Technology Assessment: NAE Report Explores the Methodology

A recently released National Academy of Engineering (NAE) report,* *A Study of Technology Assessment*, attempts to give some concreteness to a concept which up until now has been largely a high-minded abstraction. The idea of technology assessment was first given currency 2 years ago by Representative Emilio Q. Daddario's Subcommittee on Science, Research, and Development. Technology assessment represents a systematic effort to foresee the impact of various technological developments and to identify strategies capable of producing consequences which, from the standpoint of the public interest, are most desirable and of avoiding or altering consequences which are unfavorable.

This concept was discussed in a report last August by the National Academy of Science's Committee on Science and Public Policy (*Science*, 5 September), which dealt with the need for technology assessment and with how bureaucratic mechanisms might best be established at the federal level to carry out or sponsor such assessments. However, the present report, prepared by NAE's Committee on Public Engineering Policy† and (like its predecessor) commissioned by the House Committee on Science and Astronautics, is concerned principally with the methodology of technology assessment.

Experimental Assessments

It is based on the insights gained from three experimental assessments carried out under the NAE committee's direction. One was a "problem-initiated" study concerned with subsonic aircraft noise. The other two were "technology-initiated" assessments, one on the use of television and the computer as teaching aids in higher education, the other on "multiphasic health screening" (using advanced technology to give comprehensive examinations to large numbers of people). The academy already had committees working on related topics, and part of the data base needed for the experimental technology assessments was available. The assessments were not full-scale assessments but rather tests of assessment methodology.

From these studies, the NAE committee concluded that technology assessment is indeed feasible and can provide a means of educating both the government and the public about the short- and long-term effects of technological development and about various alternative policies for guiding development. The report's other major conclusions include the following.

- The selection of a preferred course of action, from among alternative strategies derived from a technology assessment, is not a suitable task for the technology assessment group. "This function," it said, "should remain the prerogative of the legislator after he has been provided with bases for application of his judgment."

A Matter of Semantics

[The Academy of Sciences report, on the other hand, said that, while those making technology assessments should play only an advisory role, they should recommend the best course of action. The difference between the two reports on this point, however, is to some degree a matter of semantics. In the study of aircraft noise discussed in the NAE report, one of the alternative policies considered was shown to have a favorable impact on more interested groups (airport operators, airport neighbors, local taxpayers, and the like) than would other alternatives. In many technology assessments, however objective and neutral the attitude cultivated by the study group, a particular course of action presumably will emerge as preferable to any other.]

- Members of technology assessment study groups—though many will necessarily be people with a special interest (the aircraft-noise study group included executives from two airlines, an airport, and an aircraft manufacturer)—are "able to focus on the public interest and to neutralize the biases of the organizations with which they are associated." The report said that thorough investigation of the sociological impacts of technologies requires the participation of behavioral and political scientists in assessments. The viewpoints of parties affected by a technological development should be brought to the assessment task force by "volunteered or solicited presentations, and with special concern to elicit views from those affected parties who are not normally organized in their own interests."
- Congress should establish a small management organization to contract for technology assessments or to organize and instruct assessment task forces. This organization would not itself attempt to make assessments, for "no permanent organization can be envisioned that could provide adequate expertise to execute full-scale assessments in all of the fields that may be required."

The NAE report does not discuss management of the technology assessment function in the executive branch but confines itself to the question of what Congress, which asked for the study, should do. However, in an interview with *Science*, Chauncey Starr, chairman of the NAE Committee on Public Engineering Policy, stressed that Congress, as the most broadly representative branch of government, was ideally suited to make political judgments on the basis of technology assessments.

Perhaps the report's most illuminating contribution is its discussion of the two categories of technology assessment, each of which calls for a different approach. It said that the kind of assessment initiated in response to an existing social problem, such as aircraft noise, lends itself to readily available systems analysis methodologies. For in-

*Available for $1.25 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

† Members of the committee are Chauncey Starr (chairman), U.C.L.A.; John R. Pierce (vice chairman), Bell Telephone Laboratories; Arnold O. Beckman, Beckman Instruments; Leo L. Beranek, Bolt Beranek and Newman, Inc.; John H. Dessauer, Xerox Corporation; Eugene G. Fubini, consultant; Clifford C. Furnas (now deceased), Western New York Nuclear Research Center; Martin Goland, Southwest Research Institute; Lawrence R. Hafstad, General Motors; Patrick E. Haggerty, Texas Instruments; James Hillier, RCA; Frederic A. L. Holloway, Standard Oil of New Jersey; James R. Killian, Jr., M.I.T.; Nathan M. Newmark, University of Illinois; and Robert I. Stern (executive secretary). Members of the Committee on Technology Assessment were George S. Schairer (chairman), Boeing; C. C. Furnas; M. Goland; Thomas C. Kavanagh, Praeger-Kavanagh-Waterbury, Engineers-Architects; H. Guyford Stever, Carnegie-Mellon University; John G. Truxal, Polytechnic Institute of Brooklyn; and John R. Whinnery, Berkeley.

stance, in the aircraft-noise assessment the study group examined ten different ways of coping with this problem, including such strategies as relocating airports, creating buffer zones around airports and exercising other land-use controls, requiring more surface transportation, and modifying aircraft hardware and flight profiles. The latter alternative seemed preferable from the standpoint of a majority of the affected groups to any other single course of action, but the report suggested some combination of alternatives might provide the best answer.

Analysis of this kind is simple by comparison with that required for a "technology-initiated" assessment such as that of the use of television and the computer in higher education. The report observed that:

> While the problem-initiated assessment focuses on solving a stated problem, the process involved in an assessment of a new technology is better represented by analogy with an inverted funnel. The assessment process begins with the new technology at the small end and emerges as a complex pattern of consequences at the large end. As cause-effect chains diverge, predictability of events diminishes. Picking the winner of a horse race is difficult-enough, and putting money on the daily double is many times riskier. Statistically, if four events in sequence are predicted, each with a reliability of 80 percent, the reliability of the final prediction falls to 41 percent. . . . Thus, the farther that predictions pretend to see, the greater their degree of uncertainty. Still further complexity is introduced when the analysis includes, as it should, the consequences of alternative governmental strategies designed to cope with the effects that have been predicted. For each new strategy considered, a series of diverging cause-effect chains is generated. The number of consequences becomes multiplied by the number of policy alternatives or strategies considered for each. Clearly, any attempt to reach broad conclusions from such a vast array of possibilities is likely to be unreasonably expensive, time-consuming, and inaccurate. Thus it is much more difficult to achieve meaningful evaluation for a technology-initiated assessment than for a problem-initiated assessment. [But] because of the uncertainty and potentially broad scope of the impacts of new technologies, their assessment is probably of most concern to Congress.

In order to cope with the complexity of the technology-initiated assessment, the NAE committee concluded that it often may be necessary to convert it to a problem-initiated study. In the educational TV-computer assessment, the conversion was accomplished by narrowing the study's focus and concentrating on the question of what promise four different levels of federal financial

Basic Research: Congress on Prowl

Congressional debate on a weapons and research bill, which began in July with headlines on the ABM, ended last week with a footnote which could demolish all Pentagon-supported basic research.

Two oddly paired congressional huntsmen are about to join a new foray against such research, armed with what looks at first glance like a rather formidable weapon. The two are Senate Majority Leader Mike Mansfield, (D–Mont.) and House Armed Services Committee Chairman L. Mendel Rivers (D–S.C.). Their weapon is Section 203 of the recently approved military procurement and research authorization bill. Devised by Mansfield to terminate Pentagon support of basic research [and introduced as a Senate amendment by J. W. Fulbright (D–Ark.)], it says the Defense Department shall not finance "any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation."

In Mansfield's view this language could cut off Pentagon support for about $400 million a year of "non-mission-oriented" basic and applied research carried out mainly at educational institutions and affiliated organizations. Mansfield apparently would like to see the National Science Foundation pick up the tab for such research in the future.

In the view of Defense officials concerned with administering the new law, however, it is "without effect," since "as a matter of policy, and surely as a matter of rhetoric, all the work we support is relevant to military needs." The Pentagon's initial reaction is to carry on as before. Officials say it will be up to Congress to challenge specific projects. In response, Mansfield's staff suggests the General Accounting Office will be asked to keep an eye on the Pentagon's performance.

All this could evolve into nothing more serious than a genteel debate over legal verbiage and some barely perceptible tightening of Pentagon guidelines. But two factors suggest that the new law could have a far more explosive effect. For one, the more the Pentagon insists that all its research projects are defense-oriented, the more ammunition it gives to students and faculty who want to end university-military ties. The other factor is Congressman Rivers.

In earlier House action, to encourage a show of more "backbone" by academic administrators, Rivers' committee ordered the Pentagon, in the authorization bill, to give 60 days of advance notice before awarding new grants or contracts for academic research, and to inform Congress of each school's record of cooperation with the military. The provision elicited strong opposition from the White House, the Pentagon, and the scientific community (*Science*, 10 October).

The provision was dropped at the insistence of Senate members of the conference committee which drew up the final version of the bill. But the House conferees declared that "the continued award of these defense research and development contracts to educational institutions which appear to be making a determined effort to either ignore or deter our national defense effort will be given very careful scrutiny," and they directed the Pentagon to be ready to supply details, "including the identity of persons receiving classified information." According to a staff member of the House Armed Services Committee, the new Section 203 will help put teeth into any investigation along such lines.

The House-Senate conferees also watered down strict Senate-approved controls on chemical and biological weapons. In the most important change, the Surgeon General was deprived of veto power over open-air testing and transportation of lethal agents. But Senator Thomas J. McIntyre (D–N.H.), sponsor of the Senate CBW amendment, promised to hold hearings soon on the Pentagon's whole CBW effort, including its observance of new safety provisions (*Science*, 22 August).

—ANDREW HAMILTON

A Washington journalist, Andrew Hamilton will be writing for the news section while Philip M. Boffey is on assignment in Japan.

Project Sanguine Short-Circuited

Under pressure from Capitol Hill and citizens' groups, the Pentagon announced last week that it would rethink its submarine-communications transmitter project, which would have turned much of northern Wisconsin into a giant, electrified grid.

The underground grid was to have been an extremely low frequency radio transmitter used to send missile-firing orders to submerged Polaris submarines, eliminating the need for the craft to surface. The Navy called it Project Sanguine.

Congressmen, led by Senator Gaylord Nelson, and conservationists had contended that heat, ground current, and radiation from the grid would endanger humans and the environment.

The Pentagon last week announced that research breakthroughs had shown that "much smaller, lower power transmitters are possible. Consequently," the announcement continued, "during a further research period, expected to last from 6 months to a year, the Navy will evaluate a number of new potential designs, some of smaller size, some located outside Wisconsin, and some that would cause no more interference problems than present commercial power units and radio transmitters."

Project Sanguine would have required an 800-million-watt power generating installation—probably nuclear-powered. Wires, buried at 3- to 6-mile intervals, would bounce signals of about 45 cycles per second off the Precambrian rock shield that underlies most of northern Wisconsin. The system would cover 22,000 square miles—about 26 counties—and would cost $1.5 billion. It would be virtually bombproof.

The Navy had said earlier that electrical radiation would be given off by the grid, as well as an indefinite quantity of low-frequency rays and heat, but officials had insisted that a $175,000 study by Hazelton Laboratories, of Falls Church, Virginia, had shown no bad side effects. Opponents fear that wire fences in the area, which Navy officials have admitted may become charged, will carry sufficient power to kill the soil and expose humans and animals to severe shock and perhaps death.

The State Committee to Stop Sanguine, chaired by Kent Shifferd, professor of history at Northland College, Ashland, Wisconsin, was formed this fall to lobby against the system. Shifferd called the Hazelton report "completely inadequate. No ecological survey of the area was done at all." Scientists from the group will examine the report.

Senator Gaylord Nelson, who was governor of Wisconsin when the project was approved 10 years ago, said he was never informed of it. He favors a serious debate in Congress to prove the necessity of the system. "This is a fundamental issue too important to be left solely to the judgment of the Navy," he said.

An aide to Nelson said that 2 years ago the Navy had begun installing a test facility—with 14-mile-long antennas—in a forest near Clam Lake, Wisconsin. That was when state officials and congressmen learned about the project. Then the Navy conducted public meetings around the state. Newspaper articles—most recently a long article in the Milwaukee *Journal*'s Sunday supplement—aroused public opinion.

Wisconsinites made their feelings known to Secretary of Defense Melvin Laird also. Laird had been a congressman from Wisconsin's 7th District from 1952 to 1968. At a meeting last month at Stevens Point, Wisconsin, Laird reportedly was blamed for Project Sanguine.

Representatives Henry Reuss and Robert Kastenmeier and Senator William Proxmire also began to lobby against the project after the Navy had revealed it.

The Navy insisted last week that "under no circumstances" would Sanguine be built unless "it could be built in a manner entirely compatible with its surroundings." Research and development work on Sanguine will continue at a cost this fiscal year of $20 million (bringing the project's budget so far to $38 million); the decision on deployment will be postponed until next year.—NANCY GRUCHOW

support for use of these technologies in higher education would hold for alleviating the problems of rising cost of education and student unrest. Even thus simplified, this assessment effort constituted too formidable a task for the NAE study group to complete within the 9 months available. The group was able only to analyze the impact that one of the four federal-funding strategies would have on such things as instructional quality, the problem of coping with poorly prepared students, the "impersonality" of education and the student-faculty relationship, and individualized instruction. A particular impact was characterized as either favorable, unfavorable, or unknown; as likely or unlikely; as controllable or uncontrollable (by manipulation of federal-funding levels). Some 30 pages of the report are devoted to a discussion of the impact of just the one funding strategy that was analyzed.

The report said that to apply only cause-effect methods to technology-initiated studies "produces a mass of data but few broad conclusions." A better approach, it added, is to "organize the assessment effort so as to obtain supplementary contributions of talented individuals or groups who can intuitively perform analysis and evaluation and thus illuminate potential areas of social impact." It emphasized that "creativity and intuition are highly personal" and that choosing the individuals to take part in technology assessment is a matter of fine discrimination, comparable in a sense to selecting the actors for a play.

The report suffers in places from vagueness. Starr told *Science* that it is vitally important for technology-assessment studies to receive wide public exposure—important both from the standpoint of educating the public and of assuring that the scientists, engineers, and other experts who serve on assessment task forces are kept honest and objective. But, while this latter point may be implied in the report, it is nowhere explicitly mentioned.

There are those, of course, who are skeptical of any kind of technology assessment that would have groups drawn largely from a scientific or technological elite deciding or recommending which new technologies the government should promote or discourage. Harold P. Green, professor of law and director of the Law, Science, and Technology Program at the George Washington University National Law Center, is very much of that mind, though he

Environmental Studies: OST Report Urges Better Effort

A staff report* from the White House Office of Science and Technology recommends that the government encourage universities and colleges to establish multidisciplinary "schools of the human environment," which would be a kind of analog to the schools of agriculture and of public health which have proved so successful as problem-focused research and training endeavors. It proposes that about $20 million in federal funds be provided initially to help interested institutions launch such programs or build upon efforts already under way—and it makes biting observations about purported multidisciplinary programs now supported by federal agencies.

The report was released to the press on 5 November by Lee A. DuBridge, the President's science adviser, who, while not explicitly endorsing the document, said that it deserves serious consideration. It is to be taken up later this month at the next meeting of the Environmental Quality Council, the new cabinet-level body over which President Nixon presides.

The report was prepared by John S. Steinhart, an OST staff member who specializes in environmental matters, and Miss Stacie Cherniack, a White House summer intern who is now a senior majoring in political science at the University of California at Berkeley. If one may judge from the force and clarity of this report, it would be desirable to have an undergraduate assist in the preparation of all government documents.

"The response to various funding programs of the government in defense, space, and a variety of other areas has caused universities to erect a wide variety of institutes, centers, and programs to respond to available funds," the report said. "In most cases these institutes have been largely paper structures, and their impact on the universities and, especially, on the students and the public discussion of the issues surrounding the work has been negligible. Curriculum, faculty rewards, and most of the research have been controlled within the departments representing the narrow academic disciplines. These departments grow narrower and more numerous year by year as the advance of modern science results in increasing specialization. [The new] institutes and centers contrast strongly with the history of agriculture and public health [programs] in which curriculum, faculty, and research were centered in schools that were nearly autonomous."

The report is based on the authors' discussions with faculty and administrators connected with multidisciplinary programs at more than 30 universities and on their visits to 6 universities (unnamed in the report) deemed to have had some success in mounting such programs. "Research done under the auspices of institutes or centers is most frequently done within existing departments, and it is only the sum of research that is interdisciplinary because each individual project is divided into the disciplines and pursued independently," they said.

According to the authors, those few centers or other units found to have genuinely effective multidisciplinary programs all had two things in common—they had substantial influence or complete control over faculty hiring, promotions, and other rewards, and they enjoyed flexibility in introducing new course work and curricula and in devising degree programs. Also, in most cases the successful programs were found to have the direct support of one of the university's more senior administrators who could help provide resources and protect the programs from "traditionally minded faculty members."

"Genteel Lying and Cheating"

The authors found that the federal government itself was held partly to blame for the failure of multidisciplinary programs. "A common complaint we heard at all the universities visited," they said, "was that there was a general lack of funds available for such wide-ranging interdisciplinary programs. What the heads of most of these institutes found themselves doing was going through a process of genteel lying and cheating in order to get money for their programs. Oftentimes, it was necessary to emasculate the programs in order to suit the specifications for federal funding."

All this the authors regarded as a shame, for they found great interest among both students and faculty in problem-focused environmental studies. According to the report, between 10 and 20 major universities already have programs of studies of this kind far enough along to be ready for federal funding. And, it said, more than 200 other institutions have expressed "vigorous interest" in starting such programs and should be given planning grants. Federal support, the authors said, should provide continuing but modest "core funding" for the programs' research and education activities as a whole; "seed money" for faculty salaries and for educational innovation as programs are being started; and student aid, at levels sufficient to enable mature people who have worked professionally on environmental problems to return to the university for further studies.

According to the report, about half of the $20 million which would be needed to start or plan the new programs could come from funds already available to federal agencies such as the departments of Interior, Transportation, HEW, and HUD, and the National Science Foundation. "It is our firm opinion," the authors said, "that the government would get more return for its money in programs of this sort than they now get from some of the existing training grants and contract research." NSF is hoping that Congress will allow it at least $6 million in fiscal 1970 for problem-focused multidisciplinary programs, some to be concerned with the environment.

The report said that there should be strong interaction between the federal funding agencies and the universities in the development of the multidisciplinary programs—a point which DuBridge found "particularly interesting." And, in order to improve chances that the agencies would administer the grants effectively, this function should be carried out under the policy guidance of the Environmental Quality Council and of a special interagency group, the authors said.—L.J.C.

* Entitled, "The Universities and Environmental Quality—Commitment to Problem Focused Education," may be obtained for 70 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

reacts more favorably to the idea of a technology assessment that is limited to an analysis of alternative policies and that stops short of recommending a particular course of action.

Green has proposed, to the horror of some, that Congress set up an ombudsman agency that would investigate all potentially harmful consequences of new technologies and call these to the attention of Congress and the public. Chauncey Starr regards this proposal to set up a devil's advocate as one which would represent simply another futile atempt to decide technological questions through an adversary proceeding. "Such a proceeding always produces a winner," says Starr, "but the winner may be wrong."

However, in describing the benefit-risk "calculus" used by government agencies in pressing new and sometimes dubious programs of technological development, Green makes a point which the advocates of technology assessment would do well to ponder soberly. In a talk given recently at a conference on law and the environment sponsored by the Conservation Foundation, Green said the problem of risk tends to be minimized through the following process of reasoning: "(i) we do not have enough scientific knowledge to tell us whether or not the risks are really significant, but our present judgment is that the risks are insignificantly small; (ii) as the project goes forward, further research will be undertaken to verify our judgment that the risks are insignificantly small; (iii) whatever risks do exist can be reduced to tolerable dimensions through technological devices; (iv) if the risks indeed are found to be be, and remain, significant, the program will of course be abandoned or drastically restricted or controlled to protect the public interest. QED." (This calculus is precisely the one followed by the Atomic Energy Commission recently in proceeding with its plans to conduct a series of unprecedently large underground explosions on Amchitka Island, in the earthquake-prone Aleutians.)

How much help is technology assessment going to be when, as will often be the case, the benefits of a proposed technological development are far better known than the risks? Starr says that one of the advantages of technology assessment is that it promises to point up information gaps. But the recognition of such gaps in the past has not brought about a noticeable slowing of the pace of technological developments, some of which (such as the continued widespread use of persistent pesticides) may yet lead to environmental or social disasters.—LUTHER J. CARTER

Atlantic Community: G. Swinger Takes Part in Discussions

The Supranational Committee is one of various organizations created in recent years to encourage scientific and technical cooperation in the Atlantic Community. Its most recent meeting produced a wide-ranging discussion of problems within the committee's jurisdiction, and Science *is pleased to present a summary report of that session.*

The meeting opened with a presentation by Dr. Grant Swinger (director, Center for the Absorption of Federal Funds, U.S.A.). After expressing appreciation for being given an opportunity to address the group, Dr. Swinger declared that Europe must look after its own needs and resist American influence. Dr. Swinger added that, in view of conditions in the United States, his organization was considering an expansion of international activities. While American dominance is to be avoided, he said specialized American skills should be looked at carefully, and, for this purpose, his organization was prepared to offer its services. "We can make available much valuable experience," he stated. (Brochures were distributed.)

The next speaker, M. Embrouiller, stated that the views he was about to express were neither his own, those of the organization by which he was employed, nor those of his government. Any further action by the committee, he said, should be temporarily suspended, though he emphasized that study and consultation should proceed. Germany, he pointed out, has just elected a new government. France has a relatively new government. Britain will hold an election within a year or so. In addition, he said, Germany recently revalued the mark. All this being so, he continued, the present moment is not propitious for undertaking significant action. (Dr. Swinger rose to express agreement, but was ruled out of order while attempting to explain that the time was ripe for an extensive study, which his organization was prepared to undertake on brief notice. Additional brochures were distributed.) M. Embrouiller continued. He said he did not wish to be misunderstood. Cooperative activity merited the highest priority. "The question was not whether to proceed, but when to proceed. Not should we proceed, but how should we proceed. Not can we proceed but how we cannot not proceed. Not the wisdom of proceeding, but the folly of not proceeding. Not . . . ." (At this point, the chairman whispered to the speaker.) Continuing, M. Embrouiller said that the present moment is simply not the right moment. He added that, in his initial presentation, he had omitted to mention the fact that Norway, the Netherlands, Denmark, Greece, and Italy will be holding elections at the national or local levels within the near future. His failure to mention these nations in his opening remarks, he emphasized, should not be interpreted in a prejudicial manner, as relations between these nations and his own had long been characterized by cordiality.

M. Embrouiller, in reply to an inquiry from the Norwegian delegate, said that he did not know when elections would take place in Norway, but that he would be pleased to make the information available as soon as possible. The Greek delegate emphatically denied that any elections were planned in his country. M. Embrouiller immediately extended an apology, citing the cordial relations that existed between the two countries.

Turning to substantive matters, the