

The background is a stylized, monochromatic illustration in shades of gray and green. It features various technological and business-related elements: a satellite dish on the left, a computer monitor displaying a person's face, a circuit board with a microchip at the bottom, and a mobile phone on the right. The overall aesthetic is reminiscent of mid-20th-century graphic design.

Forbes®

GREATEST TECHNOLOGY STORIES

Inspiring Tales
of the Entrepreneurs
and Inventors
Who Revolutionized
Modern Business

JEFFREY YOUNG

Forbes®

GREATEST TECHNOLOGY STORIES

Inspiring Tales
of the Entrepreneurs
and Inventors
Who Revolutionized
Modern Business

JEFFREY YOUNG



John Wiley & Sons, Inc.

New York • Chichester • Weinheim • Brisbane • Singapore • Toronto

This book is printed on acid-free paper. ∞

Copyright © 1998 by Forbes Inc. All rights reserved.

Forbes is a registered trademark. Its use is pursuant to a license agreement with Forbes Inc.

Published by John Wiley & Sons, Inc.

Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4744. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012, (212) 850-6011, fax (212) 850-6008, E-Mail: PERMREQ@WILEY.COM.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional person should be sought.

PICTURE CREDITS: Page xii: AP/Wide World; Page 32: IBM Archives; Page 62: AP/Wide World; Page 86: AP/Wide World; Page 114: Intel Corporation, Santa Clara, California; Page 148: *The Courier Herald*, Dublin, Georgia, and Ziff Davis Publications, Inc.; Page 176: AP/Wide World; Page 212: IBM Corporation; Page 244: Microsoft Archives; Page 278: © Rex Rystedt Photography; Page 308: © Rich Frishman

Library of Congress Cataloging-in-Publication Data:

Young, Jeffrey S., 1952—

Forbes greatest technology stories : inspiring tales of the entrepreneurs and inventors who revolutionized modern business / Jeffrey Young.

p. cm.

Includes index.

ISBN 0-471-24374-4 (alk. paper)

1. Inventions—United States—History. 2. Inventors—United States—History. 3. High technology—United States—History. I. Title.

T21.Y68 1998

608.73—dc21

98-30590

CIP

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

F O R E W O R D



So accustomed have we become to change and improvement in our daily lot and in the performance of the myriad tools that make modern life so comfortable, convenient, and relatively secure that we feel it is all somehow inevitable. A cash card from the bank just shows up in the mail, along with instructions on how to use it in ATM machines all over the world. At the grocery store one day, instead of pecking away at the cash register, the clerk simply sweeps the merchandise across a scanner. The largest bookstore in the world isn't to be found at the mall, but on the computer in your study via the Internet. Small wonder that we take progress for granted today. We see it almost as a force of nature, as certain as the wind and gravity.

There has been so much change in just the last 100 years that we can be forgiven this feeling. But it isn't true. Progress is not certain. Inventions don't just happen. Technologies don't simply appear in our lives. People make them happen. And that's what makes this book so fascinating and so important. It restores our sense of reality—and wonder—about the most ubiquitous and far-reaching technology of the last half century: the computer. Behind the screens, the disc drives, the semiconductors, and the software are human faces. Their stories are as exciting as they are extraordinary. Their achievements have transformed the world, but how they went about it, the emotions as well as the ideas that drove them, illuminate the very soul of progress.

Timothy C. Forbes

INTRODUCTION



At the completion of the first half of the nineteenth century, the railroad and the telegraph stood supreme as the two inventions that transformed their era and ushered in a new age of modernity. At the close of our own century, who can argue that commercial jet travel and the digital electronic computer have changed us any less?

Life lived 50 years ago was far different than we experience it today. Command-and-control was the preferred method of organization back then. And why not? Command-and-control won World War II for the Allies; in the high desert plain of northern New Mexico in the summer of 1945, command-and-control produced the weapon that ended the war. It is important to recall that command-and-control was shot through *all* parts of American life, not just the military. In 1956 William Whyte wrote a best-seller called *The Organization Man*. The book preached conformity and obeisance to authority. So did popular movies like *The Man in the Grey Flannel Suit*. Network television attained a 92 percent market share in 1957, meaning we all watched the same shows on TV. It scarcely occurred to anybody that this represented a lack of choice.

In the 1950s, the U.S. Department of Justice successfully prosecuted and bankrupted a small outfit called The Hush-A-Phone Company. Its sin was selling a metal cup that attached to the mouthpiece of a telephone, designed to quiet the chatter in an office crammed with telephones. Illegal! The telephone company had a government-granted monopoly, and that was that.

The worst was yet to come. On October 4, 1957, the former Soviet Union launched a 100-pound metal ball into the earth's orbit. Sputnik I

was a shocker. It was worrisome enough that the Soviets had kept pace with the American military's rollout of thermonuclear weapons during the early 1950s; now the Soviets possessed the rocket technology that could rule space and carry nuclear-tipped missiles over the North Pole.

Sputnik caused a national hand-wringing. It struck most intellectuals of the 1950s that the only thing wrong with the American style of command-and-control was too little of it! The Soviets could break a few eggs to make an omelet! James Burnham, a conservative intellectual of the 1950s, confided to *National Review* editor William F. Buckley, Jr., that America and its 181-year experiment in democracy were probably on history's losing side. Far more effective at ordering into existence all the necessary economic goods and military weapons were dictatorships like the former Soviet Union. Or so most intellectuals thought.

It sure looked bleak for the West in the autumn of 1957. But history is replete with irony, too. During the very darkest hours of 1957 came the first sparks of a digital electronic revolution that, like Zeus's lightning bolt, would go forth and slay command-and-control in all its organs and vestiges everywhere on the planet.

The spark jumped to life in July 1957. Eight young physicists in a Palo Alto laboratory staged a revolt against their boss. The boss had discovered that a tiny amount of gold wiring had turned up missing, and his plan was to subject all eight physicists to a lie detector test. The boss was no ordinary boss; it was William Shockley, the coinventor of the transistor and 1956 Nobel Prize winner in physics. He was an autocratic boss, but who wasn't in 1957? However, the eight young physicists were no ordinary young men, either. They included Robert Noyce, Gordon Moore, Eugene Kleiner, and five others, of whom much would be heard in the years ahead.

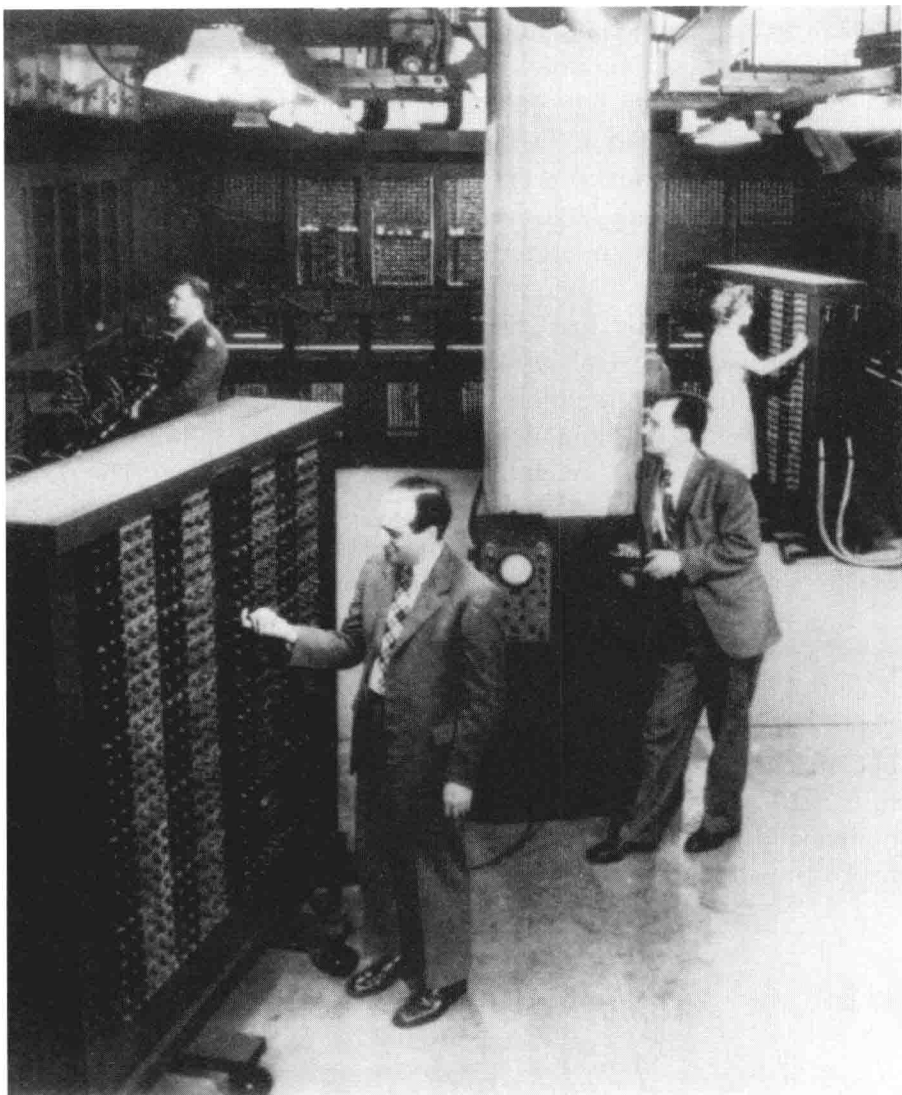
The eight physicists abruptly quit Shockley Labs, and quickly located a venture capitalist named Arthur Rock in San Francisco, who arranged for some seed capital from a New York financier named Sherman Fairchild. Thus was born, in August 1957, Fairchild Semiconductor. Two years later Noyce etched a transistor's circuitry onto a piece of silicon and called his invention an integrated circuit. Forty-one years later, in our own day, the integrated circuit's celebrated progeny, memory chips and microprocessors, roll off manufacturing floors like candy mints in Silicon Valley and Texas and Korea . . . in the millions per month . . . each tiny silicon mint carrying scores of millions of micro-

scopic transistors. Talk about economies of scale! The price of a transistor has dropped some millionfold since Noyce's invention.

Today's average junior high school math class filled with 20 used PCs costing about \$300 apiece contains more computational power than the Pentagon commanded in the days following Sputnik. The West's vastly superior computational power, a lead that started imperceptibly small but grew exponentially larger year by year thanks to the miracles of silicon, eventually grew so large that it brought down the Soviet empire. The symbol was the Afghan tribesman with a Stinger missile launcher resting on his shoulder. Just a tiny bit of silicon that endowed the Stinger missile with its heat-seeking capabilities was enough to turn a small band of Afghan tribesmen into the equal of a powerful invading army. Likewise, Western computational power put American businesses on a far faster trajectory, again, with a lead that grew every year. The results have been happy and thrilling for the West. Nikita Khrushchev's 1956 prediction that his Soviet Union would be around to witness the defeat of capitalism—"We will bury you"—has proven laughably off the mark.

Enjoy Jeffrey Young's romp through the 50-year history of the computer age. Centuries from now, the stories about the rise of the digital electronic revolution, which Mr. Young chronicles both accurately and entertainingly, will be read as fables of daring rebels who sneaked behind enemy lines, ransacked the command-and-control infrastructure, tore it out root and branch, and thus raised the hopes for all humankind that global democratic capitalism might enjoy a long and happy run after all.

Richard P. Karlgaard
Publisher, *Forbes*



J. Presper Eckert, foreground left and John W. Mauchly, leaning against pole, are pictured with the Electronic Numerical Integrator and Computer (ENIAC) in this undated photo.



C O N T E N T S



Foreword	Timothy C. Forbes	vii
Introduction	Richard P. Karlgaard	ix
1. Pioneers & Pirates	& Calculators & Computers	xii
<i>From an overlooked basement prototype to the first commercial computers.</i>		
2. Big Blue	& The Mainframe Computer	32
<i>How Thomas Watson Jr. bet his father's company and changed an industry.</i>		
3. Quantum Leap	& Transistors & Semiconductors	62
<i>William Shockley's breakthrough to the electronic age and Texas Instruments' early lead.</i>		
4. Bits	& Memory, Minicomputers & the Mouse	86
<i>America's first missile defense system defines interactivity, inspires small computers, and humanizes technology.</i>		
5. Chips	& Integrated Circuits & Microprocessors	114
<i>How a handful of scientists invented the pivotal component of the digital age and a young company, Intel, almost abandoned it.</i>		

6. Mechanics ⌘ Kits & Microcomputers	148
<i>Ed Roberts taught hobbyists how to make their own computers, then the industry he created put him out of business.</i>	
7. Wireheads ⌘ The Apple Computer	176
<i>How two young upstarts changed the shape of business—and the world—forever.</i>	
8. PCs ⌘ The IBM Personal Computer	212
<i>IBM moved in, gained dominance, and let itself be outsmarted.</i>	
9. Hard Core ⌘ Windows	244
<i>Bill Gates perfects Microsoft's business strategy by turning other people's inventions into his own marketplace successes.</i>	
10. Airwaves ⌘ MCI & Cell Phones	278
<i>Breaking AT&T's monopoly and remaking telecommunications.</i>	
11. Webs ⌘ Networks & the Internet	308
<i>How a handful of visionaries turned a Cold War communications system into a global commercial phenomenon.</i>	
Notes	345
Acknowledgments	353
Index	355



Pioneers & Pirates

Calculators & Computers

After the Second World War, the American economy went on an explosive spurt. By 1950, median income tripled, rising to \$3,000 a year—equal to \$20,546 today. Inflation also took off: A pound of hamburger meat cost nearly \$1, compared to 36 cents before the war. Cross-country telephone toll rates fell from \$6.50 a minute to less than \$2.25; call volumes doubled from 150 calls per day per 1,000 people, to 300. More than two-thirds of the nation's homes had telephones, compared to one-third before the war; and television sets were appearing throughout the country. By 1950, nearly twice as many Americans lived in urban areas (96 million) as in rural territories (54 million), a trend that had been accelerating since parity was last recorded in 1920. Even more striking, the number of office workers had grown to nearly 8 million. For the first time, there were more clerks than farm workers. It was a very good time to be selling a new and better office machine—the computer.

*A number of technologies emerged from the war effort that would change life in the United States over the coming years—radar, tape recording, nuclear power—but none would have a deeper and more lasting influence than computers. The offspring of a classified project at the University of Pennsylvania called ENIAC (Electronic Numerical Integrator and Computer), by the mid-1950s, computers had entered mainstream American culture to the degree that in the 1957 movie *Desk Set*, Spencer Tracy and Katharine Hepburn co-starred with a computer.*

The pair who patented work on the ENIAC, John Mauchly and Presper Eckert, were the first to try and profit from the new-fangled machines. But in the years immediately following the war, computers were of interest to only a specialized group, which included defense con-

tractors like Northrup, various government agencies, a few big commercial companies like Prudential Insurance, or aggressive start-ups such as A. C. Nielsen. The first machines cost pioneers more to build than expected, and the engineering problems proved difficult to solve. Without many customers, it was hard to succeed.

Then, one entrepreneur appeared on the scene who would make the fledgling business fly. When the dust settled, his company had captured the public perception as the preeminent supplier of big machines in the new field of computing. It was a company with a father-son tradition, a deep respect for salesmanship, and a brand name known in every American office: Remington Rand.

* * *

COMPUTERS, AND COMPUTING as we know it today, in a very real sense began one winter evening in December 1937, somewhere out on the flat roads and endless farmlands of the Iowa countryside. On that particular night, John Vincent Atanasoff, 34 years old and an associate professor in the Physics Department at Iowa State, took his new Ford Eight out for a drive after dinner.

It was a crisp, cold, and clear evening as he headed east out of Ames, a tiny college town 50 miles north of Des Moines in the heart of Iowa. He drove aimlessly, first turning left on the Lincoln Highway, then speeding away from the setting sun into the Iowa countryside. He sped past the red gambrel-roofed barns that were every farmer's pride and joy. In square corners and straight lines the road etched the boundaries of the surveyed "sections," each a square mile, 640 acres, in this undulating farmland. Rich, black soil, wheatlands, and cornfields were all covered in a white carpet of snow broken only by a few thin wisps of black smoke from distant farmhouse fireplaces.

As he drove his thoughts leaned toward his latest obsession: building a better calculator. In a high-backed wooden booth, at a run-down roadhouse, where he stopped for a few drinks, Atanasoff caught the seam between the mechanical age, which was just ending, and the digital age that was about to begin. As he made notes, all the pieces of the underlying architecture that we know today as a computer came into play. He jotted these concepts on paper napkins, while in the background billiard balls cracked together. Those primitive notes were to become the first

digital electronic calculator, a machine that led directly to the digital age and the first computers.

That winter's evening in 1937 Atanasoff began to invent a new calculator, one that would fulfill his dream to become a successful inventor, get him out of the academic world he was disenchanted with, and most important, let him show up the science faculty, as well as the IBM tabulator salesmen, who continually spurned him.

There had been another rejection from the tabulator salesmen that very afternoon, refusing to make the modifications he wanted to IBM's punch card tabulators. The young professor was angry, angry enough to get into his car and drive a few hundred miles to have a drink in neighboring Illinois, where the teetotalers hadn't closed down the bars the way the religious zealots of Iowa had.

In 1937 America was a land of conformity, where the painful years of the Great Depression had produced fear, deep gut-knotting fear that kept much of the nation paralyzed. An estimated 20 percent of the population was unemployed; hobos rode the rails. That year saw the Flint sit-down strikes at General Motors. Industrial militancy was at its apex as workers tried to protect what little they had. America wanted to be isolated, to be able to lick its wounds and remake itself. Even when the Japanese sank a U.S. patrol boat during their invasion of China, American statesmen thundered, but took no action.

Atanasoff was luckier than most. He owned a small house near the campus, and was the father of two small sons. He had a good job that paid him \$1,000 a year, a fortune compared to the average salary in America of \$600 a year. And he had a new car. It had all come easily for the bright young professor. As a result, he was insulated from the fear that gripped most Americans. This contributed to his image as a misfit, a square peg in the round hole of Iowa State University, a practical place dedicated to the fields of veterinary medicine, engineering, industrial science, home economics, and most of all, agricultural instruction. It was a school short on theory and long on practice, and a place where conventional wisdom was rarely questioned.

It was also a place populated by farm kids who knew how to fix a tractor when it broke down in the middle of a field far from the nearest farm implement store, a place where the governing principle was "Make it yourself," which suited Atanasoff perfectly. An inveterate tinkerer, he

was an inventor with a passion, even a sixth sense for calculating machines. He was a dreamer who was also thin-skinned enough to let the smug faculty and the IBM clowns get to him. His response would be to figure out how to make a calculator that was better than anything else on the market; he would show them just how shortsighted they were, all the way to the bank.

As he schooled his graduate students in the problems of theoretical quantum physics, the lack of an efficient calculating system had become increasingly frustrating. Instead of waiting for a better calculating machine to show up in Ames, Atanasoff decided to build one himself. He believed that somewhere in the nexus of electronics and machinery was an answer, but try as he might, so far he couldn't find it. At the time, the professional literature was filled with descriptions of the Bush Differential Analyzer. This machine, created by Vannevar Bush at the Massachusetts Institute of Technology (MIT), soon to be Roosevelt's chief wartime science advisor, used a number of gears and shafts to increase the slide rule's capabilities. This state-of-the-art machine comprised a 50-foot series of dials and rods with spinning barrels that were set by hand. Essentially, it was an overgrown slide rule, which took several people to operate. Atanasoff, along with a grad student, built a gear-driven machine inspired by the analyzer to calculate simple systems of equations with two variables. But accuracy was only possible to three significant numbers; and the systems of equations Atanasoff was facing involved 30 variables and 30 equations, which were far beyond the scope of these machines.

Atanasoff was one of the few people in the world at that time thinking about manipulating circuit elements—resistors, amplifiers, and capacitors—to create an electronic calculator. He had no literature to consult, no prior work to examine. He would have to invent his own methods.

Eventually, out in central Iowa part of the answer came to him. Binary Numbers. He recalled his mother teaching him binary math. Before marriage, she had been a schoolteacher, and when her precocious son figured out the principles of a slide rule at age 10, in 1915, she started teaching him advanced math. The lessons included binary calculation, for which she had a passion.

All counting systems are based on a recurring pattern of a certain number of digits. American math is called Base 10—1 through 9, then a

carry 1 is paired with a 0 to create 10; and so on. Number systems can be any base, say Base 4. In that scheme, 10 would be written as 22. But the number written as 10 would actually be 4. Binary math is significant because each number can be a 0 or a 1. So writing 10 would be 1010. This numbering scheme has some characteristics particularly good for any machine that has to count, because every position in a number is either on or off. Storing a number is also limited only by the number of digits that can be strung together, the number of on/off switches in a row. These are called *registers*, mechanical or electronic places where digits in a calculation or operation can be stored.

Later, Atanasoff couldn't recall why binary suddenly clicked, and gave him the direction he needed. He would convert all numbers to binary digits—strings of ones or zeros. Electronic impulses—the presence or absence of charge, a 1 or a 0—could represent each digit. It was elegant in its simplicity, and the more he examined the idea, the more he liked it.

He had a start, but how could he make it all work? Years earlier, two very important machines had been built that were going to play a role in his solution. Around 1800, a French inventor named Joseph-Marie Jacquard, the son of a weaver, invented the first automatic loom. Working with thick paper cards, he devised a method of punching patterns of holes in the cards. Through each hole a particular wire, controlling a particular thread from the many that made up the warp of the weave, moved up bringing that thread into the next pass of the loom; or if the hole were blocked, down and out of the pass. Single rows of holes represented the threads to be woven in a given pass of the loom; a series of rows of holes punched into the cards could represent complex patterns. Many cards were used to make up intricate drapery and upholstery fabrics, and these could be used repeatedly. It was probably the first machine that could be “programmed” in a binary sense. Each punched hole was the equivalent of either a 1 or a 0 in binary notation, although Jacquard never used it for mathematical purposes. French handweavers of the time saw the Jacquard loom as a threat to their livelihood, and burned a number of them to protect their livelihood; they even attacked Jacquard personally. Nonetheless, the business utility of the cards outweighed the fears of the counterrevolutionaries. By 1812, there were an estimated 11,000 punchcard looms in use in France.

Then, in the 1830s in England, Lord Byron's daughter Ada Lovelace and her associate Charles Babbage conceived of a calculating machine

called the Analytical Engine. The machine grew out of Babbage's earlier work, called the Difference Engine, completed in the 1820s. This was a mechanical device for creating logarithmic and astronomical tables. Babbage, a fellow of the Royal Society, was also active in the Astronomical Society. At the time the British government was offering a reward to the person who could find a way to automate the making of astronomical tables. The British Navy was essential to the nation's colonial empire, and all navigation was celestial. Babbage's invention won him acclaim, but very little money because the British government reneged on the deal. Fortunately, he was independently wealthy.

The more elaborate Difference Engine developed by Babbage and Lovelace incorporated the Jacquard concept to read in data from a stack of punched cards. But they intended to do more: They wanted to store data in registers, perform arithmetic operations on these numbers, and eventually print them out. Lovelace conceived of the programming instructions as an element separate from the numbers themselves; these were the underpinnings of today's programming languages. Sadly, they never built the machine. And though it was not electronic in any way, it did have one very intriguing idea: that a complex machine should have both a store and mill, the precursors of memory and a computer. This was the same conclusion that John Vincent Atanasoff came to that wintry evening in 1937, and he had never heard of Babbage or Lovelace. Living in an intellectual vacuum, driven by desire, anger, and a hope for a better economic life, and goaded by his disbelieving peers, he had imagined a new kind of calculating machine that would combine a memory region for storing numbers electronically, connected to a calculation engine that would operate on them entirely electronically.

Atanasoff would use the binary numbering system, though few were familiar with it and fewer still were comfortable with it. Its elegance, as Atanasoff knew from his years of fiddling with analog counting and calculating devices, was that he could make his machine as precise as he wanted. Binary digits don't leave room for interpretation as do a big differential analyzer and calculator shaft. As long as his circuits specifically differentiated between a 1 and a 0, as long as there was a threshold below which everything was 0, above which everything was 1, the eventual calculation would be as precise as the number of binary digits, or "bits," his memory system and registers could handle.

Once he had decided on the numbering system, he needed a way to store those ones and zeroes. At first, he thought he would have to use vacuum tubes, lots of vacuum tubes, because they were the key elements from which his circuits could be built. A tube could either store a charge or control current passing through it. One way or another, he could configure circuits using tubes to represent binary digits.

But this posed a problem. In 1937, vacuum tubes were expensive—a few dollars each at a minimum—and if he wanted fancier ones, he would have to pay \$10 apiece. Where was he going to get that kind of money? Even if he limited himself to 266 bits of memory—offered by the best IBM calculators of the day—that would mean an outlay of more than \$2,000 for the number registers alone. Then there was the additional circuitry necessary to do anything with the machine. Clearly, he would have to come up with something better. He needed both a program storage station—where he intended to use IBM punch cards to read in numbers for computation—and an interim storage place, or memory bank, for intermediate numbers and partial answers.

Punch cards were the world's standard for data storage and recovery, and they had come a long way by 1937. Reinvented by Herman Hollerith in the 1880s, they were used by the U.S. Census Bureau in 1890. Punched holes represented data, and by counting the pattern of electrical contacts, which were made through a punched hole or stopped by an unperforated space, Hollerith designed devices to tabulate, manage, and manipulate data. He patented the devices, and worked hard to maintain his market advantage. However, his company—the Tabulating Machine Company—eventually fell on hard times, only to be rescued by a former National Cash Register salesman, Thomas Watson. Watson promptly renamed the company International Business Machines, organized a paternalistic team of crack salesmen, and stopped selling tabulators. Instead, Watson planned to lease the tabulators, and completely control the market both for punched cards in the format required by IBM machines and for the machines themselves. No modifications could be made to the machines, and no company but IBM could manufacture the punch cards used in IBM machines.

It was a brilliant strategy. By the 1930s, IBM's machines were fixtures in most big offices, where account details and records were key-punched onto cards using special typewriters. Stacks of cards were fed