10. It is worth noting that earlier accounts of point velocity thresholds describe a minimum at about 60 to 180 minutes of visual angle per second; see W. E. Hick, *Quart. J. Exp. Psychol.* **2**, 33 (1950); J. M. Notterman and D. E. Page, *Science* **126**, 652 (1957); J. M. Notterman, G. A. Cicala, D. E. Page, *ibid.* **131**, 983 (1960). These studies all involved isometric, 1.5-inch stimulus traverses, whereas the current study has 1 inch as a maximum. Therefore, our best guess as to the basis for the presence of a minimum Weber ratio concerns the length of stimulus traverse, probably as it influences duration of exposure regardless of mode of exposure. Data are available from a pilot subject which support this conjecture, in that Weber ratios were decreased by approximately half in going from 0.4 to 0.6 second of isochronal stimulus rate duration.
11. Two oscilloscopes (Tektronix model 535 and Hewlett-Packard model 130-A) were used to present identical, electronically generated stimuli to the two subjects simultaneously. Both oscilloscopes were fitted with P11 5-inch cathode ray tubes having relatively short persistence traces. Each oscilloscope's tube face illumination was adjusted to a low level of brightness (0.0057 millilamberts) and supplied the only ambient illumination in the otherwise dark subjects' cubicle. The spot-stimulus was 0.03 inch in diameter, and 0.029 millilamberts in brightness.
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15. Although the precise values of the thresholds obtained might differ under *contracting* conditions for the line (as well as for the circle), and for point movement from right to left instead of from left to right, we have no substantial reason to believe that the ordering of thresholds reported here would be altered.
16. A 400-hertz modulator was used in conjunction with PRO-203W RCA electroluminescent panels, cropped to 1 by 2 inches, to generate stimuli of varying luminance. A dimly illuminated fixation cross, etched on a Plexiglas plate, was centered on each panel. For the three standards, the maximum driving voltages were 120, 240, and 600 volts, respectively.
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The Scientific Advisory System: Some Observations

This system has little effect on the broad technical decision made in Washington.

Martin L. Perl

Since World War II, scientists and engineers have been going to Washington in increasing numbers to help the government make decisions on technical questions. These questions concern every aspect of our technological society—nuclear weapons, missiles, space travel, cancer research, pesticides, and mental health. Some scientists and engineers go for 1 or 2 days a month; others take a leave of absence from their institutions or corporations and spend several years in Washington. Some serve on committees attached to the executive branch of the government; others serve through semigovernmental institutions like the National Academy of Sciences. A few work with the Congress. All of these scientists and engineers, the committees they serve on, and the positions they hold in Washington together constitute the scientific advisory system (*1*). This article is about that system, or more precisely, about a paradox connected with that system.

The paradox is easily presented. Most people will agree that the United States is besieged with perilous technological problems—how to stop the arms race and bring about nuclear disarmament, how to stop the technological destruction of the natural environment, how to raise the standard of living, or at least prevent mass starvation, in the poor countries. Most people will also agree that these problems have become much more severe in the last two decades. But in these same two decades, the United States has received enormous amounts of scientific and technical information and advice from the scientists and engineers of this country. This information is almost always technically correct and thorough; it is almost always given with the intention of solving or mitigating the problems sketched above. The paradox is simply this: How have we gotten into so much technological trouble while getting so much well-intentioned and correct technological advice?

A broad analysis of this paradox might require a study of the relationship between the scientific advisory system and the "technostructures" postulated by Galbraith (*2*). Or one might examine whether the advisory system is an example of the "techniques" that Jacques Ellul (*3*) believes are the essence of our technological society. However, I restrict my analysis to a discussion of the role played by the advisory system in the technical decision-making processes in Washington. In addition, I do not attempt to present a complete description and evaluation of the scientific advisory system, nor do I discuss the role of the scientific advisory system in the larger decisions on military technology.

Few people realize the size and complexity of the scientific advisory system, and I know of no complete study of the magnitude and structure of this system. Therefore, I refer here to a recent, but not exhaustive, study (*4*) that was carried out by a group of Stanford graduates and undergraduates, for whom I was faculty adviser. The study notes that the Executive Office of the President has advisory committees that involve several hundred prominent scientists and engineers. The best known of these committees is the President's Science Advisory Committee. Outside the Executive Office of the President, but inside the executive

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branch of the government, is a much larger advisory apparatus. This apparatus consists of thousands of scientists and engineers who serve on hundreds of committees, as well as in various temporary positions. Primarily, they advise the Department of Defense and other departments concerned with scientific, technical, or medical questions.

Semipublic institutions also provide a great deal of advice to the executive branch. For example, the National Academy of Sciences and the National Academy of Engineering, through the National Research Council, supervise the work of about 500 committees involving 7000 engineers and scientists. Other large sources of advice are the "think tanks." The Rand Corporation advises the Air Force, the Research Analysis Corporation advises the Army, the Center for Naval Analysis advises the Navy, and the Institute for Defense Analysis advises the entire Department of Defense. Taken together, these public and semipublic advisory groups involve more than 15,000 or 20,000 individual scientists and engineers.

On the other hand, very little scientific advice is given to Congress. Some technical information and advice is obtained through panels or committees attached to congressional legislative committees, and a few individual congressmen, particularly senators, receive some unofficial advice and information. Finally, the Science Policy Research Division and the Environmental Policy Division of the Legislative Reference Service provide reports and summaries on technical questions. But the total amount of scientific and technical information and advice given to Congress is very small compared to that given to the executive branch.

The Scientific Establishment

There is a large overlap between the scientists who lead the advisory system and the scientists who belong to what has been called by a sympathetic observer (*5*) the "scientific establishment." The scientific establishment comprises most of the prominent scientists and research engineers in the United States. Many of these individuals are deeply involved in science administration and in the making of science policy, both public and private. But usually their prominence has been attained through research rather than through administration or teaching. The scientific establishment has five functions or attributes.

1) Many members of the establishment are the heads of professional societies, the heads of university or industrial laboratories, and the chairmen of university science departments. Many are or have been university deans and presidents. Thus, the members of the establishment tend to be the administrators of the worlds of scientific and engineering research and education.

2) Members of the establishment represent their professions, institutions, and organizations before the federal government in requesting funds for research and education.

3) In the eyes of the press and the public, the establishment represents science and advanced technology. It is the members of the establishment who are most often interviewed and quoted. This comes about in part from their accomplishments and in part from their administrative positions.

4) Members of the establishment are the models for young scientists and engineers interested in research.

5) The establishment tends to guide the directions that research takes. This promotes the classification of a research subject as fashionable or unfashionable. This is a useful function in that it encourages researchers to leave unproductive fields, but it can also create difficulties for iconoclasts.

The scientific establishment is by no means a closed or fixed group. Not all eminent scientists and engineers are in the group, and individuals move in and out of the group as their attitudes and interests change. It should also be recognized that the establishment is not always united on issues—particularly on the allocations of funds for research.

Evaluating the Advisory System

I am mainly concerned with evaluating what I call the specific effectiveness of the scientific advisory system. Specific effectiveness is the measure of how well the system carries out its specific functions in the government. As I have already indicated, these functions are set almost entirely by the executive branch and are carried out almost entirely for the executive branch. One specific function is the gathering of information and the presentation of recommendations on limited, purely technical problems. Thus, an advisory committee might be instructed to determine if a newly discovered physical phenomenon could be used to detect submarines. Another specific function is an advisory committee's being asked to recommend a general governmental policy on a technical issue, for example pesticides.

I am also concerned with the general effectiveness of the scientific advisory system. By general effectiveness I mean the total and overall effectiveness of the advisory system in relation to the general processes of making technical decisions. In this country, technical decisions, like other governmental policy decisions, are arrived at through a complicated process. Formally, the process involves the executive branch and the Congress, but in reality much more is involved. Before a decision is made, the question may be argued in the press and by the public. The question may become an important issue in political campaigns for elective office. State and local governments may become involved and take the lead in making a decision, or they may impede a decision. Often the crucial decision is made in the courts, and only later does Congress extend it in the form of legislation. This is by no means a linear process, and most issues have to pass through it several times before they are resolved. This totality, then, comprises the processes by which decisions, including technical decisions, are made in this country. By examining the relationships of the scientific advisory system to these processes, one can determine the general effectiveness of the advisory system.

An evaluation of the scientific advisory system is greatly impeded by the confidentiality of the advising process. The advice given to a government official or to a governmental agency is almost always received under the condition that it may be kept confidential by the official or agency. That is, the advice need not be released to the press, to the public, to Congress, or even to other parts of the executive branch. Large numbers of advisory reports are made public; but, unfortunately, it is just those reports which concern the most controversial and the most important technical questions that are often never made public, or only after long delay. This is unfortunate, not only for those who wish to study the advisory system, but, more important, for the process of making technical decisions in a democracy.

The largest portion of the work of the scientific advisory system is devoted to limited technical questions. "How does method A for water desalination compare in energy requirements to method B?" "How does missile guidance system A compare in reliability to missile guidance system B?" It is with these limited technical questions that the advisory system is most successful. This success results from the competency of the advisers and from the great amount of effort that is applied to these problems. Thus, the advisory system ranks high in specific effectiveness, with respect to limited technical questions.

But suppose the questions are not limited and are not purely technical. Suppose that another specific function of the advisory system, the recommendation of general technical policies, is involved. Or suppose that the technical decision has public policy, economic, or ideological implications. Such questions I shall call broad technical questions. These broad, technical questions severely test the specific effectiveness of the scientific advisory system.

Environmental Questions

The Stanford Workshop (*4*) studied six broad, technical questions related to the environment and public health: the supersonic transport (SST), cyclamates, the safety of commercial nuclear power plants, the safety of underground nuclear tests, pesticide regulation, and herbicide use in Vietnam. On broad technical questions, the work of the advisory committees may be divided into three parts. First, the committee studies the technical and scientific aspects of the question. Here, as in limited technical questions, the committee generally exhibits high effectiveness.

The second part of the committee's work is usually the development of a program for further study and research. In this, the local effectiveness of the advisory system seems to be reasonable but not high. For example, the 1963 report of the President's Science Committee, entitled *Use of Pesticides* (*6*), recommended an extensive research program to study the safety of pesticides. Many of those research recommendations appear to have been carried out. On the other hand, the government rejected an advisory committee recommendation that additional study be devoted to the safety of some types of commercial nuclear reactors before those reactors were licensed for use (*4*).

The third part of the advisory committee's work on broad technical issues usually involves recommendations that certain technical policies be adopted by the executive branch. *Use of Pesticides* recommended that there be an "orderly reduction in the use of persistent pesticides" and that, as a "first step," the government "restrict wide-scale use of persistent pesticides [such as DDT] except for the necessary control of disease vectors." With respect to such policy recommendations, which I call action recommendations, the effectiveness of the advisory system is low. The executive branch will usually ignore the policy recommendation of the advisory committee if (i) the recommendation is contrary to existing policies of the executive branch, (ii) the adoption of the policy would expose the Administration to congressional or electoral difficulties, or (iii) there are strong pressures from special interest groups that are opposed to the new policy. These pressures may often be traced to industries, labor unions, or municipalities, which think their economic well-being depends upon the continuation of the existing policy. In some cases, such as those related to atomic energy, the recommendations of the advisory committee may also be opposed by strong technological interests within the government itself. As an illustration of the failure of an action recommendation, consider the 1963 recommendation that the widespread use of DDT be drastically reduced: this "first step" has yet to be completed in 1971. Its beginning is the result of 8 years of public pressure and of litigation by environmental and consumer groups.

As another illustration of the fate of action recommendations, consider the SST (*7*). In the beginning of 1969, as the controversy over the SST began to increase, President Nixon appointed an advisory committee to study the issue. This was a rather high-level committee, involving the undersecretaries of many federal departments. The committee and its subcommittees were charged with studying not only the technological and environmental aspects of the SST, but also the economic, balance of payment, and international aspects. The appointment of the committee was attended by much publicity that emphasized the Administration's concern with the problem. In March 1969, the committee presented a report that was almost entirely unfavorable to the SST. Lee DuBridge, a committee member and the President's science adviser, wrote (*8*):

> Granted that this [the SST] is an exciting technological development, it still seems best to me to avoid the serious environmental and nuisance problems and the Government should not be subsidizing a device which has neither commercial attractiveness nor public acceptance.

In spite of this strong disapproval, the President and his Administration continued to support the SST fully and enthusiastically. To prevent the report from being used by the opponents of the SST, it was kept confidential, even though there is nothing in it having to do with national security or military matters. Not even Congress, which had to decide on future SST appropriations, was allowed to see it. Only in October 1969 was Representative S. R. Yates (D–Ill.) able to obtain partial release of the report.

It is reasonable to require, as one of the tests of the specific effectiveness of the scientific advisory system, that the executive branch be fairly responsive to the policy recommendations of its advisory committees. Furthermore, the crucial test is its responsiveness to action recommendations. By this test, the advisory system has substantially failed on broad technical issues.

Failure on Broad Technical Issues

While some observers will agree with me that the scientific advisory system has not done well on broad technical issues, they argue that the advisory system has accomplished all that could be done. These supporters point out that there are immense political, economic, and ideological pressures that prevent rational decisions on the environment and public health. However, other groups have made progress against these pressures. For example, there is a strong environmental and consumer protection movement in this country. The originators and leaders of this movement are people like Rachel Carson and Ralph Nader, not members of any strong self-interest group. While there are scientists and engineers in this movement, few of them are members of the scientific establishment. Thus, we are still faced with the question of why the advisory system, with its large membership, its great technical and scientific competence, and its prominent men, has not been more successful on the broad technical issues.

There are a number of reasons for the system's lack of specific effectiveness on these issues.

1) *The many functions of the scientific establishment.* The functions and attributes of the scientific establishment severely limit the influence of the advisory system. In a democratic country such as ours, important decisions are not made through a set procedure of debates and position papers, but through a long and messy process. The scientific establishment, because of its functions of representing and protecting research and technical education, is reluctant to take part in much of this process. Usually its members enter the decision-making process through the advisory system at only one point—when the Administration is considering a technical issue. For this reason, the influence of members of the scientific establishment is easily negated. The withholding of reports from the public is just one aspect of that process of negation.

2) *Confidentiality and legitimization.* I have emphasized that the information and advice provided by the advisory system can be declared confidential by the official or agency that receives it, and that it is up to the official or agency to release the information. Although every government official is certainly entitled to some completely private and permanently confidential advice, the problem is that the use of confidentiality is so widespread that very often the only technical reports available on the subject are declared confidential. In that case, the press, the public, and the Congress are left with very incomplete technical information. Thus, on technical issues, the decision-making process is seriously impeded and, in many cases, the system of checks and balances nullified.

There is another aspect to the confidentiality of the advice given by the advisory system. The press, the well-informed citizen, and the Congress know that the executive branch obtains vast amounts of correct technical information and advice. They know that this advice comes from the best and most prominent scientists and engineers in the country. The final technical policy decisions made by the executive branch become associated with this knowledge. One thinks either that the technical advice has been followed or that it has been seriously considered and then overridden by other, more serious and more profound considerations. Thus the scientific advisory system, as presently constituted, provides a facade of prestige which tends to legitimize all technical decisions made by the President.

The executive branch is well aware of the legitimizing effect of the advisory system. For example, public concern about a technical issue can often be mollified by appointing a committee to study the issue in detail. There is often the hope that, by the time the report appears, public pressure will have decreased. Indeed, this technique extends far outside the sphere of technical issues. If the report appears and is favorable to the policies of the executive branch, it can be released with much publicity. Otherwise, the principle of confidentiality can be imposed. Even an unfavorable report can be used by releasing not the report itself, but a distorted summary of it. Just such a maneuver was used (*4*) with the unfavorable report on the SST.

The legitimizing aspect of the advisory system is eliminated only when some members of the system directly or indirectly disregard the principle of confidentiality, for example in testimony before Congress on the antiballistic missile and the SST. However, such actions are still rare.

3) *Socialization in Washington.* The basic way to get something done in the executive branch is to work from the inside. This means that one must be practical and hardheaded. One must work for small gains and progress in small steps. For the adviser it is a slow process, with respect to both his influence and his achievements. The adviser works first in less important committees on more restricted issues. As he demonstrates his ability, his reliability, and his reasonableness, he progresses to more important committees and to more important issues. But when he finally achieves a position of influence, his freedom to act is quite limited. This limitation comes not from any rules, but from the methods he learned while working with the executive branch. Thus, in order to retain his position of influence, he may not protest some decisions he intensely dislikes. He wants to reserve his influence for some other issue upon which he has concentrated his interest. Ultimately, the adviser may fall into the trap of considering, above all else, the technique of preserving his influence in Washington [I use the term "technique" here as it is used by Ellul (*3*)].

Socialization explains a number of things. It explains, for example, why the principle of confidentiality is so universally honored in the advisory system. The socialization also explains why the legitimizing effect is so strong. I note again that this socialization in Washington is something that happens to economists, accountants, labor leaders, and businessmen as well as to scientists and engineers. I only emphasize it here because we scientists tend to think that our objectivity and our scientific training constitute a magic cloak that protects us from socialization. It does not.

I have given some of the reasons that the scientific advisory system has a great deal of specific effectiveness on limited technical questions, yet little specific effectiveness on broad technical questions. Now what about the general effectiveness of the scientific advisory system? How does it enter into the decision-making processes for general technical questions in this country? The answer is evident from my discussion: the advisory system does not usually enter into the decision-making processes for general technical questions. Thus its general effectiveness is very low, the only exceptions being when individual members of the advisory system testify before Congress or work with congressmen. But most members of the advisory system do not believe in working in the decision-making process outside of the executive branch. They believe that, if they increase their general effectiveness, they will decrease their specific effectiveness.

The Scientific Community

My colleagues in the advisory system have sometimes agreed with the analysis I have presented. But they then say, "All right, we in the advisory system work from the inside doing what we can. Perhaps we are not as effective as you wish us to be. Why don't you work from the outside? There are 10 or 20 thousand people in the advisory system, but there are several hundred thousand scientists and engineers who are not in the advisory system. They can all work from the outside." There are, unfortunately, a number of reasons that this division of labor does not work.

1) *The scientific establishment as a*

model for the scientific community. Those members of the establishment who are in the advisory system are models for the less well-known and younger scientists and engineers. An example of consciously setting a standard of behavior is the recruitment of young theoretical physicists into summer work with the Institute of Defense Analysis. Until recently, it was customary to ask the brightest and most promising young theorists to join in this summer work. Since the invitation was extended by some of the best of the older theoretical physicists, it was very flattering to receive one. Being invited to work with the Institute was, at least for a while, a mark of attainment in theoretical physics.

It is difficult for the scientific community to work on broad technical questions from the outside when the leaders are working from the inside. After all, only a few well-known scientists, men like Pauling, Lapp, and Commoner, work on the outside. Therefore, scientists who wish to serve the country in the technical decision-making process have tended to join the advisory system. In the last few years, there has been some opposition to this tendency, primarily from the environmental and consumer movements and from the various student movements.

2) *The "don't rock the boat" attitude.* I have pointed out that the multiple functions of the establishment and the overlap of the establishment and the advisory system cause a very cautious attitude among advisers. There is a widespread feeling that the advisers should not oppose the technical policies of the Administration too vehemently or too publicly. If they do, members of the establishment fear, federal or even public support for science research and education may be adversely affected. There is certainly some truth in this fear.

This "don't rock the boat" attitude extends into most of the scientific community. This is partly because of the model of behavior set by the establishment; but there is a more compelling reason for this attitude. The natural way for the scientific community to critically and publicly examine the government's technical policies is to use the independent scientific institutions—the professional and scientific societies and the engineering and science departments of universities. Yet these are just the institutions that are being protected by the "don't rock the boat" attitude. For this reason, the scientific community and the scientific establishment will not use independent institutions in the technical decision-making process. It is usually said that these institutions must be kept "neutral."

3) *Professional rewards for service in the advisory system.* There is a grave imbalance between the professional rewards (other than direct monetary rewards) for helping the government make technical decisions from the inside and the rewards for helping from the outside. Almost all universities encourage the public service activities of their faculties if these activities bring honor or influence to the university; teaching or administrative duties may be reduced to allow for them. But almost always, these must be official public service activities. Working within the scientific advisory system is official public service, but, except for a very few universities, working with unofficial neighborhood or consumer groups to reduce the pollution from a local factory is not considered public service. Thus, for the energetic, ambitious young faculty member who wishes to help in the making of technical decisions there are strong career pressures that push him into the advisory system.

Even for the senior scientist the advisory system has career rewards. To be in Washington, to work with other members of the establishment, and to get to know government officials can be of help in a number of ways. It is helpful when seeking funds for a department or for the research of younger people. It also makes a scientist more influential in his home institution.

4) *The "it's in good hands" attitude.* Consciously and unconsciously the members of the advisory system often present the attitude that the role of the scientist and engineer in the technical decision-making process is completely filled by the advisory system. This often takes the form of such statements as, "Don't worry about it, it's in good hands." It is often implied that the members of the advisory system are professional experts on this or that technical question. Other scientists or engineers who are outside the advisory system are regarded as amateurs. This attitude depresses attempts by the scientific community at large to enter the technical decision-making process. It also encourages government officials to ignore scientists and engineers who are not in the advisory system.

Summary

The scientific advisory system is effective on limited technical questions, and such questions provide much of its work. On broad technical questions, however, the scientific advisory system is not effective. Unfortunately this category includes most of the crucial environmental questions. Finally, the advisory system, as presently constituted, combined with the multiple functions of the scientific establishment, is detrimental in important ways to the process of technical decision-making in this country. This is because the combined effect of the advisory system and the establishment is to impede the development of a more effective and comprehensive role for the scientific community in the technical decision-making process.

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