Engineers Proclaim Top Achievements of 20th Century, but Neglect Attributing Feats to Roots in Physics

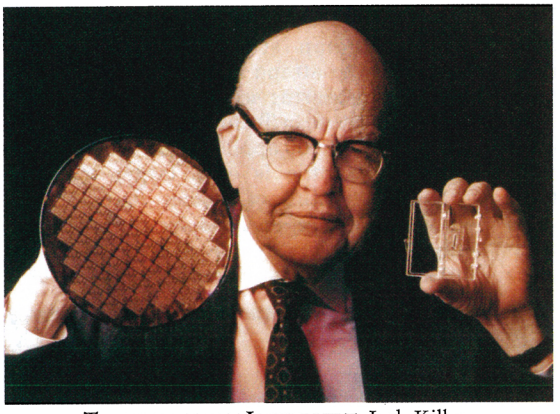
It was an opportunity not to be missed: As the millennial year 2000 approached, the National Academy of Engineering embarked on a project with the back-slapping title of "The Greatest Engineering Achievements of the 20th Century." The idea, the NAE admitted up front, was "part of an effort to communicate to the public the importance and excitement of engineering by highlighting examples of technological advance."

To be fair in the selection process and reduce the chance of overlooking any critical feats, the NAE invited the American Association of Engineering Societies and 29 other professional engineering organizations to join in nominating the technological triumphs of the century. The societies, including those representing civil, mechanical, chemical, and electrical engineers, often looked no further than their own interests. Among the early entries were the Suez and Panama Canals, the Grand Coulee Dam, Henry Ford's assembly line, Clarence Birdseye's frozen foods, and Chicago's water and sewer system. The NAE reminded the nominating groups that the most important criterion in the selection process was the significance of an engineering achievement "in terms of the contribution it has made to [improving] the quality of life in the 20th century."

By last October, the academy had received 105 nominations. It submitted these to a 29-member selection committee, headed by H. Guy Stever, former director of the National Science Foundation and science adviser to President Ford. The committee pared the number of nominations to 48 and then combined many of these into 29 larger categories. Thus, bridges, tunnels, and roads were merged into the interstate highway system, and tractors, combines, robot cotton pickers, and chisel plows were simply lumped into agricultural mechanization.

Finally, in December, the NAE committee agreed on 20 great engineering achievements. "The most difficult part of the process was in ranking the technologies," Stever recalled. "There were some heated arguments during teleconferences and, later, around a conference table. I held out for space technology for No. 1. I thought the landing on the Moon the greatest engineering achievement ever."

The committee disagreed. It decided that putting humans on the Moon was certainly an audacious event, which had challenged engineering ingenuity and quickened the heart of most people on Earth. But despite the arguments of its supporters, the committee thrust it into a category with the unimaginative label of spacecraft. Instead of identifying the Moon landing separately as symbolic of the century's technological advances, the committee placed spacecraft 12th on the list.



THE CHIP THAT JACK BUILT: Jack Kilby demonstrating his earliest integrated circuit, on a germanium wafer (right), and one of today's eight-inch silicon wafers.

In describing the category, the committee recognized that the Soviet Sputnik "shocked the world and started a space race that launched the greatest engineering team effort in American history." The space program that followed, the committee added, "had enormous impact on people throughout the world. First, it reignited the pioneering spirit that had once driven humans to explore every corner of the Earth, setting a new course for discovery in a long-dreamed-of realm—outer space. Second, it expanded the world's knowledge base. . . . Today we depend on satellites for video, voice, and data communications, defense, weather prediction, environmental monitoring, navigation, and more." Presumably, "more" includes the discoveries in outer space, by astronomers and astrophysicists, that, as the late Carl Sagan once noted, "rekindled some of that ancient human joy in understanding the natural world."

Oddly enough, *Time* magazine's web-site users had ranked the first Moon landing in 1969 in second place in an unscientific survey to identify the 20 major events of the 20th century. In the same poll, completed last January, first place went, by a wide margin, to an event in 1954 titled "Elvis teaches American teens to rock 'n' roll." By contrast with the NAE's top choice, the public's pick seemed surreal—even comic.

At the top of the engineers' list came electrification, the classic example of an enabling technology, which the NAE panel said "brought light to the world and power to almost every pursuit and enterprise in modern society." Though the panelists acknowledged that the widespread distribution of electricity has "made life safer, healthier, and more convenient—so much so that it is hard to imagine our lives without it"—it neglects to credit the physicists who, in times past, provided the theoretical and experimental underpinnings of it.

Among those who led the way was Michael Faraday, the consummate English experimentalist with a visionary's sense of the unity of nature. Faraday was the first to conceptualize the electromagnetic field, and, without intending it, made the first recorded conversion of mechanical energy into electrical energy. His contribution wasn't fully recognized until a Scottish physicist, James Clerk Maxwell, summed up Faraday's findings in four magnificently simple mathematical formulas, demonstrating not only the essential identity of magnetic and electric phenomena, but also the close affinity between visible light and electromagnetic effects.

Also associated with the new discoveries were three physics professors—a Dane, Hans Christian Ørsted; an Italian, Alessandro Volta; and a German, Georg Simon Ohm. An American physicist, Joseph Henry, deserves credit for building the first electric motor in 1829 and evolving a serviceable telegraph apparatus. And there was Nikola Tesla, a Croatian physicist who worked, first, with Thomas A. Edison and, later, with George Westinghouse, to deliver electricity by alternating voltages.

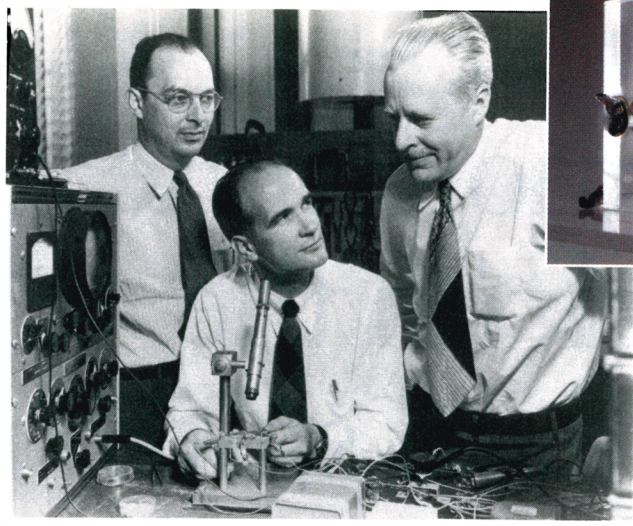
The list's No. 2, the automobile, and No. 3, the airplane, clearly met the NAE criterion of social impact and agents of change—each bringing large

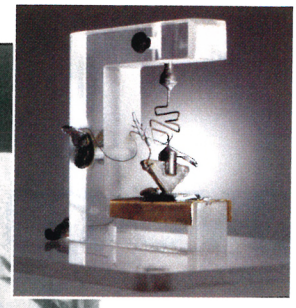
distances into accessible range and altering both urban and rural lifestyles. In placing water supply, treatment, and distribution fourth on the list the committee recognized that water and sewage systems "led to longer life expectancy, reduced infant mortality, vast increases in agricultural production, and improvements in the quality of life around the world."

No. 5, electronics, is solidly rooted in physics. "From vacuum tubes to transistors to microprocessors, electronic devices became smaller and more powerful, and more efficient throughout the 20th century. Such inventions provided the technological basis for countless innovations and products," the committee noted. It attributed the transcendent success of electronics to two inventions, though it neglected to mention the inventors—the transistor, devised in 1947 by John Bardeen, Walter H. Brattain, and William B. Shockley, all physicists then at Bell Telephone Laboratories; and the integrated circuit, created a decade later by Jack Kilby at Texas Instruments and, independently, by Robert Noyce, a founder of Fairchild Semiconductor Co. "Part of the magic of electronics is adding millions of transistors to a tiny silicon chip. The rest of the magic is performed by engineers who determine their use through the development of microprocessors"—the control center embedded in automobiles, airplanes, and computers, and making thousands of new products possible, from heart pacemakers and medical instruments, to cellular phones, compact disc players, and even credit cards.

On the NAE list, No. 6 is radio and television, both based on the work of Maxwell, Faraday, and a German physicist, Heinrich Hertz, in understanding electromagnetic waves. No. 7 is agricultural mechanization, and No. 8 is just called computers—a simple name for an array of products. The panelists, as usual, failed to mention those who made the computer revolution possible—Howard Aiken at Harvard University and John Atanasoff at Iowa State University, as well as J. Presper Eckert and John Mauchly at the University of Pennsylvania, and Alan Turing, most famous for breaking the Enigma codes used by the Nazis in World War II and then for developing a rudimentary computer at the British National Physical Laboratory and the University of Manchester in England.

The list continues with the telephone in ninth place, air conditioning and refrigeration in tenth, the interstate highway system in eleventh, and then spacecraft in the twelfth spot.





THREE WHO MADE A REVOLUTION: John Bardeen, Walter Brattain, and William Schockley, inventors of the transistor. Inset shows a model of their original.

No. 13 is the Internet, whose parent is Joseph C. R. Licklider, an acoustical physicist, who, in 1963 while at the Pentagon's Advanced Research Projects Agency, envisioned a network that would connect machines and people electronically throughout the world. But it was a British physicist, Tim Berners-Lee, who came up with the idea of a WorldWide Web in 1989.

No. 14 is imaging, a field that has brought forth the use of x rays, radar, sonar, magnetic resonance imagers, and electron microscopes, all created on the shoulders of giants in physics—including Germany's Wilhelm Röntgen, Britain's J. J. Thomson, and the US's Arthur Holly Compton.

The rest of the list consists of household appliances (15), health technologies (16), petroleum and petrochemical technologies (17), and three categories with major contributions by physicists—laser and fiber optics (18), nuclear technologies (19), and high-performance materials (20). The field of lasers, for instance, owes its origins to physicists—Charles Townes, then at Columbia University, Arthur Schawlow at Bell Labs, and Theodore Maiman at Hughes Research Laboratories, along with two Russians, Alexander Prokhorov and Nikolai G. Basov.

Stever, a physicist who worked in radar development at MIT, is reluctant to say that his discipline is the mother of many of the technologies on the list. "All the sciences have helped give birth to 20th century technologies," he observed, "although physics is dominant, without question. But, as it turned out, engineering has advanced physics by developing instruments and equipment for research. Should the engineers have given some recognition to physics and physicists? I think the list is evidence of the basic contributions of the physics community to 20th century technologies."

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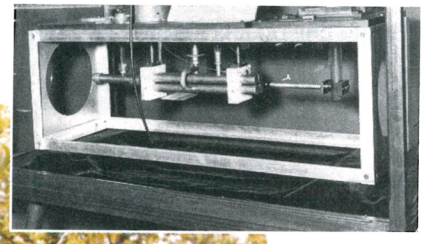

TWO WHO CREATED THE LASER: Charles Townes (left) and his brother-in-law, Arthur Schawlow. Inset shows an early laser.