From Gutenberg's Press to the Foundations of the Internet

Only six electronic digital computers would be required to satisfy the computing needs of the entire United States.

—Howard H. Aiken (1947)

In 1834 the British mathematician, economist and engineer Charles Babbage conceived of the first general purpose programmable computer, the Analytical Engine. It was a mechanical device designed to be constructed out of thousands of precisely machined metal parts. Because it would have been enormously costly to build, and there was no urgent need for such a computer in Babbage's day, the Analytical Engine was never completed. Only small portions of it were built from Babbage's engineering drawings after his death. It is known primarily from an account of its design and programming originally published in French in a Swiss periodical by the Italian mathematician Luigi Menabrea, and translated into English with annotations by Babbage's friend Augusta Ada, Countess of Lovelace, the daughter of Lord Byron. In 1837, three years after Babbage planned the general purpose programmable computer, the American painter and inventor Samuel F. B. Morse invented a practical electromagnetic telegraph using an early version of his "Morse code." In contrast to Babbage's experience with the Analytical Engine, Morse and the other pioneers in electric telegraphy found ready acceptance of their inventions. On May 24, 1844, Morse transmitted the first message on an experimental telegraph line from Washington to Baltimore using the Morse code. The message, taken from the Bible, was "What hath God wrought?"

One year later, in 1845, a visionary proposed attempting to link the United States and Europe by an Atlantic telegraph cable. At that time it took about a week to communicate a message between Europe and America— the time that it took for the fastest steamship to cross the Atlantic. This was nine years before the entrepeneur Cyrus Field organized the New York, Newfoundland, and London Electric Telegraph Company with the intention of laying an Atlantic cable. In 1858, well before the cable was operational, the *Scientific American* called the Atlantic Telegraph "that instantaneous highway of thought between the Old and New Worlds." By July 27, 1866, after two failed attempts, and two years after Babbage had described his unsuccessful efforts to build his Analytical Engine, Cyrus Field's Atlantic telegraph connected Europe with the United States. The first message sent was "A treaty of peace has been signed between Austria and Prussia." The Atlantic cable opened for business almost immediately but only the rich could afford it—the initial rates were one dollar per letter, payable in gold. At this time the monthly wage for a laborer might have been twenty dollars. Within 20 years there were 107,000 miles of undersea cables linking all parts of the world.

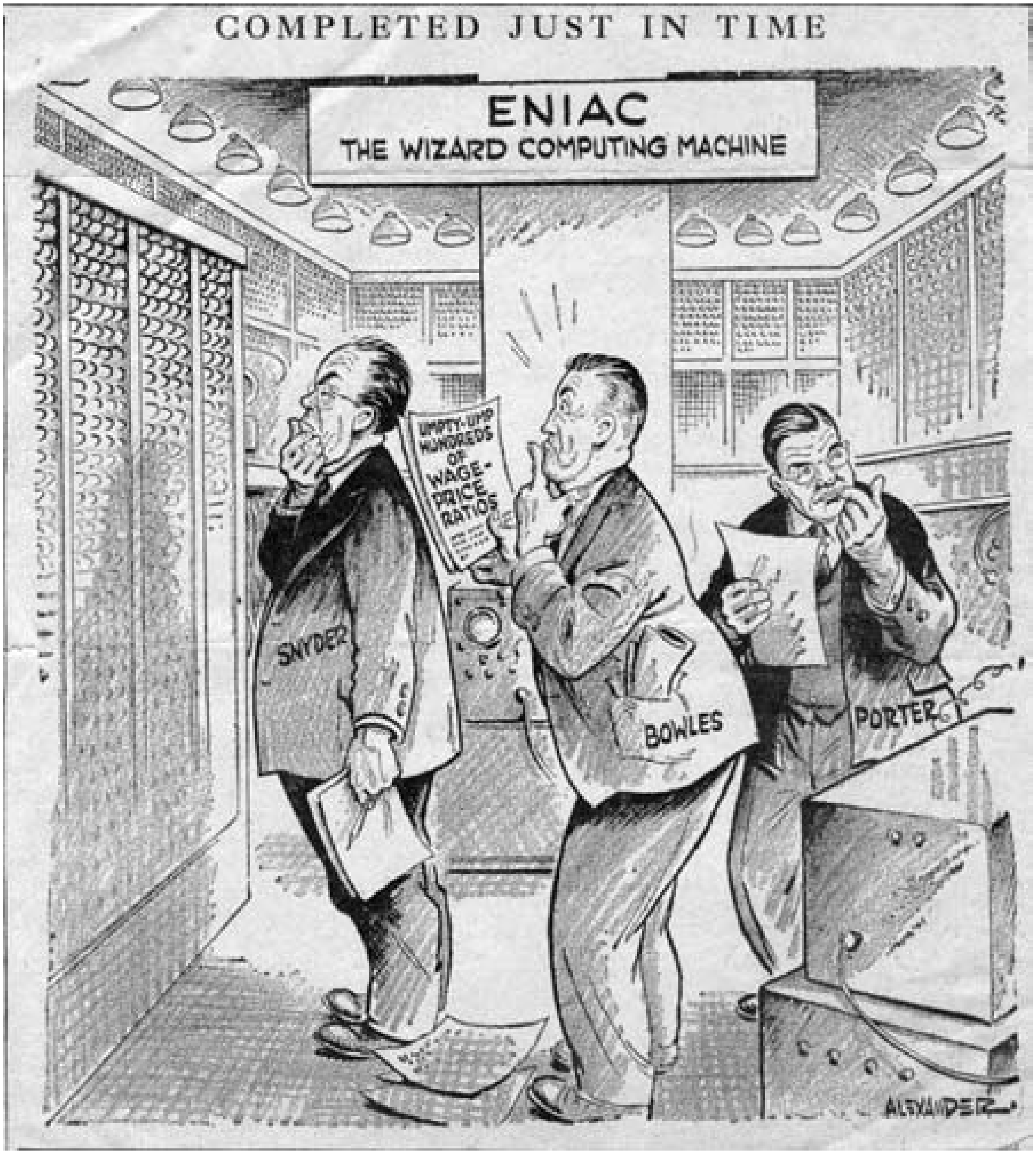
Ten years after the successful completion of the Atlantic Cable, Alexander Graham Bell invented the telephone. Speaking to his assistant in the next room, Bell's first message over the telephone was, "Mr. Watson—come here—I want to see you." Telephone technology, including communication theory, would evolve along with electric telegraphy at Bell's company, American Telephone and Telegraph (A T & T), especially at Bell Telephone Laboratories (Bell Labs). Though the final "T" in A T and T is now of only historical interest, the two technologies operated side by side for many years, and the electric telegraph enjoyed a period of usefulness of more than one hundred years. In 1945 the number of telegraph messages sent in the United States finally peaked with the transmission of 236,169,000,000 messages.

Roughly one hundred years after Babbage and Morse, Howard H. Aiken and his team at Harvard were the first to realize Babbage's dream of building a general purpose programmable computer. With the support of the U. S. Navy and IBM to meet the urgent computational demands of World War II, Aiken's electromechanical Automatic Sequence Controlled Calculator, also known as the Harvard Mark I, became operational in 1944. Constructed out of switches, electromechanical relays, rotating shafts, and clutches, it was built using more than 750,000 components, and around 500 miles of wire. It measured about fifty feet in length and eight feet in height, with a total weight of about five tons. During operation it sounded like "a long room full of old ladies knitting away with steel needles." It performed mathematical calculations one hundred times the speed of man.

The following year, just months before the end of World War II, the ENIAC became operational. It was developed with the support of the U. S. Army by Pres Eckert and John Mauchly and their team at the University of Pennsylvania. Using 18,000 vacuum tubes as switches instead of the relays used in the Harvard Mark I, and weighing 30 tons, the ENIAC was the world's first large-scale general purpose electronic digital computer. Its design and construction required 200,000 man-hours of work. It was 1000 times faster than the Harvard Mark I, or 100,000 times the speed of a human doing mathematical calculations. The ENIAC consumed 174 kilowatts of electricity. For the next three to four years the ENIAC was the only operational electronic digital computer in the world. Pioneers in the nascent field of electronic computing knew that because of their enormously increased speed, electronic computers would eventually supersede mechanical or electromechanical calculators. Yet the earliest electronic digital machines were so large, so difficult to build, so expensive, so unreliable, and so hard to use that some of the earliest pioneers could not foresee their commercialization or widespread application. Howard H. Aiken, developer of one of the first general purpose programmable computers, may remain best known for his famous miscalculation, spoken in 1947 when the ENIAC was the only electronic digital computer on earth, that the computing needs of the entire United States could be satisfied by no more than six electronic digital computers.

Within fifteen years after the ENIAC was operational there were about 6,000 mainframes operational in the United States and about 10,000 worldwide. The fantastic extent to which computation increased during between 1945 and 1960 may be difficult to imagine, even though during this time computers were typically inaccessible to the public, sequestered in special air-conditioned rooms staffed by professional data processing personnel, and used for scientific research or big business or government work. As an illustration of how much work could be done by only one electronic computer, it was estimated that during the operational life of the ENIAC from 1945 to 1955 this huge, comparatively primitive, and relatively slow electronic machine, operating at only 100,000 times the speed of man, performed more arithmetic calculations by itself than all of mankind had performed during the millennia up until its invention.

Between 1961 and 1964, Leonard Kleinrock at MIT developed a mathematical theory of data communication, including the theory of packet-switching. In October 1965 Lawrence Roberts put Kleinrock's theory to the test with the first actual network experiment, tying MIT's Lincoln Labs' TX-2 to SDC's Q32. This was the first time that two computers talked to each other, and the first time that packets were used to communicate between computers. October 29, 1969, under Kleinrock's supervision, the first host-to-host message was sent over the ARPANET from UCLA to Stanford Research Institute. Because the Stanford machine crashed during the effort to transmit the first word, "Login," the historic initial message was simply "Lo." When this happened, virtually no one but the participants in the experiment paid any attention. Networking computers was a concept too remote for anyone except computer professionals to imagine at that time. Though the ARPANET was funded by the



ENIAC The Wizard Computing Machine. The original drawing, from Pres Eckert's collection, of the first cartoon to depict the ENIAC. It is most probably the first cartoon to depict an electronic digital computer. The cartoon was published in the *Philadelphia Bulletin* on March 12, 1946, within a month after the public dedication of the ENIAC. It depicts U.S. Treasury secretary John W. Snyder and two other men identified as "Bowles" and "Porter" standing with perhaps appropriately bewildered expressions in front of the unprecedented new machine. From *Origins of Cyberspace* (2002), no. 1115.