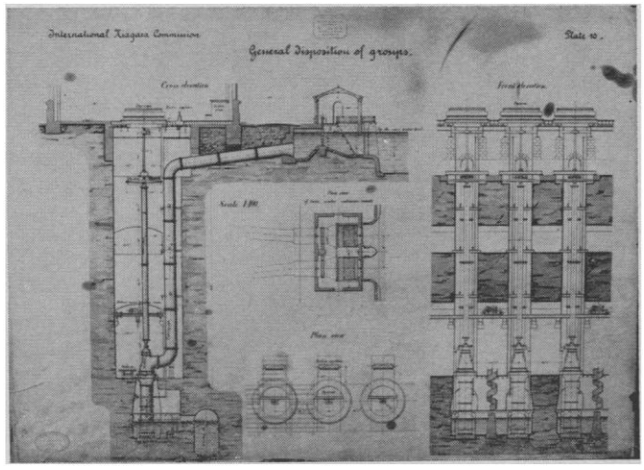

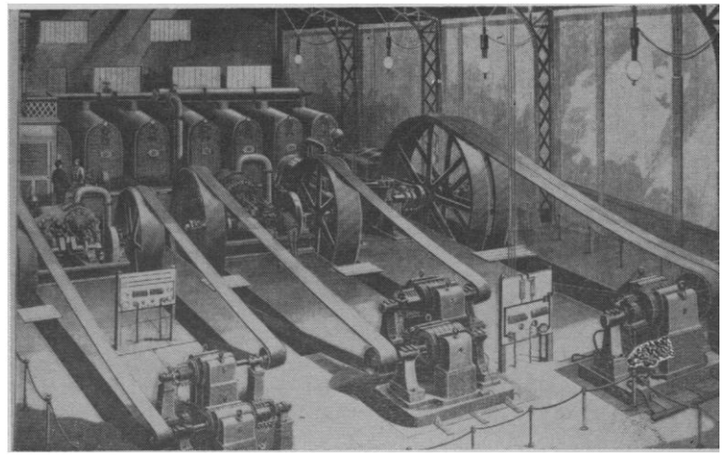

Revolution in Electrical Technology (1870-1900)

AAAS Symposium • 27 December 1970 • Chicago

If the word *revolution* is simply taken to mean rapid and far-reaching change, then the last third of the 19th century witnessed a revolution in electrical technology. It was in this period that telegraph and telephone, electric light, the electric streetcar, and centrally distributed electric power entered into everyday life. Curiously, this revolution nowadays receives little attention. The innovations then introduced are familiar to us because we grew up with them. In spite, or, perhaps, because of this familiarity, our understanding of them is superficial; all the more so now that they have long since lost the charm of novelty. The driving forces behind this revolution are by no means adequately understood. We seldom reflect on how its events may have appeared to contemporaries and especially to participants.

Both branches of electrical technology, those dealing with communications and with power, were subject to the same historical forces. In the middle of the century, not only the basic physical phenomena were discovered, but also key inventions like the electric motor, the generator, the arc lamp, the telegraph (and, by 1861, even the telephone) had been realized, at least in principle.

The first of these inventions to be introduced on a large scale was the telegraph. By the time of the American Civil War it had become the leading mode of long-distance communication, with vast economic consequences. The progress of electrical power, in contrast, was delayed chiefly by the limitations of the only available source of current—the chemical battery. The invention of the self-excited generator, and its perfection into a device which could convert steam or water power efficiently and continuously into electric currents, initiated a new era. The first beneficiary of this innovation, arc lighting, came to a brief flowering in the 1880's, soon to be replaced by another development. Incandescent light was introduced in a remarkable manner. Edison was not content to present his newly invented lightbulb as a solitary artifact. Instead he conceived of it as part of a new system, for which he also designed all other components, and which he presented to the world as a whole with his Pearl Street power station in 1882. Next electrical inventors and entrepreneurs concentrated on the problem of electrical traction. The first economical and reliable system of streetcars was achieved by Frank J. Sprague in Richmond in 1888. If this innovation proved to be only slightly less short-lived than the arc light, it provided an invaluable proving ground for the technology of central power distribution and for the electric motor. Soon the electric motor assumed a far more significant role as a new source of power in the textile factory, in the machine shop, and in countless other functions.

No sooner had direct current (d-c) matured as a basis for power distribution than it faced a new rival, alternating current (a-c). The proponents of a-c pointed to the simplicity of their generator and above all—owing to the newly invented transformer—to the ease and economy with which a-c could be transmitted over long distances. The defenders of direct current, among them Lord Kelvin and Edison, argued for preserving a system that was tested in practice and that possessed a proven motor and the capability of energy storage in batteries, two features that the a-c system could not match. However, when G. Ferraris and N. Tesla presented practical a-c motors, the outcome of the contest was no longer in doubt.

How rapidly the issues changed is demonstrated by the history of the Niagara Falls hydroelectric project. In the late 1880's, when the planning began, energy was to be transmitted from

(Above left) Water turbines and dynamo for the Niagara Falls hydroelectric power plant. An early (1890) proposal drawing by the Swiss firm who eventually won the contract for the turbine design. [Smithsonian Institution]

(Above right) Steam-electric central power station generating the current for the arc lighting of the 1889 Paris Universal Exhibition. Six-gramme d-c generators are driven by three British-built steam engines. [*The Engineer* **68**, 248 (1889)]

the turbines to the consumer either in the form of compressed air or by a combination of d-c with ropes and pulleys. As these mechanical schemes were quietly discarded, the discussion shifted to the rivaling systems of d-c and a-c. News of several successful a-c transmission lines, notably of the 110-mile high-voltage line from Lauffen to Frankfurt, Germany, in 1891, led to the official adoption of a-c in 1893. The contest ended in a competition between General Electric and Westinghouse, both proposing similar systems, of whom the latter received the contract.

To understand rapidity and magnitude of change in this young field of technology, one has to study the peculiar interaction between two forces that at first glance seem quite incommensurable: scientific discovery and financial interest.

As no other branch of technology before, the electrical industry owed its foundations to science. Not only were its pioneering inventions closely related to the experimental work of such men as Oersted, Faraday, and Henry. The electrodynamical work of Kelvin, Maxwell, and their contemporaries led to practical improvements that empiricism alone never could have achieved. The practical inventors, in turn, were surprisingly knowledgeable in contemporary physics. Even Edison, with his fondness for ridiculing scientists, used the methods, although not the jargon, of the experimental physicist; and knowing his limitations, he would not hesitate to enlist the help of academically trained mathematicians.

If the fast growing electrical technology was in part moved by purely intellectual forces, it also involved enormous financial stakes. The early telegraph business, for example, provided the basis for the industrial empire of the Siemens brothers. Lord Kelvin made a quick fortune in his work on cable telegraphy. Among the backers of Edison's and Westinghouse's enterprises were such Wall Street giants as J. P. Morgan, J. Gould, and W. K. Vanderbilt. Electrical patent rights were sold for startling sums: a record was set when Michael I. Pupin sold the American rights for his loading coil patents in 1900 to A.T.&T. for $455,000, and later the corresponding German rights to Siemens and Halske for a similar amount, remarkable prices for what some have called a mere integral of the telegraph equation.

The history of electrical technology in the last third of the 19th century will be the subject of a symposium at this year's AAAS meeting in Chicago on 27 December 1970. The complex dynamics characterizing the era will be analyzed in case studies of three crucial sequences of events. Bernard S. Finn (Smithsonian Institution), in a paper on "Cable Telegraphy, 1870–1885," will analyze the effects of scientific work, especially by Lord Kelvin, and of economic factors, on cable telegraphy. James E. Brittain (Georgia Institute of Technology), in "From Rowland to Hopkinson: Science and the Dynamo," will trace the development of the magnetic circuit concept up to Hopkinson's classic paper of 1886 which has come to be regarded as a cornerstone in the "scientific design" of dynamos. Thomas P. Hughes (Southern Methodist University) will investigate "The Battle of the Currents: A Case of Complex Technological Change," focusing on the move from d-c to a-c in the period from about 1885 to 1900. The symposium is sponsored jointly by the American Association for the Advancement of Science and by the Society for the History of Technology.

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AAAS TELEVISION PROGRAMS

National Educational Television (NET), in cooperation with the AAAS, presents a series of five 1-hour nightly programs (26–30 December) entitled *Science '70: A Year-End Report.* The programs will be produced nightly by WTTW-Channel 11 (Chicago) and will be carried nationwide to 190 stations by the Public Broadcasting Service. The programs will be shown live from 9 to 10 p.m. in Chicago; check local listings for times in other cities.

The themes will be *Human Behavior—Science Looks at U.S.; Environment—Design for Living; Science and Politics; Health and Medicine: From Gene to Man;* and *The Not-So-Silent Minorities.*

NET correspondent David Prowitt will anchor the series and act as Executive Producer. The Producer is Steve Gilford.

Program of the AAAS Annual Meeting appears in the 20 November issue of Science. *Reports of symposia are in the following issues: 28 August, "Human Behavior and Its Control"; 4 September, "Land-Use Problems in Illinois"; 11 September, "Aleutian Ecosystem"; 18 September, "Reducing the Environmental Impact of Population Growth"; 2 October, "Critical Issues in Research Related to Disadvantaged Children"; 9 October, "Women in Science"; 16 October, "Advances in Human Genetics and Their Impact on Society" and "Genetic Diseases and the Quality of Life"; 23 October, "The International Biological Program"; 30 October, "Mood, Behavior, and Drugs"; 6 November, "Urbanization in the Arid Lands," "World Cities of the Future," and "Industrial Approaches to Urban Problems"; 13 November, "Biocybernetics of the Dynamic Communication of Emotions and Qualities" and "The Developmental Sciences: State and Fate of Research Funding"; 27 November, "Teaching of Science," "Science Education in the Seventies," and "Urban Ecology Today"; 4 December, "Interstellar Molecules and Chemistry," "Solutions to Environmental Problems," and "Crime, Violence, and Social Disorder"; and 11 December, "Water Supply and Water Management Problems of the Great Lakes," "Minor Metals of the Geochemical Environment, Health and Disease," "Separation and Depression," "Problems in the Meaning of Death," and "Techniques and Status of Modern Parapsychology."*

Program Notes

AAAS Annual Meeting

Chicago, Illinois

AAAS Herbicide Assessment Commission

On the morning of 29 December at the Annual Meeting of the AAAS, the AAAS Herbicide Assessment Commission will present a report on its work of the past year. The Commission was set up at the 1969 Annual Meeting of the AAAS to prepare a plan for studying the short-term and long-term effects of the military use of herbicides on the ecology and on human health and welfare in South Vietnam. Its chairman is Matthew Meselson of the biology department at Harvard University, and it is directed by Arthur Westing, professor of forestry at Windham College. Speaking with Meselson and Westing will be John Constable, professor of surgery, Massachusetts General Hospital, who accompanied them on their visit to Vietnam last August.

The report will be illustrated with color slides of that trip, during which the team met with a number of U.S. and Vietnamese officials and Vietnamese scientists. They also conducted aerial and ground observations of defoliated areas, both forest regions and areas which had undergone recent crop destruction missions, and interviewed farmers and others with personal experience with the herbicide program. They will discuss their findings and recommendations for future study.

This report will be followed in the afternoon by a panel discussion, chaired by Herbert Scoville, Jr. (Carnegie Endowment for International Peace). The topic, "Implications of Continued Military Use of Herbicides in South East Asia," will first be discussed by George Bunn (professor of law, University of Wisconsin), Richard D. McCarthy (U.S. House of Representatives), William Stone (Brigadier General [ret.], U.S. Army), and Fred Tschirley (Agricultural Research Service, U.S. Department of Agriculture). Also on the panel will be Matthew Meselson and Samuel Popkin (Department of Government, Harvard University).

Youth Council

Scientific education and research may not serve your priorities, those of society, or any other rational scheme. Young people as consumers of science education and the future instruments, beneficiaries, and victims of scientific "progress" are considering what science should become in the future. Specificially, the Youth Council of the AAAS is exploring how the AAAS, the country's largest interdisciplinary scientific organization, can positively affect science education to make it relevant to your concerns. How can the AAAS alter the allocation of resources in science toward socially useful as well as scientifically significant research? A coffee-house discussion and two workshops to explore these concerns and consider alternative strategies for action will be held at the AAAS Annual Meeting in Chicago. *Coffee House*: Sunday evening, 27 December. Room 512, Conrad Hilton. (Check program for time.) *Workshop for students*: 9:30 a.m., Tuesday, 29 December. Room 547, Conrad Hilton. *Workshop for working scientists, teachers, and technicians*: 2:00 p.m., Tuesday, 29 December. Room 547, Conrad Hilton.

In addition, a Youth Room with coffee, books, films, and people will be open throughout the meeting (Room 547, Conrad Hilton).

Please come work with us. We need your help.

Symposia to Be Taped

During the AAAS Annual Meeting, the following symposia will be taped. Copies of such tapes will be available (in reel and cassette form) early in the year. Visit the AAAS Audiotape Program Booth, Exhibit Hall, to find out more about these tapes and others produced in 1968 and 1969.

Tapes: Advances in Human Genetics and Their Impact on Society; Are We Winning the War Against Urban Fires?; Automobile Pollution; Chemistry Instruction and Social Concern; Chemistry of Learning and Memory; Crime, Violence, and Social Control; Economics of Pollution; Effects of Large-Scale Use of Herbicides and Defoliants; Elementary Particles and Symmetry; Human Cell Biology; Industrial Approaches to Urban Problems; International Science Education; Interstellar Molecules and Chemistry; Is Population Growth Responsible for the Environmental Crisis in the United States?; Is There a Generation Gap in Science?; Lake Restoration; Latest Results of the Deep Sea Drilling Project; Numberless Scientific Applications of Computers; Problems in the Meaning of Death; Public Policy for the Environment; Reducing the Environmental Impact of a Growing Population; Science Education in the Seventies; Science and the Federal Government; Scientific Organizations, War-Peace Issues, and the Public Policy Process; Separation and Depression; Teaching of Science; U.S. Contributions to the International Biological Program; University Open Admissions; and Urbanization in the Arid Lands.