Punched-Card Systems and the Early Information Explosion, 1880–1945

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New Users, New Machines

American business enterprises radically changed their scale and scope between the Civil War and the First World War. The small local firms that had previously dominated production were complemented by big corporations. Also, the new industrial society was based on large transportation, communication, and insurance companies that only had existed on a very small scale before 1830. Alfred D. Chandler and other business historians have described the organizational forms essential to operate the new complex companies. A key component of administrative coordination was establishing the managerial tool of upward communication. Upward communication was designed to provide top management with an accurate and current picture of the company's various operations and to ensure accountability along the line.

Various kinds of operational statistics were devised for collecting and analyzing data generated by the day-to-day operations in enterprises. Cost accounting was such a tool that railroads had been using since the 1870s, and similar instruments emerged in diverse industries by the 1880s.[1] Many companies enhanced their processing of business figures through the introduction of tabular report forms, and adding machines started to become available to mechanize processing collected data in the 1890s.[2]

Herman Hollerith's first punched-card system had been built and applied with great fanfare for processing the United States census in 1890. However, applying punched cards to compile operational statistics in businesses demanded a substantial improvement in Hollerith's equipment and an enlargement of his business approach. The first punched-card system had been shaped exclusively to count people for census data, and this embodiment had been stabilized to the degree required for

building fifty-six tabulators.[3] These tabulators were rented to the Census Office, but remained Hollerith's property and were returned when the census operation was terminated in 1894. To process operational statistics, this equipment needed to be improved to facilitate adding numbers punched on cards.

Hollerith's business had been based on the 1890 Census Office as his sole substantial customer, posing modest organizational demands. Extending the business to encompass many customers' processing different kinds of operational statistics would require establishing a more elaborately organized company.

The history of the punched-card application in census operations until 1905 and the emergence of business statistics as an application field illuminate how stabilized the first punched-card system actually was and provide insight into the dynamic of opening a stabilized technology to reshaping.

Hollerith's Innovations in the 1890s

The contract to supply punched cards for the 1890 census kept Hollerith busy for a while. However, he did not feel that his first punched-card system had reached a stable position. In 1892, he revived innovations aiming at significant changes to the system along three different paths: introducing pneumatics as a new basis for card reading, developing a keyboard-based adding machine, and constructing an adding tabulator. All three paths probably derived from experiences and discussions in the Census Office. Only in 1894 did Hollerith start to look outside the census network. Although he never implemented his ideas of a pneumatics-based punched-card system or the improvements to the Lanston adding machine, the adding tabulator became the cornerstone of his punched-card system.

Hollerith filed patents for a system using pneumatic technology in 1892. The major difference between this system and his first punched-card system for the 1890 census was the use of pneumatics instead of electricity for card reading.[4] Hollerith's pneumatic innovations were probably triggered by operational problems with the mercury cups in the pin-box card reader. Mercury could accidentally be spilled from the cups, breaking the reader.[5]

Hollerith pursued two paths toward processing addition-based statistics from the mid-1880s on: a keyboard-based adding machine and an adding tabulator. The former was an alternative technology to punched cards, though Hollerith was not the only one to consider this solution. In the late 1880s, efficient adding machines started to emerge on the market. Hollerith's development of a keyboard adding machine was based on the Lanston adding machine that Hollerith had acquired in 1882. At that time, however, it had proved too expensive to produce. Now, he revived his interest and made additional innovations with Lanston. In 1897, the outcome was a strong and serviceable construct, which could be built cheaply and in viable quantities.[6] However, Hollerith was prevented from marketing the product by a problem with the patent. When the problem was finally resolved in 1899, Hollerith no longer had any need to pursue this path, as he had a well-functioning adding tabulator and customers interested in buying it.[7]

Building an adding tabulator was the alternative path to processing addition-based statistics. In the mid-1880s, Hollerith invented his first adding unit for a tabulator.[8] Basically, this was an electric version of the step wheel from Gottfried Wilhelm Leibnitz's mechanical calculating machine from the 1690s, of which an improved version was batch produced as the Thomas calculator in the nineteenth century. This machine was well-known in the United States by the 1880s.

In the early 1890s, Hollerith modified his adding tabulator from a spring-driven prototype to a more dependable version. This project was inspired by discussions at the 1890 census of the problems of tabulating the agricultural census. His development work took place in the Census Office, using agricultural census material, but punched cards were not applied to compile agricultural statistics in the 1890 census.[9]

As early as the mid-1880s, Hollerith was involved in processing both counting- and addition-based census statistics. His choice of the counting-based population census as his first application field provided a substantial job with limited technological complexity. It is far more complicated to build an adding unit than it is making a counter, as he discovered during his subsequent innovations between 1892 and 1894. His adding unit only became reliable in 1896 through trials on business statistics. However, his focus on the development of addition capability rather than process improvements indicates that he did not perceive speed as a *reverse salient*

to his system using Thomas P. Hughes's concept. He only recognized this problem during the processing of the United States census in 1900.

Hollerith's business efforts were focused on governmental statistics from the outset. He found time to travel abroad to receive honors and cultivate potential customers, which indicates that he was never planning to exclusively be a supplier to the federal censuses in the United States. He also looked up state census jobs in the United States. He tried, in vain, to get the order to process the 1895 state censuses of New York and Massachusetts,[10] but these jobs were small compared with a federal census. From 1894 to 1895 he traveled four times to Europe. He won a big contract for processing the Russian census in 1897 and contracts for censuses in Canada, France, and Norway. However, he did not gain any further census contracts in Europe, which was disappointing because of the large number of national statistical organizations that would have been natural contacts for him.

Hollerith had attained inside knowledge of the United States census statistics community, and the European statistics communities appeared similar. They received him well and awarded honors in recognition of his work. He was elected member of the Royal Statistical Society in London in 1894, and in the following year his speech was well received at the Institut International de Statistique, the international statistical association, in Bern, Switzerland.[11] It was one thing to address learned audiences, but it was quite another to bring home orders. After all, he was the lone salesman for his system, and foreign governmental orders took time to materialize. He had not yet recognized the drawbacks to the efficiency of his first punched-card system, and its rejection by most European census offices could be attributed either to an opposition to progress or to the lack of funds. However, it was more serious that in 1900 France and Austria discontinued their use of punched cards after both countries had processed a census.

Hollerith struggled with the problems of supplying the nonpermanent census office in the United States and of getting other census offices in the United States and abroad to apply his first punched-card system after 1890. Therefore, he would probably have run into severe problems if he had decided to rely on census processing as the sole application of his first punched-card system. So, he chose to extend his business to other customers as well.

Early Challengers

Life insurance companies were the first businesses to emerge as commercial punched-card users. American life insurance companies had extended their strategy to address a wider public in the 1840s and the new policies, which were later called "ordinary insurance," were written for relatively large amounts and premiums were generally paid yearly. As the number of insurance companies rose quickly, so did their number of policies and their assets. In the 1870s, the American insurance companies introduced "industrial insurance," consisting of small policies on the lives of industrial workers and their families, with very small premiums collected weekly. Compared with the ordinary policies industrial insurance involved more transactions for smaller amounts, leading to bigger total transaction costs. Further, the extension of life insurance to encompass different social groups caused problems, as the insurance companies lacked a detailed tabulation of life expectancy as a function of various conditions, such as occupation and present age, that could be used to calculate premiums. An intercompany mortality study was suggested in 1889 at a meeting of the Institute of Actuaries of America. A collaborative study would be based on a much larger sample than could data in any single company.[12]

By that time, the life insurance companies had accumulated vast amounts of data from managing policies over several decades using index cards to process statistics. The information on each policy was copied to a written card, the cards were sorted by hand into piles according to the categories to be tabulated, and each pile was counted manually. This procedure had the advantage that each step could easily be checked. Further, card-based processing enabled cheap unskilled workers to do most of the processing, whereas earlier methods based on individual processing of every policy had relied heavily on actuaries and actuary assistants.[13]

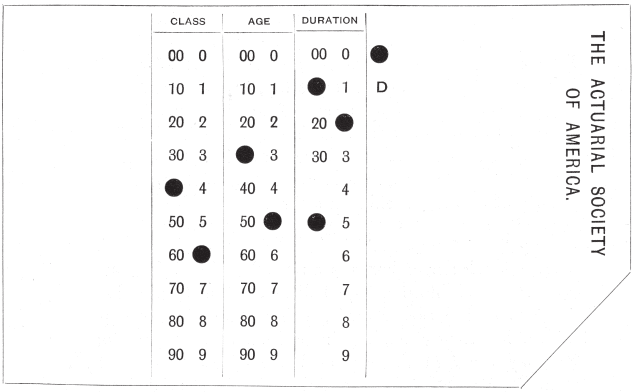
In March 1889, the actuary of the Metropolitan Life Insurance Company in New York City approached Hollerith.[14] The Metropolitan was among the five biggest insurance companies in the United States, but Hollerith declined, as he was busy working to gain the contract to process the census in 1890, which he got nine months later. Further, during the summer of 1889, he found time to travel to Berlin and Paris to exhibit his machines. Eventually, thirteen months later, in April 1890, Hollerith

demonstrated his first punched-card system to twenty-five members of the Institute of Actuaries of America.[15]

The Prudential Insurance Company was another of the top five insurance companies in the United States. Hollerith's demonstration in April 1890 prompted them to rent two tabulators, but no additional insurance orders appeared for several years. Prudential used punched cards to produce statistics to monitor their huge number of policies. First, the cards were used to compile statistics to monitor acquisitions, that is, the kind of policy and the age of the policy holder. Later, the cards were also used to produce statistics on which kinds of policies generated claims.[16]

There is no indication of a significant change in the tasks in the early 1890s that could have provided Prudential with a reason to introduce punched cards for processing their actuarial statistics. No new governmental regulations appeared, and most other life insurance companies kept using their existing methods to compile statistics for another decade. It might well have been the Prudential actuary, John K. Gore, who initiated the introduction of punched cards to the company, as he was active in the subsequent development of punched-card processing at Prudential.[17]

Gore made a mechanical sorter the core of the punched-card system he built subsequently, which indicates that he found Hollerith's simple sorting box inadequate. As the actuarial department was a permanent organization, they had no problem managing their statistics production, which distinguished them from the nonpermanent Census Office. Further, their data processing used written cards, and the actuarial departments carried out substantial sorting to reduce the labor of computation. Hollerith's punched-card system from 1890 included a manually operated sorter box coupled to the tabulator, but the sorter box was slow and could not be mechanized, so Hollerith had to start from scratch to build a mechanical sorter. Consequently, Gore and his brother-in-law started to build a punched-card system suited for life insurance statistics. They possessed the necessary mechanical skills to build their own punched-card sorter, which became the core of their system. Their system used a smaller card, only 57 percent the size of the card in Hollerith's first punched-card system. Further, Gore's card had only ninety punching positions, compared with the 288 positions on the Hollerith card.[18] In addition, the Gore system had a punch but not a tabulator.[19] Prudential's contract with Hollerith was probably terminated by 1895 as Gore started to build his system.



The Gore punched card for the American Prudential Assurance Company. (David Parks Fackler, "Regarding the Mortality Investigation, Instituted by the Actuarial Society of America and Now in Progress," *Journal of the Institute of Actuaries* 37 [1902], 11)

Gore's sorter introduced mechanical sorting and was the first punched-card machine to be run by an electric motor. It was completed in 1895 and was used for several decades at Prudential.[20] Gore's sorter was based on a circular configuration, quite different from Hollerith's subsequent sorter design, and it enabled sorting by ten different punching positions scattered over the card—most of the later sorters could only sort one column at a time. Gore's sorter had a speed of only sixty-five cards per minute, but that was about twice the speed of an operator using Hollerith's sorting box.[21] The mechanical process had great advantages when a great number of cards were to be sorted.[22]

It is noteworthy that the Actuary Society of America chose the Gore system at Prudential for its cooperative mortality investigation of about 2.3 million life insurance policies issued between 1870 and 1900. In fact, the amount of data to be investigated was reduced so that it could be stored on the small Gore punched card.[23] The actuaries accepted the construction of Gore's punched-card system with a sorter but without a tabulator.

In contrast to Gore's approach to punched-card processing, Hollerith built a prototype adding tabulator, which he tested by using the returns of the agricultural 1890 census. While working on this in 1894, Hollerith was approached by J. Shirley Eaton. Eaton was a railroad accounting manager

at the New York Central and Hudson River Railroad and suggested using punched cards for railroad audit and statistics. Hollerith liked the proposal and developed an application that he presented in late 1894.[24]

Timing was one reason that Hollerith preferred railroad audit and statistics to actuarial statistics. Hollerith's census contract would expire later in 1894, making him susceptible to a suggestion from a potential customer—especially as no new insurance order had emerged since the two tabulators were rented by Prudential in 1890. Further, railroad accounting required the adding tabulator that he was experimenting with, and not a mechanized sorter, which he would have had to build from scratch.

In the big railroad companies of the 1890s, freight accounting and statistics had become huge tasks for the accounting departments. A major problem was to audit the freight shipments to ensure that each package reached its destination and that the shipments were paid for. This had previously been accomplished by comparing the goods shipment reports from the forwarded and the received stations. The waybills formed the basis for this task, but they were awkward to handle and sort. After the waybills had been audited, the shipment reports were first used to compile the distribution of records of the freight incomes to the railroad's own various track sections and to foreign companies. Subsequently, the reports were used to compile statistics on the frequency and length of the freight trains on all the railroad's track sections.

Hollerith's presentation to New York Central and Hudson River Railroad persuaded the company, in 1895, to improve their waybill audit by using a punched-card system supplied by Hollerith. The Pennsylvania Railroad, by contrast, chose to audit their waybills using typewriters. This decision revealed the main task at hand, namely, to compile lists of the reports from the forwarded and from the received stations for comparison. Punched cards had the advantage that they could be rearranged by sorting and they could "automatically" be added on a tabulator. In practice, at this early stage of development, the advantages of using punched cards were small compared with manual methods, but they proved an appropriate tool for railroad freight auditing.

Railroads did not rush to adopt punched cards. Only in 1903—nine years after the initial test—did the Long Island Railroad Company become the second railroad to use punched cards for this purpose. This railroad was a part of the Pennsylvania Railroad Company, which followed in

1904.[25] By then Hollerith had improved his punched-card machines substantially. But at this point the adding tabulator worked well and a sorting machine was available.

The system that Hollerith developed for New York Central in 1894 was based on an improved version of his original spring-driven adding unit from 1887, now operated by use of an electric motor. For this application, he developed a new punched-card layout to accommodate the waybill information. The information was punched in columns with the numerals from zero at the top to nine at the bottom, which was an ingenious and enduring design.[26]

Auditing railroad freight accounting began by punching the information in the waybill copies from the received stations on cards. Then, the cards were totaled using the adding tabulator and the result was checked against the reports from the dispatching stations. When that had been done, the cards were sorted according to forwarding station, checked against the reports from the stations, and added on the tabulator. This concluded the basic processing and the cards were then available for compiling various statistics on goods traffic.[27] This audit procedure ensured that the cards were accurately punched and, consequently, no separate verification was needed, in contrast to later bookkeeping applications.

Hollerith's system for railroad auditing from 1894 had two weak technical elements: the sorting box and the adding tabulator. As the cards were sorted without a simultaneous tabulation, it was easier to sort by hand. Thus, the company soon abandoned the sorting box. The real stumbling block proved to be the adding tabulator. After working for nearly a year to get the contract, Hollerith's system was tested at the railroad in 1895. However, after a few months, the railroad turned it down because the tabulator's adding unit was not reliable.[28]

This left Hollerith in a critical position. The census contract had expired the previous year and he had relied on getting the New York Central and Hudson River Railroad as a customer. Unfortunately, he had lost this vital customer and was without income. Fortunately, within a few months, he managed to build a new adding unit for his tabulator that the railroad accepted for a second trial. The new adding tabulator proved to be a success, and the New York Central Railroad became a customer in 1897.[29] At first it appears impressive that Hollerith was able, in just a

few months, to build a radically redesigned adding unit. But he was not without experience in this field. He had gained knowledge from his work on the Lanston adding machine, and the new adding unit was basically an electrical version of a mechanical adding unit.

Hollerith's new adding tabulator had four adding units, which resembled cash registers. In lieu of the keys, nine electromagnets were activated through the electric reading of numbers on a card, and the results were displayed through small glass windows. An important new feature was the introduction of plugboard programming, which facilitated the tabulator adjustments for a new application.[30] Until then, Hollerith had programmed his tabulators by screwing wires to contact points. Plugboards were used by operators to route telephone calls before automatic dialing systems came into use and worked by establishing electrical connections. Austrian Otto Schäffler had introduced the first plugboard to program a punched-card system in 1890.[31]

The features of the column-based punched card, addition, and plugboard programming became the basis for most subsequent punched-card machines in the company, which eventually became IBM. At the same time, the punched-card system for the New York Central Railroad highlighted the punching mechanism as a weakness in the apparatus. The pantograph punch was slow to operate, and its punching positions were imprecise and caused false readings. To alleviate this problem, Hollerith devised a new punch that operated like a one-handed typewriter and was radically different from his old pantograph punch. Using the new punch, the card was placed on a carrier and moved, column by column, under the punches as the keys were operated. Eleven keys were provided, ten for punching the numerals zero to nine and an additional key for skipping over and leaving a column blank. The new punch was more precise than the pantograph punch was, thus enabling a narrower column width, but it was harder to operate as there was no amplification of the punch operator's pressure. Simultaneously, Hollerith introduced a longer card than the card from the population census in 1890, $7\frac{3}{4}$ inches (19.7 cm) instead of $6\frac{5}{8}$ inches (16.8 cm).[32] The new card held thirty-six columns, instead of twenty-four, which later increased to forty-five columns in 1907 and to eighty columns in 1928. The last two formats became industry standards.

The new key punch was patented by Hollerith, but he developed it in cooperation with Eugene Amzi Ford from one of Hollerith's machine

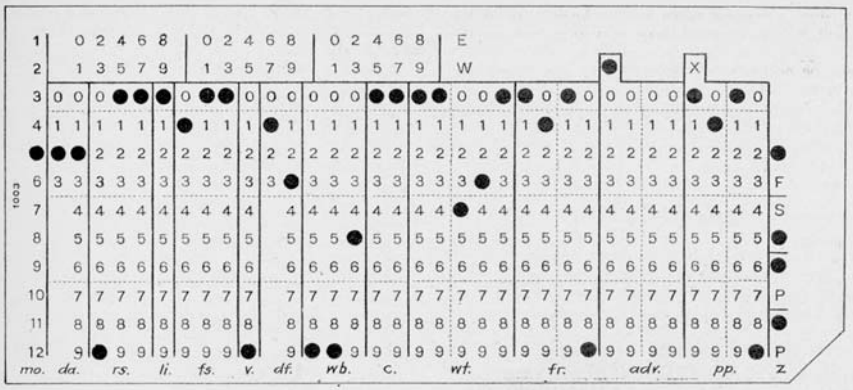


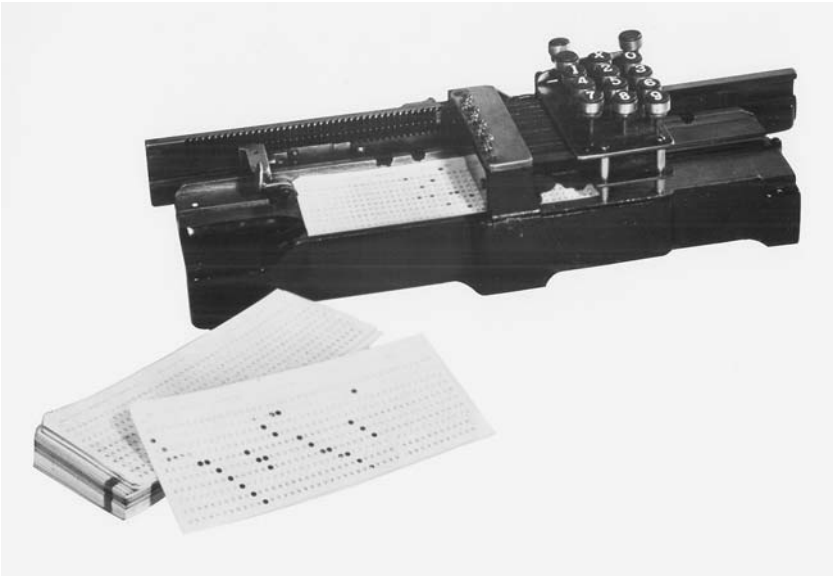
Fig. 2.—New York Central Traffic Card. (Three-fourths the actual size.)

NOTE.—The letters at the bottom do not appear on the card, but were added by the engraver. They mean, in their order, month, day, receiving station, line, forwarding station, via, date forwarded, way bill number, commodity, weight, freight, advanced charges, prepaid.

Hollerith's first column-based punched card designed for New York Central and Hudson River Railway. However, the transformation to column layout is not complete, as shown by the twelve-digit column to the left and the two top nonstandard columns. ("Recording Waybill Statistics by Machinery," *The Railroad Gazette* 34 [1903], 527)

producers, the Taft-Peirce Manufacturing Company of Woonsocket, Rhode Island. Ford had gained his experience from building typewriters in the 1880s. Now, he used his expertise with keyboard devices to innovate Hollerith's key punch.[33]

The outcome of Hollerith's collaboration with the New York Central Railroad in the 1890s was a punched-card system comprising a column punched card, a keyboard punch, and an adding tabulator. The main differences compared with Gore's punched-card system were that Gore had a sorter, while Hollerith had an adding tabulator. If they wanted to expand their businesses beyond their current applications and market segments, Hollerith needed a sorter and Gore lacked a tabulator. Hollerith did work on a sorter but considered it less important than an adding tabulator.[34] Gore never found a second customer, while Hollerith only got his second railroad customer six years after his first. The punched-card trade still moved very slowly, which made the contract to process a Russian census important for Hollerith.



The Hollerith key punch from 1901 with perforated 45-column cards. This punch remained the standard for decades and shows the shift to a column perception of the punched card from the field-oriented perception expressed in the pantograph punch. (IBM Corporate Archives, Somers, New York)

In December 1896, Herman Hollerith was awarded the contract to supply punched-card machines to process the first census of all of Russia the following year, shortly after this his contact started with the New York Central and Hudson River Railroad. However, in the two years that followed the expiry of the contract to process the United States 1890 census, Hollerith had had no substantial income and he needed money to live on and to pay his basic business expenses. To raise money and secure his family, he considered selling his business to Western Electric Company, one of his suppliers.[35] In March 1896, he got a contract for two tabulators to process returns from the French census of 1895. He went to the Library Bureau in Boston and arranged that they would market his punched-card system abroad for ten years.[36] The Library Bureau had been founded in 1876 as an offshoot of the American Library Association and had built up a good business in supplying library equipment and supplies. By the mid-1890s it was a general office supplier and had established offices in London (1894) and Paris (1896).[37]

Only eight months after entering the contract with the Library Bureau, in November 1896, Hollerith's business fortunes turned; he attained the contract with the New York Central Railroad and was about to sign the contract to process the Russian census. Only then did Hollerith incorporate his business, and the new company was named the Tabulating Machine Company (or TMC). He assigned his patents, sold his business assets to the company, and got a controlling 50.2 percent of the shares.[38]

Buying Tabulating Machine Company shares proved most lucrative. During the years from 1897 to 1905 the average nominal yearly dividend was 13.8 percent. As the original shareholders paid a price of $70, their average yearly dividend was 19.7 percent. Another indication that business went well is Hollerith's termination, in 1899, of his contract with the Library Bureau after only three of its ten years' duration. He was discontented with their sales efforts and had gained confidence in the Tabulating Machine Company's ability to generate revenues.[39]

In 1901 Hollerith bought the controlling interest in the Taft-Peirce Manufacturing Company of Woonsocket, Rhode Island, that produced some of his machines. The Tabulating Machine Company was earning well, and the motive for the purchase may have been to implement a vertical integration of the development, innovations, production, marketing, and maintenance of his punched-card equipment. However, Taft-Peirce had financial problems and over the next few years it proved a liability to the Tabulating Machine Company, which invested a great deal of money in the company. In 1903 Taft-Peirce went into receivership, but within two years its acting receiver managed not only to pay off the firm's debts but also to repurchase the shares held by the Tabulating Machine Company. Taft-Peirce thus continued to manufacture Hollerith's punched-card machines.[40]

The 1900 Census and Hollerith's Break with the Census Bureau

The system to process the returns of the 1900 population census was chosen by a contest, as had happened ten years earlier. This time, Hollerith and Charles F. Pidgin were the contenders.

During the 1890s, Charles F. Pidgin, as chief statistician in Boston, was in charge of the Massachusetts state census in 1895 and numerous

statistics assignments that demanded addition. Through this experience, he developed several systems for processing statistics. He had no formal training in mechanics, but his patents demonstrate electromechanical and mechanical knowledge and the ability to design devices of limited technical complexity.

For counting statistics, he had developed a single-card system, proposed for the federal census in 1890, using transcription by markings and card colors. During the 1890s, he added a sorting box, which enabled the tabulation of a table with up to 144 entries.[41] Pidgin also invented a new tabulation system using a large keyboard with up to 540 keys, one key for each entry in the table under compilation and a counter for each key to count the number of individual entries made in that entry.[42] Compared with punched cards, the large keyboard had the disadvantage that it was necessary to use the census forms to compile every table. Furthermore, it was not possible to verify the entered information—although this was of minor importance for census processing. Except for processing the United States census in 1890, the punched cards were rarely verified in statistics applications, as 100 percent accuracy was not required.

Pidgin also developed two systems for tabulating statistics that required addition. The first was a sorting arrangement to generalize his card system. The other was a new adding machine with slide entry, which the National Cash Register Company considered sufficiently important to acquire as late as in 1909. This gives one indication that Pidgin's role should not be neglected. Another indication is Hollerith's nervousness about Pidgin's inventions. To satisfy his curiosity, Hollerith even hired a private detective from Pinkerton's detective agency in New York to go up to Boston to carry out a little industrial espionage. But Hollerith did not learn much information from this mission.[43]

Both Pidgin and Hollerith were members of the United States census network. They shared a preoccupation with mechanizing the tabulation process. Both were full of ideas, but only Hollerith proved to have the technical and entrepreneurial skills needed to design, produce, and maintain systems for mechanized processing of statistics on millions of units.

At the contest for processing the 1900 census, Hollerith entered the same system that had secured him the contract for the 1890 census, and once again it was the only mechanized system that was presented. Pidgin offered two systems: an improved version of the card system offered ten

years earlier and his large keyboard system. Not surprisingly, Hollerith's system was the fastest, and he was awarded the order.[44] Another mechanized system would have been required to beat Hollerith. The 1900 census returned a population of 76.2 million, a rise of 21 percent in ten years, and the tabulations were similar to those a decade earlier. The total cost of tabulating the population statistics rose by 6 percent, a fall in cost per capita of 13 percent.[45]

This contract was a great business opportunity for Hollerith, as thirty-five of the tabulators had already earned money from both the United States census in 1890 and the Russian census in 1897, and so maintenance was his only expense. A contest on processing speed alone offered no incentive to introduce the new adding tabulator, built from 1894 to 1896 for the New York Central Railroad. The main bottleneck in population census processing was the speed at which the information could be processed; addition offered no advantage. Both the counting tabulator from 1890 and the new adding tabulator were fed by hand, but the counting tabulator from 1890 held more counters and this meant faster processing.

As well as the systems proposed, two alternatives had emerged during the 1890s: John K. Gore's punched-card system in the Prudential Insurance Company and keyboard-based adding machines. Gore's card was limited in capacity, and he would have needed to build a system that used a bigger card to get the order for the 1900 census, including a tabulator to count the large number of cards. However, no evidence exists to suggest that Gore ever tried to get customers outside the Prudential Insurance Company.[46] The other was a system of keyboard-based adding machines. Since 1890, both Burroughs and Felt and Tarrant had marketed these machines, but adding machines as such offered few advantages when they were applied to process the population census, which only required counting.[47]

The competition in 1899 to be awarded a contract to process the upcoming United States census was based exclusively on processing population statistics. However, during the following year, punched-card processing of the agricultural census became an issue, probably inspired by the successful adding-based processing of information at New York Central Railroad. After a thorough investigation in the Census Office of the technological options available, the Hollerith system was chosen. This

time the investigation included the Burroughs and Felt and Tarrant adding machines. The Hollerith system still had no mechanical sorter, but this problem was not raised by the Census Office.[48] It was easier to hand sort punched cards than paper forms, as would be the case if adding machines were chosen.

The contract for the agricultural census required Hollerith to supply two punched-card systems: one for farm statistics and another for crop statistics. The farm statistics were compiled from forms covering all information on each farm, using a farm card. The farm card system was the same as that used at the New York Central Railroad, $7\frac{3}{4}$ by $3\frac{1}{4}$ inches (19.7 × 8.3 cm) with thirty-six columns, which allowed more information to be stored on a card than on the twenty-four columns of the first punched-card system from 1890. Crop statistics covered all produce or kinds of animals on each farm, and one card was used for each crop or animal on every farm, giving an average of twenty cards per farm.

The card for processing crop statistics was smaller than the farm card, as fewer data were recorded. It was $5\frac{5}{8}$ by $3\frac{1}{4}$ inches (14.3 × 8.3 cm) and had only twenty columns, that is, it was shorter than the farm card but had the same width. This enabled the new key punch developed for the New York Central Railroad to be used in both systems, but the tabulators differed. The tabulators for crop statistics had fewer sensing units and fewer adding units.[49] The two agricultural punched-card systems show that Hollerith still custom-built punched-card systems. Now he had three systems in use in the Census Office, all to be returned when the census work was finished. However, the innovations for the agricultural applications were limited to the adaptations necessary for the small crop card.

Sorting created a bottleneck, especially for crop statistics that were stored on 116 million cards. Therefore, Hollerith resumed his earlier sorter considerations and developed a horizontal sorter that introduced a mechanical feed in the Hollerith punched-card machines. Gore's sorter had had this facility since 1895, and it was the only way to get around the monotonous work of manual sorting.[50] Hollerith used this opportunity to get rid of the mercury cups in the sensing unit, which had probably caused problems in processing the 1890 census. In the new sensing unit, the cards were stopped momentarily for sensing and then ejected into the sorter chutes. The speed was about two hundred cards a minute, several times faster than manual sorting or than using the Gore sorter.[51] Twenty

sorters were manufactured and sold to the Census Office on their order. This indicates that Hollerith did not believe that there would be a general demand for the sorter from punched-card users, but shortly after New York Central Railroad rented several sorters.

The sorter equipped Hollerith with a mechanical feed that could be a way to achieve a higher processing speed. It was obvious that a mechanical feed could relieve the operators from the monotonous card-reading chore. Hollerith soon adapted his mechanical feed from the sorter for the counting tabulator. The average speed was about 210 cards a minute, about five times the speed of a manual feed. As the cost for a tabulator with the mechanical feed was only 50 percent higher than for one with manual feed, the cost performance was improved by a factor of 3.3. In 1901, the Census Office rented several tabulators with a mechanical feed.[52]

Inventing a mechanical feed and constructing a sorter machine were crucial contributions of the 1900 census to the shaping of Hollerith's punched-card systems. By introducing these features, punched cards gained a significant advantage over the more manual-based systems for processing statistics compiled from the census. While Hollerith's first punched-card system from 1890 had enjoyed only limited success in Europe, the new punched-card systems introduced from the 1900s were highly successful. The reasons for this were the technical improvements and that Tabulating Machine Company established agencies in Europe. The mechanical feed and machine sorting became basic parts of Hollerith's standardized statistics-processing system, which he introduced in 1907.

By 1902, the ad hoc office of the census in 1900 had become the permanent Census Bureau by Congressional legislation. This changed its relationship to governmental bodies and to Hollerith as a supplier, which, eventually, led to the termination of Hollerith's census contract and a lawsuit brought by Hollerith against the Census Bureau from 1910 to 1912 for patent infringement.[53]

The simplest way to understand the conflict between the Census Bureau and Hollerith is as a personal feud between two individuals. This was the approach adopted in the court case, as well as in John H. Blodgett's analysis from 1968.[54] Geoffrey D. Austrian extended his analysis to include the influence of government in industry as the context, specifically the problem of how public activities were limited by patent law, but this is not substantiated in contemporary material.[55] However, an analysis of the organizational

position of the Census Bureau provides a context essential to the understanding of the conflict between the Bureau and the Tabulating Machine Company. It also complements the understanding gained so far of the origin of the first punched-card system in the organizational limbo created by the absence of a permanent census organization prior to 1902.

The Census Bureau was created as a large and potentially powerful federal agency under the Commerce Department but had few responsibilities beyond providing data for apportionment. A quarter of a century of political controversies over its role and location followed. The Census Bureau tried, in vain, to become the central federal statistics bureau. Little departmental control had been exerted on the successive temporary census offices.[56]

The establishment of a permanent organization offered Hollerith improved business opportunities. But a permanent institution had to look more carefully at costs. While an ad hoc institution only had to raise money a few times to get equipment, a permanent institution had to do it every year. President Theodore Roosevelt's administration (1901–1909) was keen on statistics as a solid basis for social legislation, but he was also at the forefront of the struggle against trusts and monopolies. From the late 1880s, Hollerith had supplied punched-card systems and had also held a monopoly, as Gore and Pidgin never succeeded in becoming challengers to his business.

Statistician Simon Newton Dexter North became director of the Census Bureau in 1903. His position in relation to Hollerith was weak, as only the Tabulating Machines Company was able to supply reliable punched-card equipment, and by then a return to manual methods was inconceivable. The approaching expiry of Hollerith's early patents from 1906 would bring them into the public domain. This made a possible Census Bureau production of punched-card machines a bargaining position in relation to Hollerith. In addition, a machine production could strengthen the Census Bureau's position in the controversy over its role in the civil administration and the degree of control by the Commerce Department to which it should be subject. In the negotiations between Hollerith and North, a private company was up against a governmental body and two uncompromising men faced each other. Both stood by their rights, and both lost.

Until 1904 the Census Bureau continued to rent tabulators on Hollerith's conditions but at the yearly renewal of the contract that year, North

demanded a lower rent. Simultaneously he approached the Secretary of Commerce and asked for funds for the Census Bureau to build punched-card machines and the reason given was to save money. The Tabulating Machine Company accepted a price reduction for the fiscal year 1904–1905. Hollerith was against this concession, but he was overruled by his board of directors.[57] In early 1905, North obtained an appropriation for the costs of experimental work to develop tabulating machinery. At the same time, he tried to extend his contract with the Tabulating Machine Company for further use of their tabulating machines for the fiscal year 1905–1906. Hollerith made the new contract conditional on the government's abstention from experimental work on tabulating machines. North could not accept this, as he was confident that the Census Bureau would succeed in building punched-card machines. For his part, Hollerith did not want to supply his machines to serve as models for Census Bureau machine constructions, and his machines were withdrawn.[58] North saw no conflict between building machines and renting machines from the Tabulating Machine Company. He would, of course, not circumvent any valid patents, and he believed that he would have no reason to do this, as Hollerith's early punched-card patents would expire shortly.

The break left the Census Bureau with only its purchased punches and sorters. The Bureau was not ready to return to manual methods, and the development of new machines in its machine shop would take time. Therefore, they contracted with Charles F. Pidgin for his manual card system with a sorting box. The Pidgin system was used to compile immigration statistics, but it caused great problems, and the contract was terminated within six months.[59]

The tacit cooperation between the federal government and Hollerith from 1880 to 1905 on census processing illuminates their options and limitations. The federal government had a basic and critical problem with census processing as long as the census offices remained temporary. An alliance centered on a network of leading personalities within the Census Office and the engineer Herman Hollerith was established. Within this network, which was based on personal relationships rather than contractual agreements, Hollerith invented and developed his punched-card system.

The basis of this tacit cooperation disappeared as Congress solved the fundamental census management problem by establishing the Census Bureau on 1902. However, the rift between the Bureau and the Tabulating

Machine Company only surfaced when the Bureau, the following year, got a new director, Simon N. D. North, who did not consider himself a member of this network. The Census Bureau became concerned with the cost of processing equipment. Further, a production of punched-card machines in the Census Bureau itself became a tool in the organization's struggle to gain a key role in the federal administration. The main reasons for the break with Hollerith were a change in the census institution's economics and the strife within the federal government, but the actual breakdown of the relationship was brought about by two unyielding personalities.

When the relationship broke down in 1905, Hollerith lost his most important customer. Even so, that year seemed to be exceptionally good for the Tabulating Machine Company shareholders, as they received dividends of 60 percent of the nominal share value. Although this was 7.5 times higher than the year before, no dividend was paid for the following three years.[60] So, the high dividend in 1905 might have been a deliberate action to boost confidence and to cover up the company's crisis.

For Hollerith, the main problem was the loss of his primary user since 1890. He was known in America and abroad for his census machines but no longer held a census contract. Even though he had already found new customers, this was a personal blow. More ominous problems, perhaps, were that he had been overruled by his board of directors and he was having difficulties running the Taft-Peirce Company. Was he losing the grip of his company? He had been its sole manager and was able to run it as long at his main activities were limited to a small number of customers and based on machines and punched cards produced outside his company. But his business had grown, and he had internalized machine production by acquiring Taft-Peirce. Hollerith seemed to be approaching the limits to his one-person management style. The drifting census contract exposed this problem for the first time, and expansions during the following years would provide further confirmation of its existence.

Business Market Breakthrough and Standardization

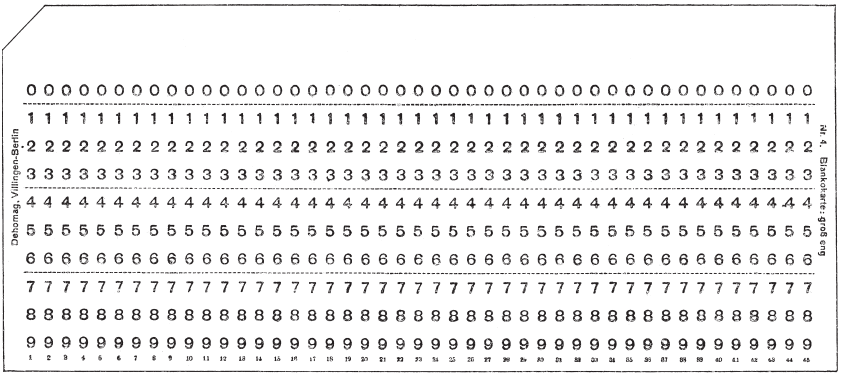
At a time when the market for keyboard office machines was becoming substantial, the loss of the census contract in 1905 compelled Hollerith to take the plunge into the private business market. Since 1901 he had

been developing a more offensive business strategy with a wider range of customers. Previously he had used most of his efforts to respond to challenges defined by others, in the census offices and at New York and Hudson River Railroad. In 1900, he had been approached by two big insurance companies, but he turned them down as he then was busy on the contract to process the returns in the census in 1900.[61] He focused on building a mechanical feed and a sorting machine for that assignment. He got the order to process the census and soon his machine building projects moved to the workshops of Western Electric Company, his main machine producer. Through innovation, Western Electric was able to convert Hollerith's feed and sorter design into reliable machines.

Hollerith started to expand the scope of his applications to attract additional business customers in 1901. He used a lot of energy to attract private industry's interest in his punched cards, and the preserved correspondence paints a picture of Hollerith as his company's sole salesman, an impression substantiated by other sources. First, he responded to the insurance approach he had received the year before by circulating brochures to several life insurance companies.[62] In addition, he started to develop punched-card applications for three business applications: wage administration, sales analysis, and cost accounting. He found customers for punched-card-based cost accounting and sales analysis, and he used this customer base to attract additional business customers.[63]

When Hollerith's pain from the blow of losing the census contract in 1905 eased, the private business market proved attractive, fast growing, and able to sustain the Tabulating Machine Company. However, while his business strategy so far had been based primarily on the large-scale task of census processing, he would now have to rely on a large number of smaller customers. This larger number of customers compelled Hollerith to standardize his various ad hoc punched-card systems. The outcome was a second set of punched-card machines that embodied his second punched card closure and formed the basis for the Tabulating Machine Company's product range for two decades.

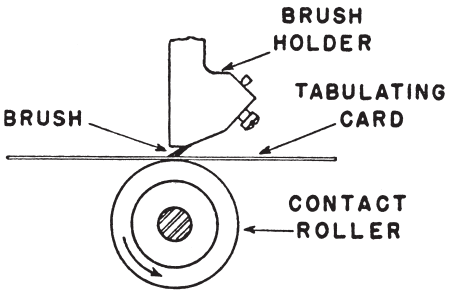
In 1905, Hollerith built, marketed, and maintained three different punched-card systems: The first punched-card system for the census office from 1890 with a 24-column punched card, the punched-card system originally built for the New York Central and Hudson River Railroad in 1894



Hollerith standard 45-column punched card from 1907. Hollerith based his second punched-card closure on this card, which stayed a standard within the Tabulating Machine Company and its successors until 1928. When the Powers and the Bull companies' punched-card machines were developed, they too used this card. (Robert Feindler, *Das Hollerith-Lochkarten-Verfahren für maschinelle Buchhaltung und Statistik*. Berlin: Verlag von Reimar Hobbing, 1929, 24)

with a 36-column punched card, and the system built for the crop statistics of the 1900 agricultural census with a 26-column punched card. In addition, he had planned a never-implemented wage system from 1901, which used a small card with twelve columns. The new applications between 1903 and 1906 were based on machines in production by 1902, several of which reused tabulators returned from processing the agricultural census in 1900.

Simultaneously, Hollerith developed a new series of punched-card machines, produced from 1907, which was his second punched-card closure with two new basic features: the standard 45-column punched-card and brush reading. The first closure was his punched-card system for the 1890 census, with a counting tabulator and entirely manual operation. Later Hollerith introduced several new features—a column-based card, a keyboard punch, an adding tabulator, a mechanized card reader, plugboard programming, and a sorter—into his subsequent ad hoc punched-card systems. By 1907, he united these features using a 45-column punched card and a new mechanism to read cards. The 45-column card was the same size as the card for the New York Central and Hudson River Railroad, but it had more columns.[64] The additional columns were squeezed



Hollerith introduced dynamic brush reading of cards in 1907. It remained the only card-reading method used in electromechanical punched-card machines as long as they were produced. (Wallace John Eckert, *Punched Card Methods in Scientific Computation.* New York: Columbia University, 1940, 4)

into the card by introducing a smaller tolerance, which was made possible by the introduction of the new dynamic brush reading.[65] Now, the mechanized reading took place while the card was moving.

In the old pin box, the reading took place while the card was halted and functioned as a stop to the collapsible reading pins, whereas in the new system the card acted as an electric insulator. Now the card passed between steel brushes and a row of brass rollers, one set for each column on the card. A hole in the card allowed an electric current to pass between the brush and the brass roller, thus closing the circuit. All parts of the machine were synchronized with the movement of the card and registered the digit value of a hole according to its row on the card. Dynamic card reading was more complicated to implement, but it enabled faster card handling, because the card no longer had to stop during the reading process.

The new tabulator was very different from the wood casing of its predecessors. Now black metal panels were used, mounted on steel frames, which lent the new tabulator a more functional appearance. New, more compact adding units were introduced, and they were incorporated into the base of the machine. Plugboard programming, originally invented by the Austrian Otto Schäffler in 1890, now became a standard feature. The new tabulator held up to five adding machines and ran at a speed of one hundred fifty cards per minute.[66]

The new sorter was vertical to save space in the office. The cards were fed from the top of the 5-feet-high (1.50-m-high) unit into thirteen chutes, one for each of the twelve positions in a column of the card and a reject chute for a blank column. The machine's speed was improved to process

two hundred fifty cards per minute with the introduction of the new continuous card reading rather than the previous intermittent action. A drawback of the vertical design was the limited chute depth. A chute held up to two hundred cards and had to be emptied when it became full; otherwise the cards became severely crumpled.

Hollerith introduced his standard punched-card system from 1907 without fanfare, and there is no indication that it was the result of a grand plan. It was the outcome of the dynamic innovation of cards, machines, and production, based on the increase in users and steadily growing scope of primarily statistics applications. However, though the outcome proved to be sound from a technical and business perspective, the development, production, and sales of the new standardized punched-card system strained Hollerith's personal development approach, made him modify his pricing principles, caused production problems, and necessitated an increase in share capital.

Hollerith was basically a drawing board engineer with limited machine shop experience. However, Eugene A. Ford of the Taft-Peirce Company, an experienced shop engineer, played a crucial role in the development of his new series of machines. He was needed to make new machines that were simple to produce and easy to maintain. While Hollerith's first punched-card system from 1890 had no turning parts, his new sorter and tabulator operated by electromotors, which made design and production more demanding. Ford had played a critical role in designing Hollerith's keyboard punch. Hollerith acknowledged this by engaging Ford as an inventor in 1905, which did not, however, imply that Hollerith established a research and development department. In the years around 1900, the first American industrial research laboratories were established at the American Bell Telephone Company and the General Electric Company.[67] Hollerith did not follow their lead because the Tabulating Machine Company was small. Ford became a single inventor, as Hollerith was, and Ford's primary workplace was in Uxbridge, Massachusetts, far from the Tabulating Machine Company in Washington, D.C., and from the firm's machine production.[68]

The advent of Hollerith's new standardized punched-card system caused three sets of problems: pricing, supply, and financing. Originally, Hollerith's machine rental was based on the number of rented machines. For his new private business customers after 1901, he had changed this practice to price by the number of cards supplied, plus a fee per card for

the machines. All contracts specified that cards were to be purchased solely from Hollerith. This was important for his business, as 48 percent of the company's total revenue from 1909 to 1913 originated from card sales.[69]

Hollerith's second problem with the production of his new standardized punched-card machines was establishing a production of reliable machines able to keep up with the orders in 1907 and 1908—a problem that was aggravated by his reluctance to produce more of the machines for his earlier punched-card formats. The outcome was an order backlog, which he spent two years filling. Some companies, like Union Pacific Railroad, waited for two years to receive their machines, but no one is recorded as having abandon punched cards because of the delay.[70] However, once the production of his new machines was on track, the success of Hollerith's new standardized set of punched-card machines was evident from the Tabulating Machine Company's soaring total revenues, which rose by 55 percent in 1909 and by 51 percent in 1910.[71]

This expansion caused financial constraints in the company due to the policy of renting out of their machines, as the investment was returned more slowly than in selling the machines. Most of the expansion was based on money earned by the company, and this remained the general strategy throughout the punched-card era, only deviated from a few times. However, the substantial expansion of the Tabulating Machine Company's business was a major reason that no dividend was paid to the shareholders from 1906 through 1908. The share capital was increased by $100,000 in 1908, which was the only external money injected into the company to accomplish this transition and subsequent expansion of business.[72] Dividend payment resumed in 1909.

Punched Cards and World War

The First World War provided growing revenues to the Tabulating Machine Company. The vast resources of modern industrial society enabled the operation of huge armies employing vast armament and munitions resources. Millions of soldiers were drafted or recruited, equipped, fed, housed, trained, equipped, transported, and clothed. Armaments and munitions were produced on a so-far-unseen scale and scope. This made the First World War a test of the capability of modern industrial societies

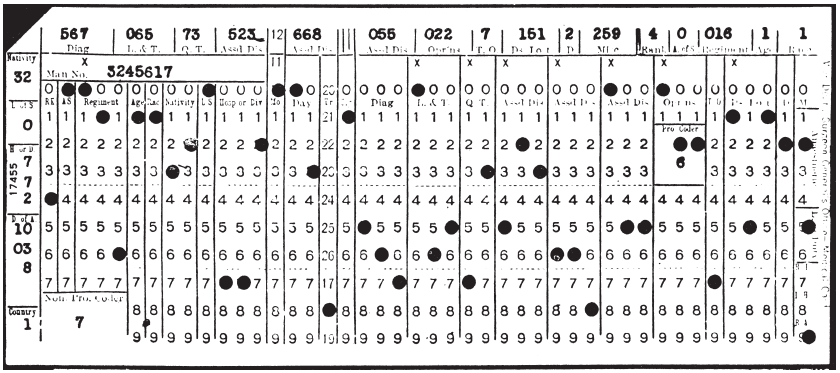
at the expense of dead and wounded soldiers and of impoverished populations. The United States and Great Britain prevailed, so did Germany in spite of the defeat; France got by; Russia succumbed.

The task of mobilizing men and society for warfare was approached according to the experience of the various nations in government regulation and in organizing business. To a large extent, this task was accomplished by blowing up to a national scale known ways and tools of organizing big production and distribution. A key tool was operational statistics processed by using punched cards.

The First World War started in August 1914, but the United States only entered in April 1917. Though the United States only waged war for nineteen months, by the end of hostilities in November 1918, it had managed to send one million soldiers to France in addition to providing a vast amount of weaponry. This was accomplished through a controlled expansion of the American army and by an introduction of a government command economy. The bureaucratic means applied reveal the methods and ambitions in the United States at that time.

The United States armed forces were based on voluntary service and some 180,000 individuals were serving in 1916. Then conscription, which had not been known since the Civil War, was introduced. Registration of young men commenced, and about 24 million men were registered. In 1917 there were 640,000 people under arms, 2.9 million in 1918.[73]

Scaling up the army when the United States entered the war stressed the manual system for processing medical and casualty statistics. Therefore, punched cards were reintroduced to compile medical and casualty statistics. Originally, Hollerith's first punched-card system had been tested for this task from 1889 to 1890, when the army had 27,000 people on active duty. At that time the army had preferred its well-established manual method. Then the basis for this choice had changed in two ways: Punched-card technology had been substantially improved in the intervening quarter of a century, and the number of people on active duty had grown substantially. Managing a vast army dispersed over several continents required quick and reliable statistics. A special medical record section was organized in the Surgeon General's office in October 1917, and this introduced punched cards to process the vital statistics from the United States' entrance into the war.[74] The cards held a printed "Man Number" identifying the soldier. This enabled checking the data on the card against that in



Card for processing illness statistics in the U.S. Army during the First World War, using a 45-column system. The limited capacity of a card made it necessary to split the data onto two cards: one for medical cases and another for surgical cases. This is an early example of problems caused by limited data capability of the 45-column card. Note: In the illustration the numbers are typewritten. In practice, they were penciled. (Albert G. Love, "Medical and Casualty Statistics," in *The Medical Department of the United States Army in the World War*. Washington, DC: Government Printing Office, 1925, vol. 14, 1221)

the personnel file, but the card held no perforations to facilitate mechanized location of the individual, for example, through his "Man Number." As in the census in 1890, the cards were designed exclusively for statistics processing and were not used to locate individuals.

The national economy was mobilized through the introduction of the command economy.[75] To control the economy, the government in the summer of 1916—before entering the war—carried out a census of the production capability of about 80,000 industrial establishments. This census was managed by a special administrative body, the Industrial Preparedness Committee of the Naval Consulting Board, and was processed using punched cards.[76] Notably, it was not carried out by the Census Bureau. Later several special administrative bodies pushed to control the economy, such as the Food Administration, the Fuel Administration, the Railroads Administration, and the War Industries Board.

The War Industries Board controlled the production and distribution of virtually all goods and services. Hundreds of subordinate departments, boards, and committees collected and processed data for the War Industries Board. To sustain such extensive control of the material economy,

the government applied Hollerith punched-card equipment.[77] The Railroad Administration controlled the railways that still were operated by their prewar managements. A basic tool for this control was extensive standardized operational statistics. Punched-card processing within the various railways eased this task, which further encouraged the diffusion of punched cards.[78]

The First World War in the United States became a showcase for the application of punched cards for various operational statistics. Punched-card processing was quick and exact, but neither the army nor the government applications could be distinguished from the statistics processed at the Census Bureau and the operational statistics produced by private companies. Over the next two decades, improved punched-card systems would mirror changing bookkeeping practices. Also, they would provide a way to reach a large group of individuals, as applied in the Social Security pension program. During the Second World War punched cards would be used in the United States, France, Germany, and Great Britain to improve their warfare capabilities.

Reshaping Punched Cards

The first closure of punched-card technology was challenged, ameliorated, and the second closure was shaped between 1890 and 1907. Hollerith's limited commitment to the first closure is remarkable. Though he had built and owned more than fifty tabulators that embodied this version, he proceeded until about 1905 to develop machines that significantly extended the capabilities of punched cards. However, subsequent history shows that Hollerith saw the punched-card system for the census in 1890 as one system, the system for New York Central Railroad as another, the system to process farm statistics in the census in 1900 as a third, and the system to process crop statistics in the census in 1900 as a fourth. Until around 1905, his perception of technology was closely related to its application. This explains his stepwise improvement strategy in this period. He built an adding tabulator, designed the column-based punched card, built an improved and mechanized card reading tool, and constructed a machine sorter.

Each of these improvements was based on endeavors to attract and improve concrete punched-card applications, all of them statistics tasks,

except the auditing at the New York Central Railroad. The limited scope of each improvement project and its intimate relation to a concrete application explains how business opportunities of limited scale came to contribute to the form the technology took and how business and technology were linked. This was a business strategy based on direct and close contact with his relatively few customers, with the United States census operation as his prime user.

This strategy was not challenged by Hollerith's success at the New York Central Railroad and other early private business assignments. Private businesses did not have sufficient volume to change his business strategy fundamentally until his census contract was terminated in 1905 and private business market increased considerably. The outcome was the standardized punched-card system for statistics processing, the technology's second closure. The machines had improved processing performance, durability, and maintenance, but most of their capabilities for the users had been shaped through applications since 1890. Hollerith devised only a few new features for which it is not possible to document the application that shaped them. The most conspicuous feature was the extension of the 36-column punched-card to forty-five columns, which offered the possibility for the processing of 25 percent larger records. However, the main accomplishment of the standardized punched-card system for statistics processing from 1907 was that it allowed simplification of the Tabulating Machine Company's business.

Although the introduction of the standardized punched-card system for statistics processing simplified the Tabulating Machine Company's production and maintenance, the expansion of business that this involved came to challenge Hollerith's personal management approach to technological development and sales. Even though the changing networks were a crucial dynamic factor in the history of punched-card systems up to 1907, Hollerith's technological system remained by and large unchanged. Hollerith ran the Tabulating Machine Company himself. He was the inventor and managed production and sales. From 1901 to 1905, Hollerith owned the Taft-Peirce Company, which produced his machines, but it was kept as a separate entity, and he eventually sold the company. The only change he made was to improve his innovation capability by engaging Eugene Ford in 1905. But Ford worked far away in his own workshop up in Massachusetts. Further development of the increasingly complex

punched-card machines would require a development strategy involving a group of people in one location.

At the same time, basing the company on many business customers required a different approach from that needed for a few big customers. Hollerith preferred to have the contact with the customers himself. This was possible when he had few customers, but a large number of customers could not be reached by one person. Hollerith abhorred advertising and salesmen. He preferred advertising through word of mouth, as his machines were of an excellent quality. He supported this process by calling on customers and sending them letters, acting as his own salesman. This marketing strategy resulted in several customers. The foreign census orders from 1890 to 1896 were because of the satisfaction in the United States Census Offices, promoted by Hollerith's circulation of reprints of enthusiastic articles. The business market provides similar examples. The description in *Railway Gazette* in 1902 of the application at New York Central and Hudson River Railroad inspired the applications at Marshall Field and Union Pacific Railroad.[79] Enthusiastic punched-card installation managers wrote to colleagues and friends recommending the system. Soon the tried-and-trusted applications—railroad audit and statistics, shop operation statistics, and sales analysis—were taken up by new customers. Another example was the companies supplying electricity to customers; the use of punched-card statistics spread from the initial application at the New York Edison Company, in 1903, to several corporations in leading cities throughout the country, like Boston, Brooklyn, Chicago, Minneapolis, and Philadelphia.[80]

At the same time, old customers bought additional installations for other departments.[81] By mid-1907, several big companies were customers: Marshall Field, Eastman Kodak, National Tube, American Sheet and Tin Plate Company, Pennsylvania Steel, Western Electric, and Yale and Towne. In addition, Hollerith negotiated with Simmons Hardware, Heinz Pickle, Regal Shoe, Carnegie Steel, and several railways.[82]

The increase in the Tabulating Machine Company's business required several salesmen, but Hollerith did not want to delegate. This was a fundamental problem for the company, which grew more urgent as the business continued to expand.