nary crank-type engines. Like the Lear system, the water to be converted to steam is mixed with soluble oil; this eliminates freezing and lubrication as problems. Johnson's system can get up steam in about 15 seconds.

"If it's gone about in the right way," Johnson says, "steam cars could be produced in 3 years." And although his company is not interested in producing such cars themselves, it looks as if Johnson's technology could help show the disbelievers that steam works. "We were originally just looking for a power source suitable for driving a low wing aircraft," Johnson said in a recent interview. "After 3 years of research on all kinds of power systems—turbines, Rankine, internal-combustion, everything—we found that the Rankine-cycle steam engine could do the best job in terms of power-to-weight ratio, torque, and noise. We weren't even interested in emissions. We were just looking for the best power source."

But the emission characteristics have became important. Since a steam car burns almost all its fuel, there is very little unburned material emitted, unlike the case with the internal-combustion engine. Maga, the California Air Resources Board executive, says the improvement in air quality that can be achieved by controlling internal-combustion-engine emissions is very slight. "Last year we had a six percent reduction in hydrocarbons in Los Angeles," Maga said recently. "That kind of progress is very slow." But Maga is cautious in his appraisal of steam cars. "What seems to have been needed up to now," he says, "was somebody with a lot of money. If Lear has been able to solve the problems that have historically been associated with steam, then maybe steam cars will be able to compete with internal-combustion cars. And if they can, that would be very good for air pollution."

—ANDREW JAMISON

Andrew Jamison, a Harvard junior, last summer worked as a Science *news department intern.*

TRACES: Basic Research Links to Technology Appraised

The belief, cherished by most scientists, that basic research plays a vital role in technological innovation was questioned in 1966 by the Department of Defense report *Project Hindsight*, which concluded that contributions to defense from basic research since 1945 have been small. The National Science Foundation (NSF) has recently released the results of a study which found that basic research was of overwhelming importance in five recent technological innovations of wide value. The NSF report, *Technology in Retrospect and Critical Events in Science* (*TRACES*), does not rebut the *Hindsight* conclusion, but rather shows that the Department of Defense evidently did not go back far enough in assessing the role of basic research in technical innovation. *TRACES* found that about 90 percent of the basic research behind an innovation has been accomplished a decade before development of the innovation. The *Hindsight* conclusion was apparently correct as far as it went.

The study was made by the Illinois Institute of Technology Research Institute under a $164,000 contract with NSF, and was similar in method to the DOD study. A list of some 20 recent technological innovations of wide importance and diverse application was assembled, from which five were randomly chosen for detailed study—magnetic ferrites (materials used in computer memories and similar applications), the video tape recorder, the oral contraceptive pill, the electron microscope, and matrix isolation (a technique which is revolutionizing certain chemical processing industries). In the detailed study of each innovation a team of experts traced the critical findings, experiments, reports, and so on, backward in time to the innovation's origins in basic research. Each of these was termed a "key event" and was classified as due to "nonmission research," "mission-oriented research," or "development and application." Events were traced as far back as the 1850's.

To take a simple example from the trace of magnetic ferrites, the development of hard ferrites in the late 1950's at the Philips Research Laboratories (Holland) was preceded by two mission-oriented research efforts at Philips in the early 1950's. These in turn were preceded by a sequence of nine nonmission events in crystal chemistry, including Pauling's bond theory of crystals in 1929, Bragg's work on x-ray diffraction in crystals between 1914 and 1920, and Roentgen's discovery of x-rays in 1895. In addition to crystal chemistry, the fields of telecommunications, ceramic materials, and magnetic theory contributed traces of nonmission research, mission-oriented research, and development and application in the history of magnetic ferrites. The traces often interconnect, revealing communication between disciplines, and the overall trace is quite complicated.

The traces for the five innovations show *what kind* of key event occurs *when* in the history of a technological innovation. Separate graphs of nonmission events, mission-oriented events, and development and application events plotted against time reveal some basic facts about the process of technological innovation.

TRACES found that, of the 341 key events documented, about 70 percent were nonmission research, 20 percent were mission-oriented research, and 10 percent were development and application. The number of nonmission events per decade reached a maximum two or three decades before the innovation, and 90 percent of the nonmission research was completed 10 years before the innovation. Mission-oriented events and events in the development and application category reached a maximum in the decade preceding innovation. Interplay between nonmission and mission-oriented research and communication between disciplines were important to technological innovation, and in some cases it was evident that mission-oriented research stimulated nonmission research which, in turn, produced events of crucial importance to the innovation.

The team of experts who searched

the literature for each of the five traces evidently found strong justification for the idea that undirected research, with knowledge for its own sake as the only goal, provides a reservoir of understanding essential to subsequent technological innovation. The report will be a valuable piece of supportive evidence when NSF faces congressional authorization hearings in early March.—PETER THOMPSON

APPOINTMENTS

J. T. English

I. L. Bennett, Jr.

Joseph T. English, assistant director for health affairs in the Office of Economic Opportunity, to director of the Health Services and Mental Health Administration of the Department of Health, Education, and Welfare. . . . **Ivan L. Bennett, Jr.**, deputy director of the Office of Science and Technology and director of the department of pathology at Johns Hopkins University, to director of the New York University Medical Center and vice president for health affairs at the university. . . . **Robert C. Wood**, Secretary of the Department of Housing and Urban Development, to director of the Harvard–M.I.T. Joint Center for Urban Studies; he succeeds **Daniel P. Moynihan** who has become chairman of President Nixon's new Council on Urban Affairs. . . . **William D. Carey**, director of the Human Resources Programs Division of the Bureau of the Budget, to senior staff member in the Washington office of Arthur D. Little, Inc. . . . **Philip O. Montgomery, Jr.**, professor of pathology at Southwestern Medical School, University of Texas, Austin, to associate dean of the medical school there. . . . **Cyrus Levinthal**, associate professor of plant physiology at Columbia University, to chairman of the department of biological sciences at the university.

RECENT DEATHS

Fred Alt, 56, director of the testing division of the Oceanographic Instrumentation Center, U.S. Naval Oceanographic Office; 4 January.

Franklin L. Austin, 53; research project leader in the Industrial Crops Laboratory, Northern Research Laboratory; 26 December.

Leo O. Colbert, 84; former director of the U.S. Coast and Geodetic Survey; 24 December.

Ben Davidson, 52; director of the geophysical sciences laboratory of New York University's School of Engineering and Science; 20 December.

John C. Donaldson, 80; professor emeritus of anatomy at the University of Pittsburgh School of Medicine; 16 November.

Maximilian R. Ehrenstein, 69; professor emeritus of biochemistry at the University of Pennsylvania School of Medicine; 28 December.

Theresa Huang, 30; a research psychologist at the American Institute of Research, Silver Spring, Md.; 19 November.

Edwin B. Mains, 78; former director of the herbarium of the University of Michigan; 23 December.

Charles Muzzicato, 67; a radiologist who once served as the national chairman of the American Medical Relief for Italy and was also once a commissioner of New York City's Civil Service Commission; 20 December.

Victor E. Shelford, 91; eminent ecologist and former professor of zoology at the University of Illinois; 27 December.

Courtney C. Smith, 52; president of Swarthmore College and American secretary of the Rhodes Scholarship Trust; 16 January.

Georgi N. Speransky, 95; founder of the Russian School of Pediatrics; 14 January.

Mario H. Zarlengo, 30; assistant professor of biochemistry at the University of Colorado Medical School; 19 October.

A POINT OF VIEW

Excerpts from an article by William L. Cary, professor of law at Columbia University, on "Topics: No Tenure for University Presidents" which appeared in the New York Times *16 November 1968 (© New York* Times*).*

The disturbances on American campuses highlight the diverse roles of the president of a large university, and pose the question whether this is an office that he should hold until retirement age. Does he more closely resemble the professor-scholar who stays on till seventy, or the chief executive of a corporation who does not have tenure? . . .

I believe the president of a large university should be appointed for a term of years (such as ten) and no more. Even reappointment for a second term is questionable, for it places the trustees in the same embarrassing position. Men of breadth recognize this, perhaps the finest example being Conant (who went from Harvard to new and creative roles). Brewster at Yale has said that he does not expect to spend his whole life there. After all, Yale wisely appoints its deans for a term; why not its president?

If the president has made a contribution, there should be proper gratitude. But need it follow the tradition of academic tenure? Professorial appointment until retirement may be questioned, but at least it has a rationale: the need for independence and total dedication to scholarship.

The president, on the other hand, no longer need be a scholar. He is much closer to being the head of a major company than a teacher. Yet business corporations have escape hatches, and the universities have none. When a change is needed, one can be made chairman rather than president, or head of the executive committee. The salary and prerequisites continue. Why are there not comparable formulae in the university world?