The cultural changes that were involved in the gradual domestication of the cereal grains and legumes cannot be reconstructed from archeological evidence in any detail, and for the present hypothesis they are not critical. The principal point is that geologic, climatic, biologic, and cultural conditions in the foothills of the Zagros-Taurus Mountains 11,000 years ago or shortly thereafter were for the first time combined in a manner favorable for plant domestication. The success of the cultural transformation that ensued is attested by the relatively rapid spread of agriculture to other parts of temperate Eurasia, and by the increased complexity of sociopolitical organization in the Near East based on an agricultural economy.

If the Mediterranean-type vegetation, including the three cereal grains and legumes in question, thrived in the late Pleistocene in some refuge such as northwestern Africa, one might reasonably ask why these plants were not domesticated there and then. Perhaps the other elements in the formula were not suitable. Moroccan prehistory is not well known. Certainly there is no record of domesticated plants until long after the events described here (*28*). In any case, it should be possible to design archeological and paleoecologic studies in Morocco—especially in the Atlas Mountains—to test many aspects of the hypothesis.

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30. I thank R. J. Braidwood of the University of Chicago for supporting my field studies in the Near East, and numerous colleagues on those and subsequent occasions, notably Willem van Zeist, Charles A. Reed, Jack Harlan, Patty Jo Watson, Richard A. Watson, and Charles Redman, for helpful discussions. Useful critiques were also offered by G. E. Gibbon and anonymous reviewers.

Science, Values, and Human Judgment

Integration of facts and values requires the scientific study of human judgment.

Kenneth R. Hammond and Leonard Adelman

Scientists and policy-makers are uncertain how scientific facts are to be integrated with social values. For their part, scientists are uncertain whether their contributions should be restricted to presenting the facts, thereby leaving the policy judgment entirely to the political decision-makers, or whether they should also advise politicians which course the scientist believes to be best. And politicians, for their part, are uncertain how much scientific information they are supposed to absorb, and how much dependence they should place on scientists for guidance in reaching a judgment about policy (*1*). As a result, "the scientific community continues its seemingly endless debate about the role of science and scientists in the body politic" (*2*).

One principal reason for the "endless debate" is that scientific progress has increasingly come to be judged in the context of human values. These judgments find their ultimate expression in the forming of public policy because it is during that process that the products of science and technology are integrated, or aligned, with human values; it is during that process that scientific and technological answers to questions of what can be done are judged in the context of what ought to be done.

The key element, therefore, in the process of integrating social values and scientific facts is human judgment—a cognitive activity not directly observable and generally assumed to be recoverable

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only by (fallible) introspection and "self-report." These characteristics, among others, have led to the general belief that human judgment is beyond scientific analysis and therefore little has been learned about the cognitive activity that produces crucial decisions. The integration of social values and scientific information in the effort to form public policy remains largely a mystery.

The fact that an essential element in the policy formation process remains a mystery has serious consequences, one of which is a search for safeguards. Means must be found to avoid both poor judgments and self-serving judgments. Two general methods have been recommended by scientists for these purposes: (i) the adversary method, in which scientists with differing judgments are pitted against one another in front of a judge or jury, or both, and (ii) the search for and use of scientists who have somehow gained a reputation for wisdom in the exercise of their judgment. Neither of these methods provide enlightenment with regard to the judgment process that produces the ultimate decision. Consequently, we reject both methods because they are "ascientific"; they leave the body politic at the mercy of a cognitive activity which remains as much a mystery as ever.

We contend that policy judgments can be brought under scientific study and, as a result, a process that is now poorly understood can be examined, understood, assisted, and thereby improved. To support this contention we describe a scientific framework for integrating (i) scientific information (the province of scientists) and (ii) social value judgments (the province of the electorate and their representatives) in a manner that is scientifically, socially, and ethically defensible, and offer an example of its use. First, however, we briefly consider two contrasting viewpoints concerning the role of science and scientists in the body politic.

Contrasting Viewpoints of the Role of the Scientist

There are two main viewpoints; one is that scientists should merely present unbiased information, while the other is that scientists should provide advice with regard to the implications of scientific information. The first view can be illustrated by the comments of Phillip Handler, president of the National Academy of Sciences (NAS), in an interview with Otten, of the *Wall Street Journal*. Otten (*3*) writes: "Once the scientific community has presented the facts, however, it must leave final decisions to the policy-makers and the public, Mr. Handler asserts. 'Science can contribute much to enhancing agricultural production, but American policy with respect to food aid is not intrinsically a scientific question.' Similarly, science can study whether energy independence is technically feasible or whether Soviet underground nuclear tests can be detected, but [Handler] insists, [scientists] must then let regular policy-makers decide whether to try for energy independence or just what arms control proposals to put to the Russians." Otten concluded that "Both science and government seem well served by this reasonable man."

Handler's viewpoint as represented in the above quotation is exactly in accord with the two Executive Orders (1918, 1956) concerning the role of the National Research Council. These documents indicate that scientists are to render information to those who are entitled to receive it, but they do not imply that scientists should offer their judgment as to what public policy should follow from their studies.

In practice it may be impossible not to offer such judgments. With the ever-increasing reliance of society on science and technology it is difficult to imagine how modern scientific information could be conveyed to nonscientists without providing such judgments. In a recent editorial in *Science*, Boulding (*4*) argued that if policy judgments were not offered by scientists, they would be demanded by politicians.

> Every decision involves the selection among an agenda of alternative images of the future, a selection that is guided by some system of values. The values are traditionally supposed to be the cherished preserve of the political decision-maker, but the agenda, which involves fact or at least a projection into the future of what are presumably factual systems, should be very much in the domain of science. . . . [But] if the decision-maker simply does not know what the results of alternative actions will be, it is difficult to evaluate unknown results. *The decision-maker wants to know what are the choices from which he must choose* [italics ours].

Toulmin (*5*, pp. 102–103) goes further than Boulding. Whereas Boulding notes that politicians may demand policy judgments from scientists, Toulmin argues that it may be part of the scientists' responsibility to offer policy judgments before such judgments are requested by political decision-makers. Thus, "In the early days, the picture was always of the politician as the man who *first* formulated for himself questions about the political options, about the choices he had to make: on this view, he *subsequently* turned to people called 'technical advisors' and asked them how to do this or that, how much each option would cost, and so on. A lot of people still see the relationship between the scientist or technologist and the politicians on this model. . . ." But, Toulmin observes, ". . . even during [World War II] scientists were being transformed into people who could very often see a fresh range of policy options *before* the politicians could." Significantly, Toulmin notes that "To some extent, the institutional relationships between politics and science have not yet caught up with this change."

Thus, Toulmin points out that the decision-maker not only wants to know "the choices from which he must choose," as Boulding put it, but he also wants to know which choice the scientist thinks he should choose. Senator Muskie's call for a "one-armed scientist" (one who would not qualify his advice with "on the other hand") exemplifies the politician's demand for an unequivocal answer to the question of what ought to be done as well as to that of what can be done.

This situation has not escaped the attention of students of the role of scientists in the formation of public policy. The presence of, the demand for, and the exercise of value judgments has led to a sharp focus on the values, and thus on the motives, of the scientists who participate in the preparation of NAS reports that affect public policy.

The Focus on Scientists and Their Motives

In his book *The Brain Bank of America* (*6*, p. 54) Boffey attributes self-serving motives to scientists who provide information and advice to the government within the framework of NAS committees, and thus questions their objectivity and honesty. For example:

> The Academy claims that the most distinctive feature of its committees is that they are independent of any pressures of special interests. . . . But the Academy's record in recent years suggests that its protestations of Supreme Court impartiality should not be taken at face value. In actual practice, many of the Academy's reports have been influenced by powerful interests that have a stake in the questions under investigation.

Boffey admits, however, that "We found no cases of direct, personal conflict of interests at the Academy—no cases, for example, where a committee member profited financially as a direct result of the advice he rendered" (*6*, p. 54). The charge that "many of the Academy's reports have been influenced by powerful interests" is directed toward the broader social and political motives which he claims influence scientists' judgments.

The NAS has already accepted the principle that the motives of scientists must be examined. Boffey (*6*, p. 87) notes with approval that the NAS demands a "bias statement" from the scientists who provide information to the government, a report that is intended to reveal one's true interests, as may be inferred from a list of "all jobs, consultantships, and directorships held for the past 10 years, all current financial interests whose market value exceeds $10,000, or 10 percent of the individual's holdings; all sources of research support for the past five years, and any other information, such as public stands on an issue which 'might appear to other reasonable individuals as compromising of your independence of judgment.' " Thus the NAS has already fallen victim to the ethic of the lawyer (and the journalist). Trust no one, is the rule, unless they can offer this negative proof: I am not now, nor have I ever been, under the control of any incentive to lie, cheat, or otherwise compromise my judgment. Whereas this approach may begin with a request for a "self-report" on sources of bias, it seldom ends there, as scientists know all too well. Investigation is undertaken by others, and by other means, precisely because the focus has been successfully turned away from methods to persons and their motives.

The results of the focus on persons and their motives can be seen in Polsby's review (*7*) of Boffey's book. Polsby indicates what the results might have been had he taken a similar approach in his review by raising suspicions about Boffey's impartiality and thus his motives. That is, by using "Boffey's own primary method of demonstration: a glance at somebody's background gives a 'motive' for selected characteristics of his performance," Polsby finds that "Boffey's employer for the writing of this book was Ralph Nader (identified as 'consumer champion Ralph Nader' on p. 186), who of late has gotten rather heavily into the business of sponsoring exposés of establishment-type establishments. . . . Under these circumstances of employment, could Boffey have done other than to produce an attack, no matter how flimsily founded, on the Academy?" (*7*, p. 666).

Polsby's review shows the customary result of such mutual destruction. Boffey's approach, he concludes, "is only good for so much mileage. . . . Arbitrarily imposing the symmetrical assumption . . . that Boffey and the Academy are both fatally incapacitated by conflict of interest has the effect of condemning both the Academy and the book out of hand" (*7*, p. 666). In short, because neither the critic nor those criticized can be trusted, the reader, the consumer, and the public remain buried in doubt as to where the truth lies. Thus, Polsby acknowledges that, "After reading *The Brain Bank of America* I do not know what to think about the Academy as an organization for evaluating the state of scientific knowledge" (*7*, p. 666). In all likelihood, Polsby is not the only reader of Boffey's book who no longer knows what to think about the Academy.

It is precisely because scientists have learned that it is not only fruitless, but harmful, to focus on persons and their motives that they have learned to ignore them in their work as scientists. When scientists look for the truth and the truth appears to be in doubt, neither scientific work nor the scientific ethic requires the investigation of the characteristics of the person working on the problem; instead, they require the analysis of the method by which the results are produced. Unfortunately, in the confusion of the "endless debate" there has been a tendency to forget the scientific procedure and its associated ethics. The focus on persons and their motives has led not only to the filing of bias statements but to the advocacy of the adversary method for the settlement of disputes about the truth—a method which is ascientific not only in its procedure, but in its greater commitment to victory rather than to truth.

Scientists as Adversaries

The concept of a "science court" reached Congress several years ago when Kantrowitz (*8*) urged that members of Congress "appoint a science advocate for (each) side of the story. . . ." He further suggested that a procedure be worked out which would be "modeled on the judicial procedure for proceeding in the presence of scientific controversy." The final judgment would be exercised by a group of scientific judges who would cross-examine each other and challenge each other's position. Kantrowitz's argument is currently being given serious consideration by members of the scientific community. *Physics Today* (published by the American Institute of Physics) recently indicated that a science court was worth trying, as did H. Guyford Stever, director of the National Science Foundation (*9*).

Members of the scientific community are not unanimous, however, in their appraisal of the value of the adversary system, as the following interchange between Platt, Dror, and Waddington in a Ciba symposium indicates (*10*, p. 210):

PLATT: In the U.S. . . . we are beginning to have something called "adversary science," where scientists speak on public issues, doing their best, like lawyers, for a particular side, and then in a later case perhaps doing their best for the opposite side. The hope is that in this kind of open confrontation, as in a court of law, one comes closer to the truth than by having just accidents of committee structure or unanswered polemics decide the matter.

WADDINGTON: I would strongly oppose that way of advancing science.

PLATT: But somebody should make the total case for a nuclear plant, and somebody should make the total case against the plant for environmental reasons, so that we can see all of both sides before we decide.

DROR: Why shouldn't the two sides make two balanced presentations for and against? Why total . . . ?

PLATT: Do you know a better system?

DROR: Yes, reliance on professional judges in courts; and careful policy analysis on television for the public.

PLATT: Who judges the judges?

DROR: Who judges the juries?

WADDINGTON: That is a piece of politics, not a piece of learning. Learning is not advanced by legal procedures.

The above interchange not only indicates a divergence in viewpoint with regard to a science court and illustrates the morass (Who judges the judges? Who judges the juries?) into which scientists can be drawn because of the focus on persons, but it also points to the unproductiveness of the effort. Even if the concept of a science court were to be accepted by scientists, and even if scientists could be persuaded to make the "total case for (say) a nuclear plant" (*10*, p. 201), the adversary procedure would indicate only who had been judged to be the winner in the arena of competing scientific facts and scientific judgments. Integration of scientific judgments with social values would remain buried in the minds of the judges and the juries (and their judges); the "endless debate" would not be terminated.

It remains to be seen whether a science court, with its judges and juries and its ascientific adversary proceedings in which one scientist is pitted against another will be accepted by scientists. In any event, scientists not advocating the adversary method recommend a different ascientific method, the person-oriented approach.

Scientists' Advocacy of the Person-Oriented Approach

When scientists have addressed themselves to the function of human judgment in policy formation they have treated the unexamined intuitive abilities of persons as though they were somehow superior to the scientific method. For example, in its report on technology assessment to the House Committee on Science and Astronautics, the Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering observed (*11*, p. 17) that "applying only cause-effect [i.e., scientific] methods to technology-initiated studies produces a mass of data but few broad conclusions." Apparently assuming that it had no other recourse, the committee called for ". . . contributions of talented individuals or groups who can intuitively perform analysis and evaluations . . . ," an approach which "demands an integrated combination of information and value judgments that cannot always be formulated explicitly."

Not only does the COPEP report illustrate the advocacy of a person-oriented approach to the combination of "information and value judgments" that appeals to the mysterious as a substitute for the scientific method, it provides a clear case of the failure to recognize that it is precisely such person-oriented "combinations of information and value judgments that cannot always be formulated explicitly" that are defenseless against charges of self-serving bias.

Skolnikoff and Brooks (*12*) were critical of the NAS study of science and public policy-making because it suggested that persons who provide science advice should have personal qualities of "intelligence, wisdom, judgment, humanity and perspective" on the ground that "These qualities are so obviously desirable for anybody in a high position that they are hardly helpful criteria." Yet they are as willing as COPEP or the NAS committee to let the process of combining facts and values remain subject to the unexamined vagaries of human judgment. For example (*12*, p. 38):

> Judgment on both technical and nontechnical issues and on their interaction is thus required [on policy issues]; a logically reasoned single answer is not possible. Judgment is necessarily affected by biases, policy preferences, ignorance, differing estimates of the nontechnical factors, and other vagaries. There is nothing wrong with this; it is unavoidable.

But there is something wrong with this, and this situation is avoidable. What is wrong is that both solutions indicated above focus on persons rather than on method, and both confuse scientific and valuative judgments. That is bad practice; it is bad for scientists, bad for leaders in government, and bad for the public that both are trying to serve. It is bad because it condones and encourages confusion of thought and function, substitutes an appeal to the unknown in place of the knowable, and makes scientists easy targets for charges of self-serving bias. The argument advanced by Skolnikoff and Brooks merely puts a brave face on a bad situation, for they imply that because scientific and valuative judgments cannot be separated there is nothing wrong with confusing them. That argument suggests that if such judgments could be separated, it would be wrong to confuse them. We argue that, from the point of view of science, it is not impossible in principle or in practice to achieve such a separation (*13*).

A scientific approach toward the role of judgment would be quite different from the person-oriented approach that is embedded in the adversary system. A scientific approach would emphasize that judgment is a human cognitive activity and is therefore subject to scientific analysis, as are all natural phenomena. The premises of a scientific approach to the relation of science to public policy are: (i) human judgment is a critical part of the policy-making process; (ii) it is a part of the process that remains poorly understood; and (iii) it might well be improved through scientific study. Rather than searching for persons who possess mysterious talents, or indicating that the present situation is unavoidable, the scientific approach to this problem would be similar to the scientific approach to all problems: carry out theoretical and empirical analyses of the process in a manner that is subject to criticism and that provides cumulative knowledge.

The remainder of this article (i) provides an example that illustrates the social costs of employing the adversary system and the person-oriented approach and (ii) outlines a scientific framework for integrating scientific information and social values in the formation of public policy (*14*).

An Example of Contrasting Approaches

In 1974, the Denver Police Department (DPD), as well as other police departments throughout the country, decided to change its handgun ammunition. The principal reason offered by the police was that the conventional round-nosed bullet provided insufficient "stopping effectiveness" (that is, the ability to incapacitate and thus to prevent the person shot from firing back at a police officer or others). The DPD chief recommended (as did other police chiefs) the conventional bullet be replaced by a hollow-point bullet. Such bullets, it was contended, flattened on impact, thus decreasing penetration, increasing stopping effectiveness, and decreasing ricochet potential.

The suggested change was challenged by the American Civil Liberties Union, minority groups, and others. Opponents of the change claimed that the new bullets were nothing more than outlawed "dum-dum" bullets, that they created far more injury than the round-nosed bullet, and should, therefore, be barred from use. As is customary, judgments on this matter were formed privately and then defended publicly with enthusiasm and tenacity, and the usual public hearings were held. Both sides turned to ballistics experts for scientific information and support.

Adversary, Person-Oriented Approach

From the beginning both sides focused on the question of which bullet was best for the community. As a result of focusing on bullets and their technical ballistics characteristics, legislators and city councilmen never described the social policy that should control the use of force and injury in enforcing the law; they never specified the relative importance of the societal characteristics of bullets (injury, stopping effectiveness, or ricochet). Instead, the ballistics experts assumed that function. When the legislators requested their judgment as to which bullet was "best," the ballistics experts implicitly indicated the social policy that should be employed. That is, in recommending the use of a specific bullet, they not only implicitly recommended specific degrees of injury, stopping effectiveness, and ricochet, but also recommended a social policy regarding the relative importance of these factors. In short, the legislators' function was usurped by the ballistics experts, who thus became incompetent and unauthorized legislators—incompetent because of their lack of information about the social and political context in which a choice would be made; unauthorized because they assumed a function for which they had not been elected.

In parallel fashion, the ballistics experts turned their scientific-technical function over to those who should have formed social policy—the legislators. When the experts presented scientific information to policy-makers about various bullets, they found themselves disputing ballistics data with legislators who preferred a different type of bullet. Thus, the legislators, none of whom were ballistics experts, in their turn served as incompetent ballistics experts in the hearings.

When legislators and scientists accept the adversary system with its concomitant person-oriented approach as the primary means for integrating science and social values, they may expect to find a reversal of roles, and when scientists accept the person-oriented approach they may expect to be confronted by challenges to their objectivity (*15*). The outcome is well represented by the comment of one legislator who said to an opponent (*16*): "You have your expert and we have ours. . . ."

A Scientific Approach

We now consider, by way of an example, a scientific method for integrating scientific information and social values that is scientifically, socially, and ethically defensible. This method was employed in solving the dispute about handgun ammunition for the police as described above. A broad outline of the method is presented (*17*).

The general framework of the method as it was applied to the above problem is shown in Fig. 1. Basic to any policy involving scientific information are objectively measurable variables (Fig. 1, left). Scientific judgments regarding the potential effects of technological alternatives are also required (Fig. 1, middle). Finally, social value judgments by policy-makers or community representatives are necessary (Fig. 1, right). The overall acceptability of an alternative is determined by how closely its potential effects satisfy the social values of the community.

Application of this framework to the bullet dispute involved three phases: (i) externalization of social value judgments; (ii) externalization of scientific judgments; and (iii) integration of social values and scientific judgments. Each phase is discussed in turn.

Phase 1: Externalizing Social Value Judgments

The participants in phase 1 included the mayor and city council, other elected officials, representatives of the DPD (including the chief), and official representatives of community organizations, including minority groups and members of the general public. Each person was asked to make judgments concerning the relative desirability of hypothetical bullets, described in terms of their (i) stopping effectiveness, (ii) severity of injury, and (iii) threat to bystanders. These value judgments were made at the console

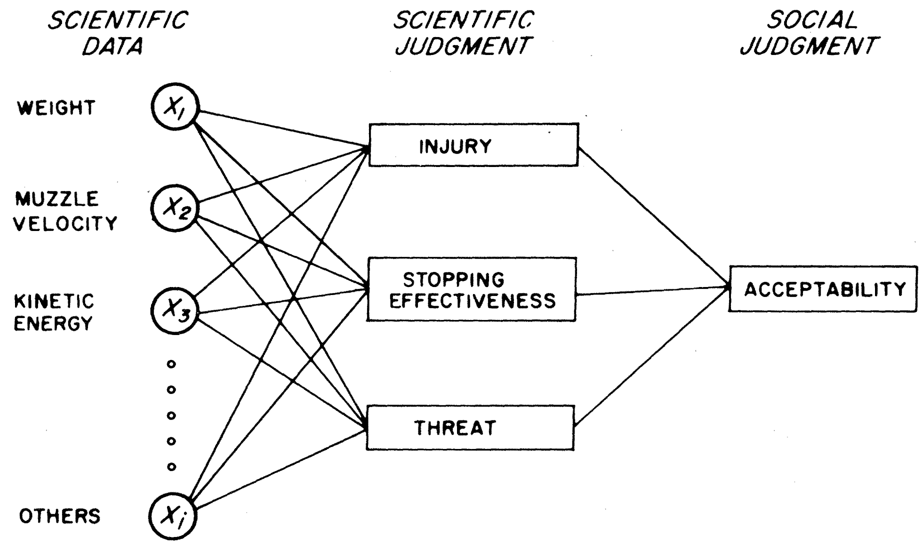

Fig. 1. A pictorial representation of a framework that combines scientific facts with social values.

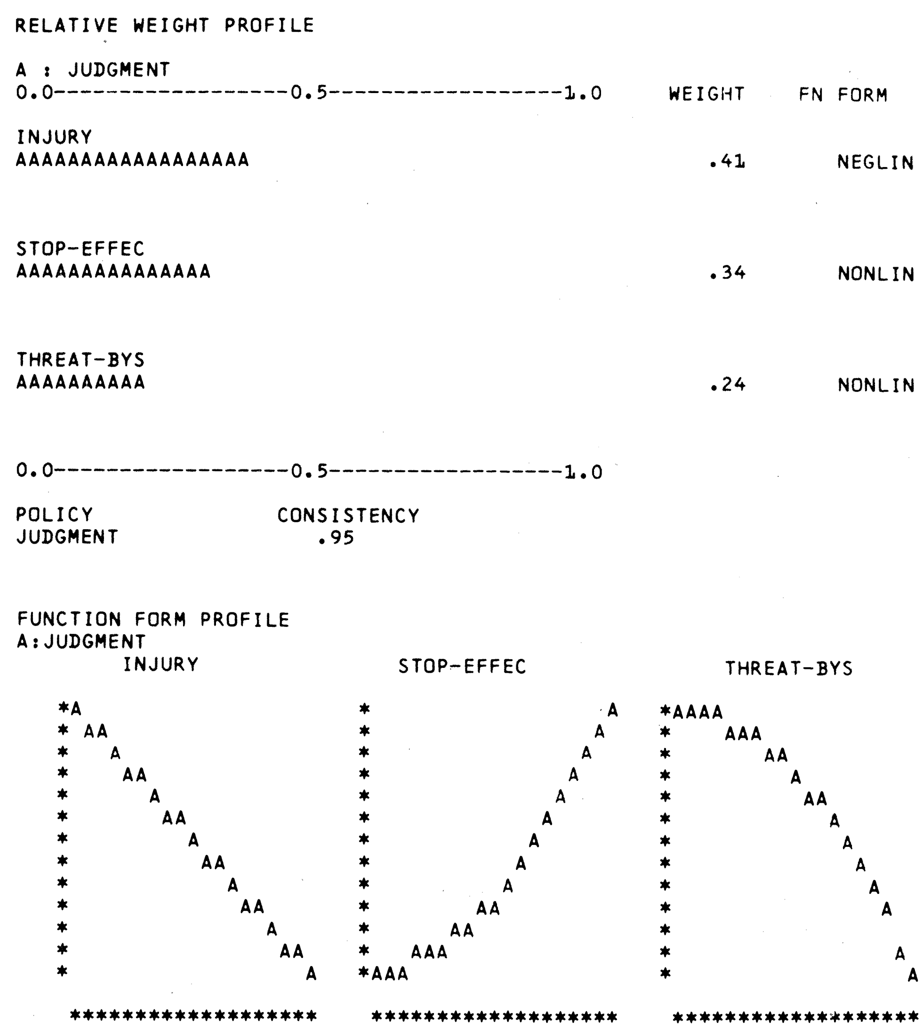

Fig. 2. A reproduction of a participant's interactive computer display of relative weights and functional relations. *FN*, function; *NEGLIN*, negative linear; *NONLIN*, nonlinear.

of an interactive computer terminal. After their judgments were made, the participants were immediately shown the relative importance they gave to each of these three functional characteristics of bullets. That is, a statistical analysis was carried out on the data and the results were then displayed at the terminal for the participant to observe (*18*). In addition, each participant was shown the form of the relation (linear, curvilinear) between his or her judgment and each of the three characteristics mentioned above. In this way, each participant saw the relative importance he or she attached to stopping effectiveness, injury, and threat to bystanders, as well as the optimal point for each (a typical display is shown in Fig. 2).

After viewing the display, the participants were asked if the results reflected their considered judgment. The data, corrected when necessary, were then stored, and a cluster analysis was carried out in order to discover whether different groups held different judgment policies. Widely differing policies with regard to the relative importance of each characteristic were found, although the functional relations between bullet characteristics and judgments were all found to be approximately linear in form.

The above procedure provides objective, visible data not otherwise available. The same procedure was used to externalize the required scientific judgments.

Phase 2: Externalizing Scientific Judgments

A panel was assembled that included one firearms expert, one ballistics expert, and three medical experts in wound ballistics. The judgments of these experts provided scientific information regarding the stopping effectiveness, severity of injury, and threat to bystanders of 80 bullets. The data for these bullets were obtained from the National Bureau of Standards. Each dimension (stopping effectiveness, injury, and threat to bystanders) was judged separately for each of the 80 bullets; agreement among the experts was found to be quite high (*19*). Only the results for stopping effectiveness and injury are summarized here, as these were the central factors in the controversy.

Three factors were found to be important in judgments of stopping effectiveness: (i) The maximum diameter of the temporary wound cavity; (ii) the amount of kinetic energy lost by the bullet in the target; and (iii) the muzzle velocity of the bullet. The close, but not perfect, relation between stopping effectiveness and injury (shown in Fig. 3) is reflected in the fact that independent judgments of potential injury were positively related to the amount of kinetic energy lost, maximum diameter of the temporary cavity, and degree of penetration.

The data in Fig. 3 are important because they suggest that, contrary to previous, unexamined assumption, there is not a perfect relation between stopping effectiveness and injury; increasing one does not necessarily increase the other. These data illustrate the value of scientific information by indicating the possibility of finding a bullet that increases stopping effectiveness without increasing injury (*20*).

Phase 3: Integrating Social Values and Scientific Information

Social value judgments and scientific judgments were combined by means of the equation in Fig. 4, where the separation and combination of the judgments of policy-makers and scientists-technologists may be seen. We used the following algebraic form of this equation

$$Y_s = W_1X_1 + W_2X_2 + W_3X_3$$

where Y_s is the overall acceptability of a bullet; W_j, $j = 1, 3$, indicates the weight, or relative importance policy-makers placed on stopping effectiveness, injury, and threat to bystanders; and X_j, $j = 1, 3$ are the experts' judgments regarding stopping effectiveness, injury, and threat to bystanders.

Because phase 1 resulted in a variety of different weights on stopping effectiveness, injury, and threat to bystanders,

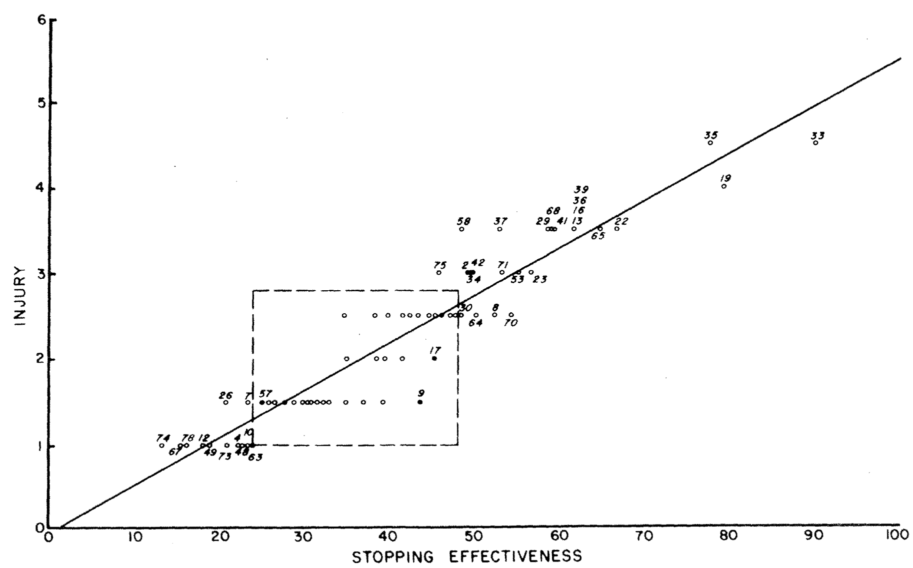

Fig. 3. The average ratings of stopping effectiveness and injury are plotted above. Each point on the graph represents a bullet. The diagonal line, determined by linear regression analysis, indicates the average value of injury for bullets with a specific level of stopping effectiveness. Bullets above the line produce more injury than the average bullet with the same stopping effectiveness; bullets below the line produce less injury.

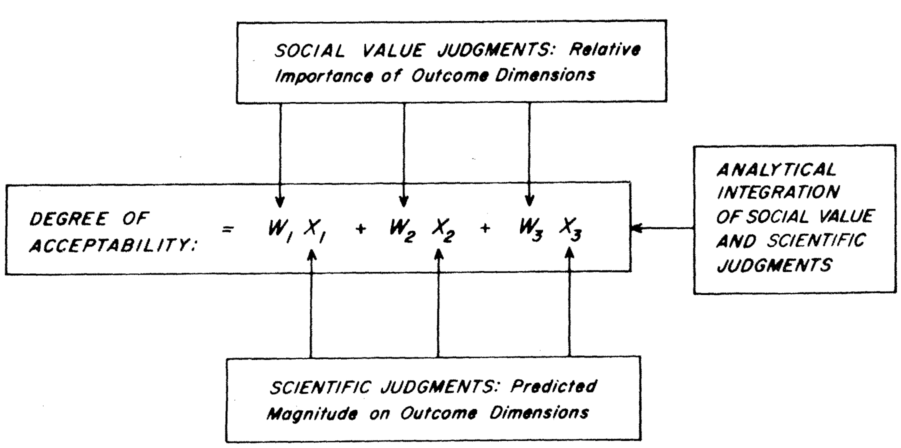

Fig. 4. A schematic representation of the analytical combination of scientific facts and social values.

the city council took all three factors into consideration by placing equal weight on each. As a result, when considering stopping effectiveness and severity of injury only, the appropriate bullet is one which lies farthest from the line of average relation in Fig. 3, this distance from the line being measured perpendicularly from the point to the line. Bullet 9 in Fig. 3 satisfies this criterion. It has greater stopping effectiveness and is less apt to cause injury (and less apt to threaten bystanders) than the standard bullet then in use by the DPD (bullet 57). In addition, bullet 9 (a hollow-point bullet) is less apt to cause injury than is bullet 17, the hollow-point bullet recommended by the DPD. Bullet 9 was accepted by the city council and all other parties concerned, and is now being used by the DPD (*21*).

Finally, three points should be mentioned with regard to the application of judgment analysis to the above problem.

1) Intense political and social conflict existed prior to our participation in the project. During the controversy a Denver police officer was killed by a hollow-point bullet; as a result, hundreds of policemen staged a march that ended in demands on both the police chief and the governor that the police be permitted to use hollow-point bullets. Members of the city council and others seemed convinced that the usual adversary methods had failed, and that they faced a dangerous impasse. The fact that the above procedures were used in these circumstances indicates that elected officials and special interest groups can accept a scientific approach to critical social problems, even when they have become immersed in sharp political dispute. Moreover, interviews with members of the city council and others not only indicated a high degree of satisfaction with the procedure but appreciation of its impersonal approach as well.

2) The procedures were applied to complex technical judgments. As far as we could determine, at the time of the research no standard quantifiable definition of severity of injury (with regard to handgun ammunition) had ever been developed. Moreover, in developing such a definition, and in making their judgments, the ballistics experts considered 11 distinct characteristics of handgun ammunition.

3) The procedure is general in nature. Despite the apparent simplicity of the framework presented in Fig. 4, judgment analysis can be applied to a variety of complex problems involving value judgments and scientific judgments by differentiating the elements in Fig. 4 in a hierarchical fashion (*22*).

Scientific Defensibility

The above method is scientifically defensible, not because it is flawless (it isn't), but because it is readily subject to scientific criticism. It is vulnerable to such criticism (i) because its aim is to meet appropriate standards regarding replication, quantification, and logic for the problem under study (an aim all scientific efforts share) and (ii) because the procedure for achieving that aim is public (as all scientific effort must be). The locus and degree of imperfection in method and procedure are thus available for public inspection and subsequent improvement. In short, the process provides the opportunity for cumulative knowledge, as scientific efforts should.

Social Responsibility

The above method is socially responsible because it provides a public framework for (i) separating technical, scientific judgment from social value judgments and (ii) integrating them analytically, not judgmentally. The separation phase permits elected representatives to function exclusively as policy-makers, and scientists to function exclusively as scientists. Neither role is confused or exchanged because policy-makers are not forced to become amateur scientists, nor are scientists required to make judgments on public policy. The integrative phase provides an overt, rather than covert, process for combining facts and values. Because the social values in the community are identified before the decision is implemented, the decision process is not seen to be a mere defense of a predetermined choice; rather it can be evaluated in terms of its rational basis before the final choice is made.

Ethical Standards

Ethical and scientific standards converge in the process of combining facts and values because both scientific ethics and public ethics require controls against bias. Scientific control against bias is illustrated by the use of the double-blind control in experiments; in the above procedure public control against bias is carried out by a similar blindness. That is, the method described above has the advantage of situating all parties (policy-makers, scientists, and the public) behind what Rawls (*23*, p. 136) calls "a veil of ignorance." It fits Rawls' requirement that the participants should not "know how the various alternatives [would] affect their own particular case and they are obliged to evaluate principles solely on the basis of general considerations." In the approach described above, the technical experts were not aware of the relative importance the policy-makers placed on the three societal characteristics of bullets, nor were the policy-makers aware of the technical judgments made by the scientists-technologists in regard to specific bullets. In short, by implementing Rawls' veil of ignorance, both scientific and ethical standards were met.

Conclusion

Current efforts to integrate scientific information and social values in the forming of public policy are confused and defeated by the widespread use of ascientific methods—the adversary system and the person-oriented approach. The adversary system suffers from an ascientific commitment to victory rather than truth; the person-oriented approach suffers from an ascientific focus on persons and their motives rather than on the adequacy of methods. The reason for the widespread use of both lies in the failure to recognize that human judgment can be brought under scientific, rather than ad hominem, analysis. The argument advanced here is that a scientifically, socially, and ethically defensible means for integrating science and human values can be achieved.

References and Notes

1. See, for example, Public Law 92-484 which established the Office of Technology Assessment.
2. J. W. Curlin, *Science* **190**, 839 (1975).
3. A. L. Otten, *Wall Street Journal*, 3 April 1975, p. 12.
4. K. E. Boulding, *Science* **190**, 423 (1975).
5. S. E. Toulmin, in *Civilization and Science: In Conflict or Collaboration?*, Ciba Foundation Symposium 1 (Elsevier, Amsterdam, 1972).
6. P. Boffey, *The Brain Bank of America* (McGraw-Hill, New York, 1975).
7. N. W. Polsby, *Science* **190**, 665 (1975).
8. Hearings before the House Committee on Rules and Administration (1971).
9. See the article by J. N. Wilford, *New York Times*, 19 February 1976, p. 3.
10. *The Future as an Academic Discipline*, Ciba Foundation Symposium 36, (Elsevier, Amsterdam, 1975).
11. Committee on Public Engineering Policy, National Academy of Engineering, *A Study of Technology Assessment* (Government Printing Office, Washington, D.C., 1969).
12. E. B. Skolnikoff and H. Brooks, *Science* **187**, 35 (1975).
13. There are clear indications that scientists are beginning to acknowledge the need for explicit methods for decision-making in areas where science and the public interest intersect. Two recent NAS committee reports [*Environmental Impact of Stratospheric Flight* (1975); *Decision Making for Regulating Chemicals in the Environment* (1975)] as well as others mentioned in the latter describe the application of normative decision theory to such problems. Although these efforts represent a clear step forward through their insistence on the use of an explicit framework for decisions, they do not indicate how such decisions might be assisted or improved through the study of human judgment.
14. For a general review of current research on

judgment and decision-making see [P. Slovic, B. Fischhoff, S. Lichtenstein, in *The Annual Review of Psychology* (Annual Reviews, Palo Alto, Calif., in press), vol. 28]. See also M. Kaplan and S. Schwartz, Eds., *Human Judgment and Decision Processes* (Academic Press, New York, 1975); W. Edwards, M. Guttentag, K. Snapper, in *Handbook of Evaluation Research*, E. L. Struening and M. Guttentag, Eds. (Sage, Beverly Hills, Calif., 1975), vol. 1; R. A. Howard, in *Proceedings of the Fourth International Conference on Operational Research* (Wiley-Interscience, New York, 1966); H. Raiffa, *Decision Analysis: Introductory Lectures on Choices Under Uncertainty* (Addison-Wesley, Reading, Mass., 1968).

15. Can the adversary system produce this confusion of roles at the national level, and does it have similar negative effects? Apparently it can, and does. For example, in Polsby's review of Boffey's book, Polsby (7, p. 666) states: "Boffey notes, in criticizing a National Academy of Engineering committee on pollution abatement, that it was no more qualified than any other group of citizens to judge what should be 'wise' public policy." (In this instance, Boffey argues that scientists overstepped their bounds and should have confined their role to presenting the facts.) "Sound doctrine," observes Polsby, "and yet Boffey criticizes another of the Academy's committees for taking on an assignment pertinent to a naval communications project that did not include evaluating its 'desirability,' and for not venturing to raise 'questions as to the basic worth' of the space shuttle program." (In this instance, Boffey argues that scientists failed to help form social policy and thus failed in their responsibility to the public.) Thus, concludes Polsby, "the Academy is damned if it does pronounce on the overall wisdom of public policies, and damned if it doesn't."
16. Public Broadcasting Service, "Black Horizons," 16 February 1975.
17. K. R. Hammond, T. R. Stewart, L. Adelman, N. Wascoe, *Report to the Denver City Council and Mayor Regarding the Choice of Handgun Ammunition for the Denver Police Department* (Report No. 179, University of Colorado, Institute of Behavioral Science, Program of Research on Human Judgment and Social Interaction, Boulder, 1975).
18. To determine the relative importance a person places on each characteristic, linear multiple regression analysis was performed to obtain the beta weights on each of the three judgment dimensions, or factors. The absolute value of the beta weight for a factor was then divided by the sum of the absolute values of the beta weights over all factors to determine the relative weight, or importance placed on each factor. The relative weights were displayed on the computer console. For technical details on the procedure see [K. R. Hammond, T. R. Stewart, B. Brehmer, D. O. Steinmann, in *Human Judgment and Decision Processes*, M. Kaplan and S. Schwartz, Eds. (Academic Press, New York, 1975)].
19. The judgment dimensions were defined as follows. (i) *Stopping effectiveness*: the probability that a 20- to 40-year-old man of average height (5′10″) and weight (175 lbs) shot in the torso would be incapacitated and rendered incapable of returning fire. Judgments ranged from 0 to 100, indicating, on the average, how many men out of 100 would be stopped by a given bullet. (ii) *Severity of injury*: the probability that a man, as described above, shot in the torso would die within 2 weeks of being shot. (iii) *Threat to bystanders*: penetration was defined as the probability that a bullet would pose a hazard to others after passing through a person shot in the torso at a distance of 21 feet. Ricochet was defined as the probability that a bullet would pose a hazard after missing the intended target at a distance of 21 feet.
20. The separation of stopping effectiveness from injury that is indicated in the graph for bullet 9 was not due to inconsistencies and inaccuracies in the experts' ratings. The three medical experts agreed that the shape of the temporary cavity is an indicator of differences in severity of injury for bullets with the same stopping effectiveness. More severe wounds are produced by bullets that have a long, wide temporary cavity; less severe wounds localize the maximum diameter of their temporary cavity and do not penetrate deeply. According to all three experts, a temporary cavity that reaches a maximum diameter of 10 to 15 cm at 5 to 7 cm from the surface, and does not penetrate more than 15 cm, would provide the best compromise between stopping effectiveness and survivability.
21. The time, manpower, and cost of the handgun study were as follows. (i) The project was completed in 6 weeks and (ii) research personnel included four people of whom one worked full time. Total cost, including salaries of the project staff, did not exceed $6000; an additional $3500 was required to pay the travel and consulting costs of the ballistics experts.
22. For examples of the application of a hierarchical framework, see K. R. Hammond, J. Rohrbaugh, J. Mumpower, L. Adelman, in *Human Judgment and Decision Processes: Applications in Problem Settings*, M. F. Kaplan and S. Schwartz, Eds. (Academic Press, New York, 1976).
23. J. Rawls, *A Theory of Justice* (Harvard Univ. Press, Cambridge, Mass., 1971).
24. Supported by National Institute of Mental Health grant MH-16437. We thank S. Cook, D. Deane, and B. Fischhoff, among many others, for their help.

Computing in the Liberal Arts College

At Dartmouth, writing a computer program is part of becoming a liberally educated person.

John M. Nevison

At Dartmouth College about half of the courses that use computer programs are in the social sciences or the humanities. Such use requires that undergraduate computing be discussed in a context broader than the sciences alone. Writing and using a computer program has become a general skill capable of wide application in a liberal arts education. Last year's course computing involved one-quarter of the faculty and three-quarters of the students.

This widespread activity is the result of three fundamental factors. First, Dartmouth's convenient computer system allows a student to learn to write a computer program in a few hours. Second, the system, like the library, is open to the whole campus. Third, the system has been supplying these services to the campus for 10 years. The purpose of this article is twofold: to provide evidence from Dartmouth College that when such a computer system is made widely available it will be widely used, and to suggest that learning to write a computer program must now be considered part of becoming a liberally educated person.

The subject is a timely one for several reasons. Recent data at Dartmouth suggest that computing will mature after a period of growth. This mature use provides several measures against which a college or university new to educational computing can gauge its own growth. Also, computing at Dartmouth grew up largely before the fragmenting forces of minicomputers and access to national networks increased the difficulty of collecting data on equipment use (*1*). Therefore, the records of the central computer at Dartmouth provide a good estimate of the campus computing activity, past and present, and yield a more precise picture than that possible on many campuses.

In the discussion that follows, data on the maturing use of computing in instruction lead to a quantitative picture of what computing means to the faculty member and to the student. The results of a recent series of interviews with instructors who use computer programs in their courses support the quantitative description of use and suggest that the ability to write a computer program is essential for the science student and extremely convenient for the social science student. The data show that students at Dartmouth frequently encounter the use of computer programs in their studies and that the ability to write a program is a skill they are likely to acquire. Finally, the discussion concludes with the suggestion that the appropriate term to describe the spread of this skill is the *computing literacy rate*.

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