27] EMCC to A. C. Nielsen, Jr., 4 January 1947, folders: A. C. Nielsen Correspondence, box 43, series 1, acc. 1825, Hagley.

[28] Agreement between EMCC and A. C. Nielsen Company, April 23, same location.

[29] Memo, Computer Contract for Watson Laboratories, EMCC, 14 January 1948, box 48, series 1, acc. 1825, Hagley.

as the early 1940s.[30] He received a BA in Mathematics and Logic from Harvard in 1930. He pursued a career as an insurance actuary at Prudential Insurance from 1934–1948, except for service in the Navy during the Second World War, from 1942-1946. While in the Navy, he worked at the Naval Proving Ground in Dahlgren, Virginia, as a mathematician and was assigned to Howard Aiken's Harvard Laboratory to work on the sequential calculator project (Mark II), successor to the electro-mechanical calculator, the Automatic Sequence Controlled Calculator (ASCC) and Mark I, which he built with IBM from 1938-1944.[31]

In the fall of 1946, after Berkeley's return to Prudential from Navy service, the company asked him to determine whether the new digital computers could be profitably applied to meet the needs of insurance companies. Berkeley wrote a memorandum on a computer designed to make the numeric calculations of Prudential's actuary more efficient, which required facilities for several mathematical functions.[32] He investigated the possibility of using Aiken's Mark I, and inquired about IBM's new semi electronic programmed calculator, the Selective Sequence Electronic Calculator, and about Eckert and Mauchly's planned computer.[33]

Calculations remained the focus in Eckert and Mauchly's company until the spring of 1947.[34] Then the contract negotiations with Prudential made Eckert and Mauchly extend the scope of their computer project to encompass alphanumeric data processing, because their company realized that Prudential demanded equipment for premium billing, mortality studies, and group insurance. Premium billing presupposed letters and numbers.[35]

Prudential had started using punched cards before 1900 and its data processing had been based on IBM equipment since the 1920s.[36] Therefore, it viewed the Eckert and Mauchly's use of magnetic tape for input and output with some concern. Although the concept seemed attractive, there were as yet no working models to prove its feasibility, and the use of tapes in place of cards

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[30] C. E. Berkeley, Memorandum for Mr. H. J. Volk, 9 February 1942, folder 35, box 4, CBI 50.

[31] http://special.lib.umn.edu/findaid/xml/cbi00050.xml#a2 (accessed 28 May 2010)

[32] Memorandum from Berkeley to Volk, 5 November 1946, folder 52, box 8, CBI 50; Preliminary version with a wider scope of numeric applications is memorandum from Berkeley to Volk, 5 November 1946, box 78, acc. 1825, Hagley.

[33] Mauchly to Berkeley, 28 March 1947, folder: Prudential Insurance, box 48, series 1, acc. 1825, Hagley.

[34] Conferences on EDVAC II Design, 11-12 March 1947; Instruction code C-2 statistical machine (EDVAC I), 7 May 1947; both in box 79, acc. 1825, Hagley.

[35] Application of high speed computing machines to certain problems of the Prudential Life Insurance Company, Electronic Control Company, 16 May 1947, box 79, acc. 1825, Hagley.

[36] Heide, Punched-Card Systems, 43-54, 101, 118.

would mean that Prudential's entire data processing operation would need to be converted on to tape.[37] Eckert and Mauchly convinced Prudential that their computer system was feasible and a superior alternative to its current IBM punch-card systems, which caused two concerns at Prudential. Eckert and Mauchly's uncertain financial position was a serious obstacle. Prudential was unwilling to sign a large contract with a small company that had serious financial problems, particularly when sizable investment was required to complete the contract. This was the case, because they had not yet accomplished designing the statistics computer for the contracts with the Bureau of the Census and A. C. Nielsen Company, and Prudential's alphanumeric requirements would imply additional research and development as well as production expenses.

While Prudential was not willing to contract for a machine, it signed an agreement with Eckert and Mauchly, in August 1947, which funded development of the computer system in return for an option to buy one later. If the option was exercised, the money provided for development would be applied to the purchase.[38] The agreement promised to complete the design and several prototypes of several key elements of the computer system by the end of 1947. Once more Eckert and Mauchly were overly optimistic in their time estimate. By the end of 1947, they had no yet completed the prototypes, and Prudential could have insisted that half its funds be returned. Instead, it agreed to amend the contract several times to allow their company more time to fulfill its obligations.[39] Prudential extended the deadlines because it was impressed with the progress being made and the development contract made it dependent on Eckert and Mauchly. In the end, Prudential signed a contract in December 1948 for building a computer system, which was to be delivered by September 1950.[40] The contract called for one card-to-tape converter and two tape-to-card converters, devices which would allow Prudential to retain its punch-card data processing systems, which was essential for Eckert and Mauchly extending their market to encompass non-numeric data processing in, for example insurance companies. The Prudential contract described Eckert and Mauchly's complete computer system, which they had named UNIVAC a year earlier, Universal Automatic Computer.[41] It was alphanumerical, had a central computer, tape drives, key-

[37] Mauchly to Berkeley, 28 March 1947, box 79, series 1, acc. 1825, Hagley.
[38] Contract between Electronic Control Company and Prudential, 4 August 1947, folder 56, box 3, CBI 50.
[39] Prudential to Electronic Control Company, 1 March 1948, same location.
[40] Prudential contract, 8 December 1948, same location.
[41] Memorandum Concerning name of Electronic Machines Made by this Company, Electronic Control Co., 24 May 1947, folder: EMCC misc. papers, box 4a, series 1, acc. 1825, Hagley.

to-tape encoders, and line printers. In order to answer demand, Eckert and Mauchly had developed their original ENIAC and EDVAC calculator designs into an alpha numeric design for data processing to succeed extensive punched card business.

The contract with Northrop Aircraft Company of Hawthorne, California, was the last to emerge by the summer of 1948. In 1947 Northrop was working on the development of a long range guided missile for the Air Force.[42] To control and guide the missile from launch to target, a complex series of computed functions had to be generated. For this end, Northrop needed a computer, and it hired John Mauchly to study whether electronic digital equipment could be adapted to satisfy its needs.[43] Mauchly's recommendations convinced Northrop of the feasibility of such equipment and it entered into negotiations with Eckert and Mauchly's company for the design and building of a computer focusing on scientific calculations. The scope of this computer was within the EDVAC design, and they accepted the contact in order to gain heavily needed business to fend-off their company's precarious financial situation and to use it as a prototype for key elements of their wider-scope computer. In October 1947, the parties made the contract for the Northrop computer, which was called Binary Automatic Computer (BINAC). [44] It would apply binary arithmetic o facilitate fast calculation and it was to be completed by May 1948.

Eckert and Mauchly were unable in meeting construction deadlines in this contract, as they were their development of UNIVAC. Although May 1948, was the contracted deadline for completion, BINAC was not operational until August 1949. It was formally accepted by Northrop in August after a demonstration. The final construction cost of BINAC was $300,000, which contrast the contracted price of $100,000.[45] Eckert and Mauchly totally underestimated the cost of innovating and building BINAC, as with UNIVAC. The two men had considerable technological expertise, but they were unable to provide good cost estimates. In 1950, their company was insolvent.

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[42] Richard E. Sprague, "A western view of computer history", *Communications of the ACM*, 15:7 (1972): 686 – 692, on 687-689.

[43] G. Gore of Northrop to J. W. Mauchly, 18 April 1947, folder: Mauchly, box 3, series 1, acc. 1825, Hagley.

[44] BINAC contract, 8 October 1947, volume 2, box 2, series 1, acc. 1910, Hagley.

[45] EMCC memo, Meeting – Northrop, 24 May 1949, box 46, series 1, acc. 1825, Hagley.

Establishing business of computers

Four years earlier, in March 1946, Eckert and Mauchly had left the Moore School of the University of Pennsylvania because they saw bright possibilities of computer business and they founded a partnership as the basis for their work in June 1946.[46] They focused on developing a computer and attaining computer building contracts through 1946 and 1947, and Mauchly travelled extensively to locate and persuade customers. In this period, they established contacts with the three companies, A. C. Nielsen Company, Prudential Insurance Company, and Northrop Aircraft, which contracted for computers in 1948. In addition, the records show that Mauchly had contacts to about twenty additional private and public organizations prospects in 1946-1947, which did not produce contracts.[47] He was busy covering the deficits inflicted by slow decisions to acquire computers and much larger costs and time needed to design and build computers than estimated when contracts were entered.

Eckert and Mauchly only incorporated their business, Eckert-Mauchly Computer Corporation, in December 1947.[48] Though the company attained several substantial contracts in 1948, its financial problems became more severe during that year. Since the start of the year, Mauchly worked hard to attack additional customers based upon a strategy to produce the company out of its crisis.[49] The company was desperate to securing adequate capital to assure the government and private companies that they could complete contracts that they would make, and the company failed to raise substantial new capital by issuing additional stocks in April 1948.[50]

But in the summer of 1948, American Totalistor Company of Baltimore supplied new capital. A totalisator was machine for calculating odds, issuing tickets, and showing payouts on horse races. In the 1930s, Electrical Engineer Henry Lobe Straus designed and built several electro-

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[46] Agreement of sale between Eckert and Mauchly, 5 June 1946, folder: Eckert-Mauchly Computer Corp. Acquisition by Remington Rand, Misc. Records, box 4, series 1, acc. 1825, Hagley.

[47] J. W. Mauchly, Prospective Contracts, 12 January 1948, folder: Mauchly, box 3, series 1, Acc. 1825, Hagley.

[48] Eckert-Mauchly Computer Corporation, Articles of Incorporation, 19 December 1947, vol. 1, box 1, series 1, acc. 1910, Hagley.

[49] J. W. Mauchly to F. W. Woolworth, 24 January 1948; J. W. Mauchly, memo, 5 February 1948; J. W. Mauchly, memo Visit to Wright Field, 13 March 1948; J. W. Mauchly, Sears Roebuck, 30 March 1948; J. W. Mauchly, Metropolitain Life Insurance Co., 31 March 1948; J. W. Mauchly, Totalisators, 31 March 1948; J. W. Mauchly, Army Map Service, 31 March 1948; J. W. Mauchly, Air Transport Association of America, 18 May 1948; all in folder: Mauchly, box 3, series 1, acc. 1825, Hagley.

[50] J. W. Mauchly, memo, 5 February 1948, folder: Mauchly, box 3, series 1, acc. 1825, Hagley; Prospect for Eckert-Mauchly, 27 April 1948, folder: Secretary´s Financial Papers, box 4, series 1.

mechanical totalisators which became the technological basis for American Totalisator Company. Straus became vice president and the company prospered because his all electric totalisator became a near-universal fixture in racetracks in North America.

In 1946, Eckert and Mauchly were approached by a challenger to Straus' dominating company. He wanted to build electronic totalisators, which he found would be much more efficient than Straus' electromechanical devices. Eckert and Mauchly declined, because they realized the facilities needed to apply a computer as totalisator was too far away from the focus of their current work. However, in March 1948, the computer design by and large was completed and Eckert and Mauchly were hungry for additional business.[51] Their approach to the totalisator industry produced a contact to Henry Lobe Straus. He became convinced that electronic computers had potential for a range of applications, including applications in the race track business, and he got American Totalisator Company to invest $ 500,000 in in return for 40 percent of the voting common stock of Eckert–Mauchly Computer Corporation.[52] Straus became chairman of the board. Eckert and Mauchly remained board members and retained control of 54 percent of the voting common stock; an additional 6 percent was held by the company's other employees.

American Totalisator's support kept Eckert and Mauchly's company floating for fourteen months, during which time the BINAC was completed and development on the UNIVAC continued. In October 1949, Eckert and Mauchly's company received an additional $ 100,000 from American Totalisator.[53] Anyway, the company's problems were not yet solved. Nine days later, Henry Straus was killed when his small airplane crashed.[54] Straus had been the prime force behind Totalisator's support and his death terminated the flow of funds from this company to Eckert and Mauchly's company.[55]

As a direct result of Straus's death, Eckert and Mauchly spent the remaining months of 1949 seeking financing from loan companies and research foundations. Finally, they sought to sell their corporation to a major manufacturer. They approached producers of calculating equipment,

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[51] J. W. Mauchly, Totalisators, 31 March 1948, folder: Mauchly, box 3, series 1, acc. 1825, Hagley.

[52] Minutes of Eckert-Mauchly Computing Corporation board of directors meeting, 6 August 1948, vol.1, box 2, series 1, acc. 1910, Hagley.

[53] Eckert-Mauchly board of directors meeting, 20 October 1948, vol.2.

[54] Eckert-Mauchly board of directors meeting, 24 November 1948, , vol.2; *Baltimore Sun,* October 29, 1949, p.1.

[55] Eckert-Mauchly board of directors meetings, 5 January 1949, 27 January 1949, vol.2.

such as Burroughs, IBM, National Cash Register, and Remington Rand.[56] Subsequently, they approached major industrial producers, such as General Motors.[57]

Remington Rand was first to act and acquired all shares of the Eckert-Mauchly Computer Corporation, 1 February 1950.[58] It became a subsidiary of Remington Rand and functioned as a separate division. It delivered the first UNIVAC computer to the Bureau of the Census in March 1951. By October 1954, Remington Rand had delivered twelve UNIVACs and had orders for four more.[59]

Mess of making business of a revolutionary new technology

I started the paper by citing John W. Mauchly's reminiscence, in 1973, of the shaping of what became the UNIVAC computer. He admitted that the shaping process was protracted which he explained by an observation that *"…it always takes a long time to change people's minds, and it takes even longer for us to change an institution."*[60]

He was correct that institutions – which he conceptualized as identical with privat and public organizations – had to change, but this only occurred once computers were installed. In the late 1940s, the organizational change of customer to demand computers had short duration compared to five years, which Eckert and Mauchly spent in designing and building the first large computer. In contrast, Mauchly persuaded the Census Bureau in five months to order a computer system, A. C. Nielsen Company used between two and three months to reach a decision, and Prudential Insurance Company reached their decision in less than a year. However, it took much more time to establish the trust needed for these organizations to sign contracts. They were uncertain of Eckert and Mauchly's company's financial capability, and did not want to be dependent on technology which perhaps never would materialize, as was the case for the

[56] Eckert-Mauchly Board of Directors meeting, 29 December 1949, vol.2, box 2, series 1, acc. 1910, Hagley; Thomas J. Watson, Jr., and Peter Petre, *Father, Son & Co.: My Life at IBM and Beyond*, New York: Bantam Press, 1990, 198-199.
[57] General Motors to G. V. Eltgroth of EMCC, 19 January 1950, box 42, series 1, acc. 1825, Hagley.
[58] Agreement, Remington Rand and EMCC, 6 February 1950, Eckert-Mauchly board of directors meeting, 16 February 1948, vol.2, box 2, series 1, acc. 1910, Hagley.
[59] UNIVAC orders, 5 October 1954, box 42, series 1, acc. 1825, Hagley.
[60] John Mauchly, talk to UNIVAC meeting in Rome in 1973, p.1, interview OH 44, Charles Babbage Institute, University of Minnesota.

Metropolitan Insurance Company's sponsoring of John Royden Peirce's development of punched card machines in the 1910s and 1920s.[61]

The demand for reduction of uncertainty and dependency gave room for the National Bureau of Standards to establish itself as the national computer intermediary facilitating civilian and military contracts.

Further, Maucly underestimated the extent of developing a revolutionary new technology twenty-five years after it took place, as he and Eckert did while they actually explored the new technology between 1943 and 1951. Before starting computer production, they had to establish company standards for designing and building completely new technology, based upon many components with reliability problems. Through this process, the scope of their computer's planned applications grew from the original calculator (ENIAC and EDVAC), to the numerical statistics calculator for the Census Bureau and A. C. Nielsen Company, and to the alphanumeric data processing machine for Prudential Insurance, which was named UNIVAC. Each extension of applications added a new element of uncertainty to the project. However, Eckert and Mauchly's rejection in 1946 of developing their computer for totalisator applications illustrates that they did not pick all requests. Their choices of customers remained within the scope they envisioned in the spring of 1946 and gradually expanded their business opportunities, like the similar extensions in the punched-card technology had expanded that industry's business opportunities in the 1920s and 1930s.

At each expansion, Eckert and Mauchly accepted new uncertainty, because they depend on one more customer to fill their company's extensive need for funds to complete their previous assignment. Their perpetual search for new customers, made Mauchly commit extensive time to locate and persuade new customers. Often, he was accompanied by Eckert, who should have committed all his time to complete their technical project. The records of Eckert and Mauchly's company provide a hectic picture of searches for funding that took time and delayed the project. Already in the summer of 1947, they had also to borrow money from Prudential Insurance to be able to keep their computer development project floating. In 1948, they received substantial venture capital from American Totalisator. However, only access to the large financial resources of the Remington Rand conglomerate, in 1950, facilitated completion and production of UNIVAC

[61] Heide, *Punched-Card Systems*, 100-102, 117-121.

computers. But Remington Rand had only resources to continue development and production of computers until 1955. That year, Sperry Corporation's financial resources were needed for Remington Rand's computer production to remain in business. The new company was called Sperry Rand.

Eckert and Mauchly's first large computer and their business were shaped through dependency on a series of customers for expertise on future use of computers and funds for innovating computers. At first glance the technical development process and the search for additional customers may seem chaotic, and, true, it held many chaotic elements. However, Mauchly was correct in 1973 to claim that he and Eckert all the way went for a general objective, which they accomplished though in Remington Rand, a different business context than they originally anticipated.