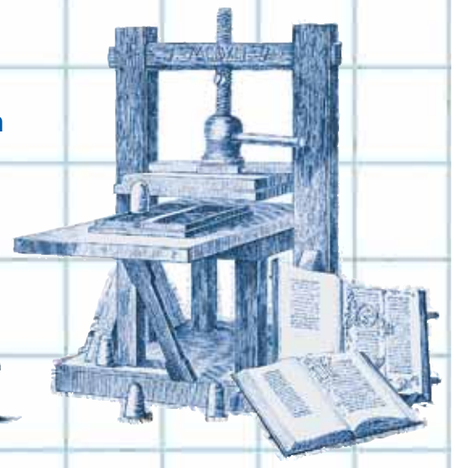
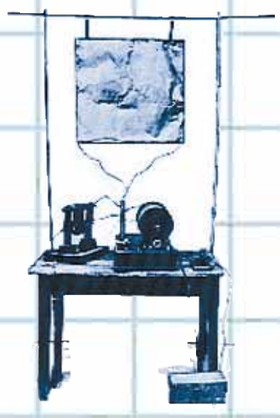
ENGINEERING THE INFORMATION AGE

The Founding Fathers

We are living in an epoch that has been variously called the Information Age, the Digital Age, the Knowledge Age, and even the Post-Information Age. (For present purposes, we'll use Information Age.) This article focuses not on the engineers and scientists who introduced this epoch by building the first computers and inventing the Internet, but on those whose transformational insights enabled these advances.

By John Taylor





Information availability — Ts'ai Lun (ca. 105 A.D.) and Johannes Gutenberg (ca. 1400-1468)

The first transformational developments on the road to the Information Age were those that broadly demonstrated the power and utility of information.

TS'AI LUN

Ts'ai Lun, a eunuch in the court of the Han emperor Ho Ti, was the first to manufacture paper. Although writing and printing on papyrus, vellum, and silk were already well established, Ts'ai Lun developed a cheaper, more transportable, more available, and more flexible alternative. The discovery brought him great wealth, but also led to his suicide to avoid the consequences of a palace intrigue.

JOHANNES GUTENBERG

German goldsmith Johannes Gutenberg invented neither the printing press nor movable type. His contribution was as a systems engineer — combining modern inks, metal type, a new press, and new processes to produce the first practical printing system. This system is widely credited with enabling the Reformation, among other major cultural shifts, as texts became widely disseminated and accessible to any reader.

Despite his systems insight, Gutenberg was not a good businessman. He became embroiled in several lawsuits, lost money on his printing system, and was forced to forfeit his equipment to his business partner.

Opening the microworld — Zacharias Jansenn (ca. 1580-ca. 1638) and Antony van Leeuwenhoek (1632-1723)

The fifth transformation provided access to the micro world.

ZACHARIAS JANSENN

A Dutch spectacle maker named **Zacharias Jansenn** constructed the first compound microscope about 1590. Although his crude instrument could only magnify between 3X and 9X, it revealed to scientists and engineers an entirely new world.

ANTONY VAN LEEUWENHOEK

Without any formal training in optical engineering, **Antony van Leeuwenhoek**, a minor functionary in the town of Delft, Netherlands, perfected the lens grinder's art and improved Jansenn's system of lenses to obtain magnifications up to 270X.

Although Leeuwenhoek is remembered for discovering the world of microbes, the scaling laws and miniaturization in solid-state electronics and integrated circuits envisioned by modern-day engineers such as Robert Dennard would not have been possible without van Leeuwenhoek's breakthroughs in microscopy.

Capturing and controlling electrons — Alessandro Volta (1745-1827) and Thomas Edison (1847-1931)

A second revolution transformed electricity from a laboratory curiosity to power for the world.

From earliest childhood **Alessandro Volta** had a passion for electricity. When he was a boy, electricity was just a laboratory curiosity, known primarily through lightning and static electricity captured in Leyden jars. In 1800, Professor Volta's "voltaic pile" combined zinc, silver, and brine into the first true battery, demonstrating the ability to store electrical charge and generate a steady current. Volta's portrait adorns the Italian 10,000 lira bill.

ALESSANDRO VOLTA

American **Thomas Edison** received more than a thousand patents, doing so with only three months of formal education. In fact, one of his teachers said that poor Tom had an "addled brain." Best known for inventing the light bulb (which he actually only improved, having purchased the patent from two Canadian inventors), Edison-developed concepts for providing electricity to homes and businesses changed the way the world functioned. Although his DC concept ultimately yielded to AC, a system proposed and refined by the likes of George Westinghouse and Nikola Tesla, electricity was now controlled and available to the public.

THOMAS EDISON

Universal connectivity — Joseph Henry (1797-1878) and Guglielmo Marconi (1874-1937)

JOSEPH HENRY

The third critical transformation enabled the global telecommunication infrastructure, leading to ubiquitous, near-instantaneous transfer of information.

In 1830, **William Henry**, the first Director of the Smithsonian and one of the founding members of National Academy of Sciences, demonstrated telegraphy, the use of electricity (actually electromagnetism) to provide signals at a distance. Although best known for his invention of the electric motor, Henry's foundational contribution to telecommunications, later improved by men like Samuel Morse and Alexander Graham Bell, may have been even more important.

GUGLIELMO MARCONI

Italian **Guglielmo Marconi**, inspired by Heinrich Hertz's confirmation of the existence of electromagnetic radiation, patented the first practical radio system in 1896. Although early radio communications used Morse code, wireless voice communication arrived in 1906, leading to commercial radio in the 1920s. Marconi continued his work in shortwave and microwave communication until his death in Rome in 1937.

Henry's telegraph proved that instantaneous communication over distances was possible; Marconi made it wireless and gave it a voice.

Electrons in solids — Michael Faraday (1791-1867) and Carl Ferdinand Braun (1850-1918)

The sixth transformation was the discovery and application of the peculiar electrical properties of semiconductors.

English chemist and physicist **Michael Faraday** started out as an apprentice bookbinder. Largely self-educated, he became fascinated with electricity after attending a lecture by Sir Humphry Davy. Best remembered for demonstrating the relationship of electricity and magnetism, Faraday's observation of the effect of temperature on the conductivity of silver sulfide was the first purposeful demonstration of semiconduction in materials.

MICHAEL FARADAY

CARL FERDINAND BRAUN

In 1874, German **Carl Ferdinand Braun**, a professor of physics at the University of Strasbourg, developed the first practical semiconductor device, the "cat's whisker diode." He also built the first cathode-ray oscilloscope (1897) and shared the Nobel Prize in physics with Marconi (1909). Braun died in the US in 1918 while attempting to protect German interests in a radio station from commercial assaults by the then-British-controlled Marconi Corporation. The invention of the transistor by Bell Labs researchers in 1947 can be directly linked to the transformational insights of Faraday and Braun.

Enabling visualization — Louis Daguerre (1787-1851)

The fourth transformation was the ability to image the real world in real time.

Louis Daguerre, a French artist well known for spectacular panoramas, capitalized on the earlier work of Johann Schultz (who discovered the light sensitivity of silver salts) and of his own colleague, Joseph Niepce (who produced the first photographic image in 1820), to produce the first practical camera system in 1837.

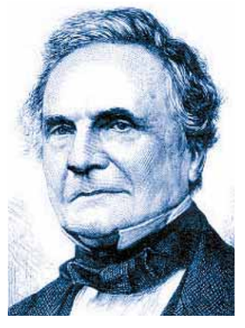
LOUIS DAGUERRE

The Information Age dawned in the middle of the 20th century. Demands for data processing, driven by the Manhattan Project and advanced aircraft designs, began to be satisfied by ENIAC, Mark I, and commercial mainframe computers. The invention/creation/introduction of the transistor in 1947 enabled power, size, and heat loads to be drastically reduced, enabling the PC. Intensifying requirements for real-time battlefield situation awareness and threat assessment following the launch of Sputnik drove DoD to the first computer networks in the late 1960s and gave rise to the full-blown Internet a few decades later. The rise of PCs and the Internet led to an increasing demand for real-time information, including graphics and images. Each of these innovations has its origin in the transformational insights of one of the "founding fathers," discussed here, who created the expectation that information should be shared and could be made accessible. Absent their contributions, the Information Age would have dawned much later, if at all.

Automating computation — Charles Babbage (1792-1871)

A final foundational enabler is the ability to manipulate numbers automatically.

Charles Babbage, professor of mathematics at Cambridge, was something of an eccentric. He loved fire and once had himself baked in an oven at 265 degrees F for five or six minutes, just to see the effect. He also hated music and was followed by people in the street who "tormented him with songs and fiddling."



CHARLES BABBAGE

Babbage's analytical engine, first conceived in 1834, had essentially all of the capabilities of a modern electronic calculator. In developing the analytical engine, Babbage stood on the shoulders of the unknown Greek who developed the Salamis counting board (ca. 500 B.C.); John Napier, who publicly propounded the concept of logarithms in 1614; and William Schickard, who developed the first adding machine (called the Calculating Clock) in 1623.

Babbage's creation was lost to history until 1937 when Harvard graduate student Howard Aiken rediscovered the work. There is a spirited debate about who really built the first modern computer. Some argue for Aiken, who developed Mark I with IBM in 1943. Others argue for Konrad Zuse, who developed the first programmable system in 1941. Still others argue for John Vincent Atanasoff, whose Atanasoff-Berry Computer (1937-1942) first used a binary structure and electronics. However, Babbage is generally credited with the seminal idea.

JOHN TAYLOR

JOHN TAYLOR, a nuclear engineer by training and a veteran of 32 years at Sandia, is the manager of ITS Strategic Planning Support Dept. 303. He has a passion for history and has authored or co-authored two books on the Civil War in New Mexico and one on the history of Catholicism in the Rio Abajo. He was also the technical editor of *"A History of Exceptional Service in the National Interest,"* the 1997 Sandia history, as well as two detailed examinations of specific national security programs at Sandia. He is also one of the principals in Sandia's Personal History Project.

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