The emperor's new clothes—1981

A review by disinterested, technically knowledgeable peers of the authors is as important for analyses of public policy as it is for papers in physics—but where are the peers?

Frank von Hippel

Physicists learn early that no statement should be accepted without question. Indeed at the core of the physicist's approach to both experimental data and theoretical structures is an insistence on asking questions, looking for patterns and checking for consistency. In this context, incorrect data, bad analysis, and overblown claims are subject to immediate challenge to prevent them from being perpetuated and making the already difficult work of understanding natural phenomena even more difficult.

The skeptical attitude of the individual physicist is reinforced at the community level by various informal and formal mechanisms of "peer review." These mechanisms are used to give feedback to individual researchers, to ensure that limited research funds are being used effectively, and to impose quality control on the research results that are published in professional journals.

While independent peer review helps to maintain the health and integrity of physics, its relative weakness in the political arena is one of the reasons why public-policy making is too often based more on prejudice than on understanding. Our society is simply too shortsighted to encourage its technical experts to put public policy analysis to the test of peer review. This means, however, that there is a great opportunity for the individual physicist who abhors that vacuum to fill it and thereby make a major contribution to the clarification of the national policy agenda.

Today, thanks to the moves during the past fifteen years towards a more open process for making public policy, the federal government publishes a great number of analyses of its policy alternatives—perhaps most notably the Environmental Impact Statements required by the National Environmental Policy Act of 1969.

These documents offer a starting point for outside peer review. However, although they often include lots of graphs, tables of numbers and references to the technical literature, they do not often seriously consider policy alternatives. The reports are written more like encyclopedias, dutifully discussing each relevant subject but with a thoroughness inversely proportional to the importance of that subject to the policy choices being discussed. This is understandable in view of the fact that these policy analyses are generally written and published by agencies that have already decided what the final policy should be. It often seems as if the principal purpose of such reports is to serve as monumental evidence that a "comprehensive" analysis has indeed been done. This symbolic significance of government reports was captured by science writer Dan Greenberg in his discussion of a report on reactor safety (Washington Post, 27 February 1979); his column is titled "What's One Foot Tall and Costs $3 Million?"

Curiously enough, even scientists who would put the work of a colleague under a microscope before accepting it, tend to find even primitive indications of credibility, such as the size and cost of reports, persuasive in the case of public-policy analysis. Perhaps this is because outside scientists are aware of the enormous resources of expertise that are available to large organizations such as the Department of Energy or General Motors but do not see how these resources are actually used. Under these circumstances it is easy to assume that even if a large technical organization doesn't know what it is doing, its mistakes must at least be a type too subtle for a non-expert to detect. Like the adults in Hans Christian Andersen's fairy tale, we tend to assume that the problem is with our own eyes rather than with the Emperor's apparel. (See figure 1.)

In large part because the larger scientific community has averted its eyes instead of observing that the Emperor is indeed naked, it is virtually standard practice on the part of large technical organizations today to do "answer analysis"—that is produce analyses in support of preselected positions—even during their internal decision making process. Whereas in science, an answer analyst is fairly firmly encouraged to find another way to make a living, in policy analysis it is too often the other way around. Thus one formerly high-level analyst recounts that he was given the following advice before he was fired:

> Bill, in general, people who do well in this company wait until they hear their superiors express their view and then contribute something in support of that view.

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(Reported by Robert Simison in the *Wall Street Journal*, 30 July 1980) Not surprisingly analyses produced under such circumstances often contain errors so egregious that even a scientific child could point them out.

The principal purpose of this article is to illustrate with three cases histories that outside peer review of public policy analysis is critically needed, that it is feasible, and that it can have an important impact. The case histories, however, also relate to issues which still are of major public concern and therefore of interest in their own right:

- the safety of today's commercial nuclear power plants
- the necessity of plutonium breeder reactors
- the consequences of "limited" nuclear war.

The APS reactor safety study

A great public debate has raged around the subject of reactor safety ever since the nation's utilities began to build commercial nuclear power plants in large numbers about 10 years ago. In 1974, therefore, the American Physical Society was moved to sponsor a Study Group on Light Water Reactor Safety. This group began its study with a month-long session during August 1974 at Los Alamos.

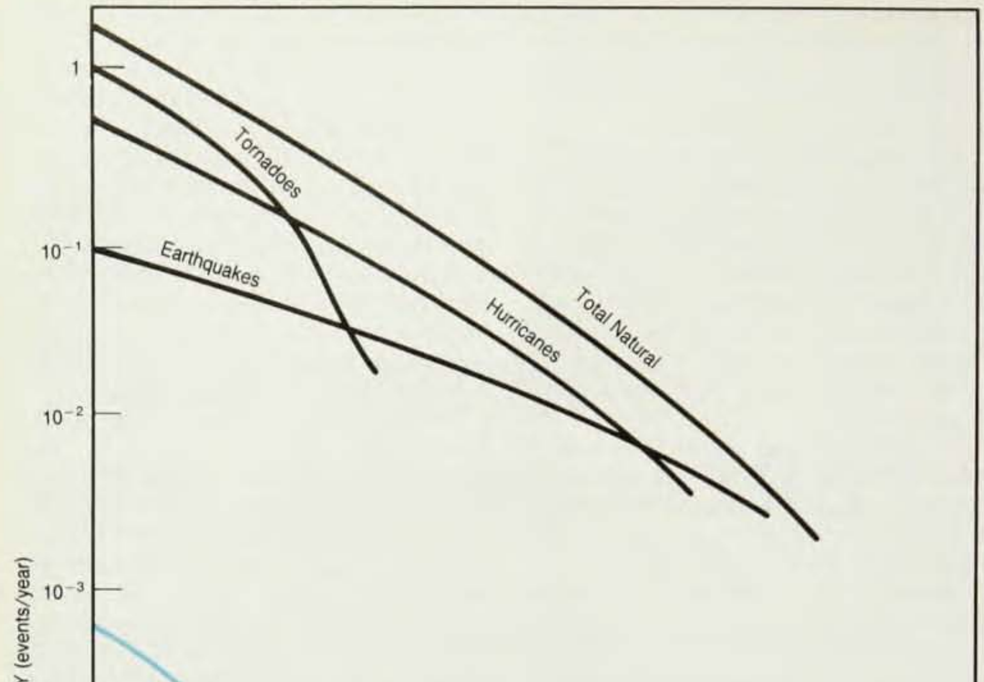
Coincidentally, that same summer the Atomic Energy Commission released its own 2000-page-long draft *Reactor Safety Study* (also known as "WASH-1400" or the "Rasmussen report").[1] This report was made most memorable by the comparison it drew in one of its summary figures between the risk to life from reactor accidents and from meteorites. (See figure 2).

If nuclear power plants had indeed been proven to be as safe as this figure suggests, then it would appear that there was little for the APS group to concern itself about. Before accepting this result, however, the group decided to try to understand how the *Reactor Safety Study* had obtained its result. In effect the group decided to do—to the extent that it could—a peer review.

It was difficult to check many of the calculations in the *Reactor Safety Study* in the short time available in a summer study because the authors of WASH-1400 had used computers so heavily. It did prove possible, however, to do "back-of-the-envelope" checks of the radiation "population-doses" calculated in the *Reactor Safety Study* for specific hypothetical releases of radioactivity to the atmosphere. (The population radiation dose is simply a sum of individual radiation doses and is a useful measure of the long term impact of a reactor accident because it gives a rough measure of the increase in the incidence of cancers and genetic defects which might result.[2])

Because the population doses calculated in the *Reactor Safety Study* for given releases of airborne radioactivity to the atmosphere were obtained by averaging over wind directions and atmospheric stability classes, it appeared to the APS group that the calculations would probably not be very sensitive to the details of either the atmospheric dispersion model or the population distributions assumed. The APS group therefore used in its own back-of-the-envelope calculations a uniform population distribution and a simplified atmospheric dispersion

The emperor said to himself " 'But I will have to go through with the procession' . . . so he drew himself up and the lords in waiting tightened their holds on his mantle and stalked on," even though he had no clothes on. (Illustration by Arthur Rackham, see reference 24.) Figure 1



Relative risk from reactor accidents according to the Executive Summary of the AEC/NRC *Reactor Safety Study* as shown in the 1974 draft and in the 1975 final version. Although an APS review of the draft showed that the fatalities were vastly underestimated, the final version shows a lower curve. In fact, deaths from cancer are not included in the later curve; including them would raise the curve two or three orders of magnitude above the "meteors" curve. Figure 2

model, which had the virtue that it could be integrated analytically. In this "wedge model" approximation the decrease in atmospheric concentration of any particular radioactive species with downwind distance r was assumed to have the functional form

$$f(r) = e^{-\mu r}/r$$

where the $1/r$ term reflects the assumed growth with distance downwind of the horizontal size of the cloud in the direction transverse to its motion, while the exponential term reflects its depletion by radioactive decay and deposition. It was assumed that vertical dispersion was limited by the thickness (about 1 km) of the atmosphere's "mixing layer."

When the group checked the results of its simplified calculations against the results of the *Reactor Safety Study* computer calculations, however, they found some major discrepancies. Ultimately the AEC calculations were found to be in error: It had been assumed that the population radiation dose from a reactor accident would stop growing within one day after a release of radioactivity. This was a bad error because, when the time integration is carried out, it turns out that the whole-body population dose downwind from a reactor accident is dominated by external radiation from cesium-137 (whose half-life is 30 years) that is deposited on downwind surfaces by the radioactive plume. It would be impractical to reduce the population-dose greatly using long term evacuation and decontamination because of the large areas of contamination involved.[3]

The authors of the Reactor Safety Study were initially exceedingly reluctant to acknowledge their error, but ultimately they corrected it in the final *Reactor Safety Study* report, issued in October 1975 by the Nuclear Regulatory Commission (which had in the meantime taken over the AEC's regulatory functions).[1]

Curiously enough, however, the figure presented in the report's Executive Summary comparing the risks from reactor accidents to other risks had hardly changed at all (figure 2). The reason is that the fatalities shown there for reactor accidents are only the early fatalities—those occurring within 60 days. In the final *Reactor Safety Study* there were several hundred cancer fatalities (which, of course, show up after more than two months) calculated for each of the early fatalities shown in the summary figure. There was almost no indication of the existence of these cancer fatalities in the Executive Summary, however; the leadership of the RSS had rejected even the suggestion that the adjective "early" be added before the word "fatalities" on the horizontal axis of figure 2 so that readers would be alerted to the fact that not all fatalities from reactor accidents are shown there.

It took four years and another bout of peer review before the Nuclear Regulatory Commission acknowledged the misleading character of the Executive Summary or accepted another, truly fundamental criticism of the Draft *Reactor Safety Study* made by the APS study group and by many other groups and individuals, namely that the calculations of accident probabilities made in the *Reactor Safety Study* were so uncertain as to be virtually meaningless.

A critical role in sustaining the review process during this period was played by Morris Udall, who chaired the House of Representatives subcommittee that oversees the Nuclear Regulatory Commission. Udall's subcommittee held a hearing on the final *Reactor Safety Study* in June 1976 and issued a very critical report on it in January 1977.[4] In response to this pressure, the Nuclear Regulatory Commission decided in 1977 to sponsor its own outside group to review the *Reactory Safety Study*.

The work of the NRC's new Risk Assessment Review Group (which included three veterans of the APS group) was made more difficult by the fact that various members had already previously taken public stands for and against the Reactor Safety Study. After more than a year of work, however, the group did piece together a report to the NRC out of agreements on many narrow issues.[5] I personally believe that this convergence was only possible because of the basic respect for truth that scientists absorb along with their discipline.

In any event, the statement issued on 19 January 1979 by the NRC in response to the report of the Risk Assessment Review Group was quite forthright:

> The Commission withdraws any explicit or implicit past endorsement of the Executive Summary. . . .
> The Commission agrees that the peer review process followed in publishing WASH-1400 was inadequate and that proper peer review is fundamental for making sound technical decisions. . . .
> The Commission does not regard as reliable the Reactor Safety Study's numerical estimate of the overall risk of reactor accident. . . .

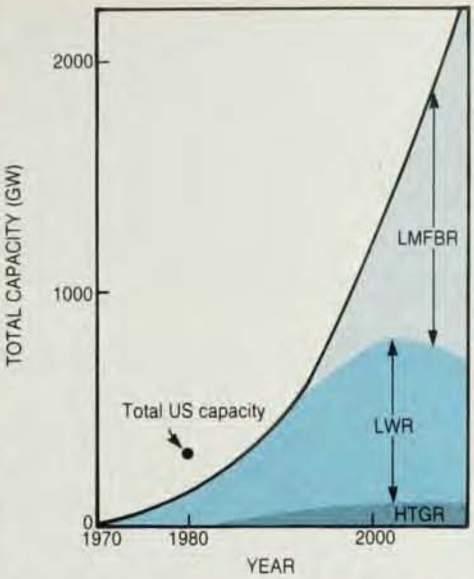
This is to my knowledge the first time that the peer review process had worked effectively enough in the public policy arena to force a federal agency to reverse its position so completely and publicly.

The plutonium breeder reactor

The federal government's program to commercialize plutonium breeder reactors has been controversial since the early 1970s, principally because the associated fuel-cycle technology is virtually indistinguishable from that required to secure plutonium for the production of nuclear weapons. In the mid-1970s, however, breeder advocates were arguing that fission was the only energy source that could be relied on to satisfy the world's growing energy appetite and that an immediate commitment to plutonium breeders was necessary if the world was not to have a nuclear fuel-supply crisis shortly after the turn of the century.

The argument as laid out in 1974 in the AEC's *Proposed Environmental Statement on the Liquid Metal Fast Breeder Reactor Program* went approximately as follows: US consumption of electric energy was expected to continue to grow at almost its historical rate and most new generating capacity was expected to be nuclear with the result that nuclear power plants were projected to be generating by the year 2020 *ten times* as much electrical energy as *all* US electrical power plants did in 1980. (See figure 3).[6] US supplies of high-grade uranium ore were believed to be sufficient, however, to fuel only the light-water reactors to be built by about the year 2000. It was felt therefore that the continued growth of US nuclear generating capacity could only be assured in the years after 2000 if much more uranium-efficient reactors such as plutonium breeders were introduced.

In 1976 a group of three physicists and a political scientist at Princeton published a critique of such projections. The group argued that electricity consumption growth rates in the future would be much slower than in the past and that therefore a commitment to the breeder could be postponed for decades at least.[7] A comprehensive critique of the AEC's cost-benefit analysis justification for the breeder program had been published two years earlier by another physicist, Thomas Cochran, who by 1976 was working full-time on the staff of a Washington-based public interest group, the Natural Resources Defense Council.[8]



Justification for the LMFBR program. Extrapolating nuclear electricity-generating capacity as shown, the AEC argued that breeder reactors were necessary to satisfy the demand. The extrapolation was based on extravagant assumptions about electricity generation and use: For comparison we show the equivalent nuclear generating capacity that would produce as much electricity as *all* US generating plants produced in 1980. (LMFBR is the liquid-metal-cooled fast breeder reactor, LWR is the light-water reactor, and HTGR is the high-temperature gas-cooled reactor) Figure 3

The issue was brought to a head in early 1977 as the result of the election of Jimmy Carter to the US Presidency. During his campaign Carter had expressed concern about the implications for nuclear weapons proliferation of the proposed "plutonium economy," and one of his first actions after the election was to order a review of the direction and pace of the US breeder-reactor development program. The review was organized by the Energy Research and Development Administration, which had in 1975 taken over all the AEC's functions other than the regulation of commercial nuclear power activities. To give its breeder review greater credibility, ERDA set up an outside steering committee, which included, along with representatives from the nuclear-energy and electric-utility industries, Cochran and two members of the Princeton group.

Not surprisingly, one of the first issues which this "LMFBR Review Steering Committee" addressed was the electricity consumption growth projections which had been used by the AEC to justify the pace of the breeder development program. As a result it soon became clear that these projections had simply been obtained by mindless extrapolation of historical growth rates.

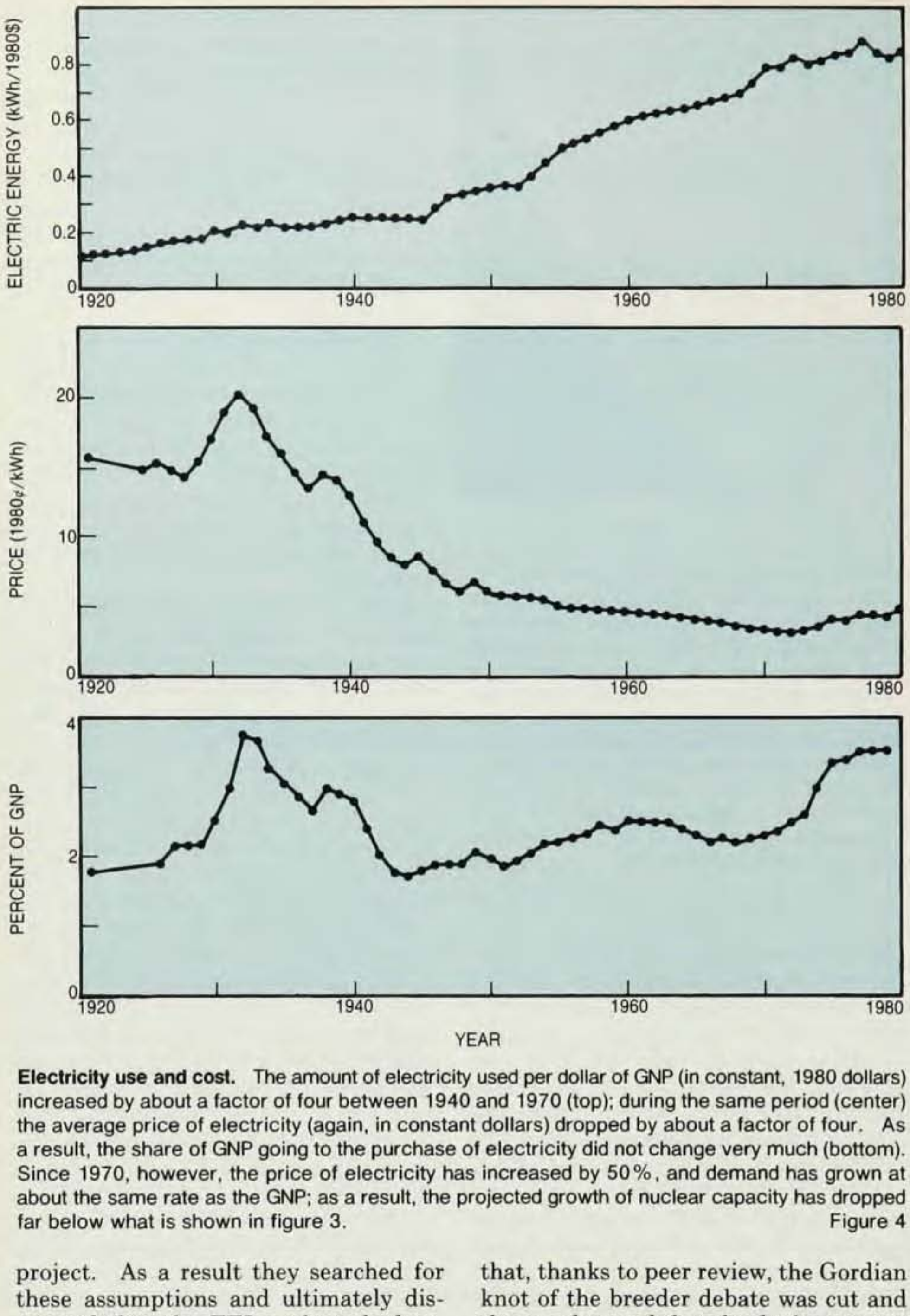
The utility representatives on the committee quickly stepped into the breach, however, and presented to the committee a newly published study by the Edison Electric Institute which projected in a "moderate growth scenario" a growth rate for US electricity consumption almost as high as had been assumed by the AEC.[9]

The EEI study did indeed look impressive—over 400 double-column pages with numerous graphs and tables. Furthermore its electricity-growth projections had been made using a huge and well-pedigreed macro-economic computer model. Physicists are not supposed to be intimidated by computer models, however, so a peer review of the EEI study was undertaken.

It was impossible to review the detailed economic assumptions made in the macro-economic model used by the EEI analysts because its inner workings were held to be proprietary by the Cambridge-based economics consulting firm that had developed it. The many adjustable parameters in the model had been fixed by fitting historical data, however, and the historic relationship between the growth of the US economy and US electricity consumption has a remarkable pattern.[10] As figure 4 shows, while US electricity consumption per unit of GNP rose by a factor of four between 1930 and 1970, economies of scale and large increases in the thermal efficiency of power plants lowered the average price of electricity by a factor of four during the same period, with the result that the share of the GNP going to the purchase of electricity was no more in 1970 than in 1930.

The EEI model projected another doubling in the electricity intensity of the US economy per unit of GNP between 1975 and 2000. This would be consistent with historical trends but it would lead to serious stresses in the economy unless electricity prices continued their historic rate of decline. At a constant price of electricity, for example, a doubling of the kilowatt-hours consumed per dollar of GNP would also double the share of the GNP going to the purchase of electricity. This would imply an intensified competition for resources between the electric-ity-supply sector and other sectors of the economy, which would in turn have significant implications for the economy as a whole. Already in 1975 over 20 percent of all US investment in new industrial plant and equipment was accounted for by the electrical utilities.[11]

The Princeton physicists therefore suspected that the assumptions made by the Edison Electric Institute concerning future electricity price trends would have a very important influence on the future, which the macro-economic model would



Electricity use and cost. The amount of electricity used per dollar of GNP (in constant, 1980 dollars) increased by about a factor of four between 1940 and 1970 (top); during the same period (center) the average price of electricity (again, in constant dollars) dropped by about a factor of four. As a result, the share of GNP going to the purchase of electricity did not change very much (bottom). Since 1970, however, the price of electricity has increased by 50%, and demand has grown at about the same rate as the GNP; as a result, the projected growth of nuclear capacity has dropped far below what is shown in figure 3. Figure 4

project. As a result they searched for these assumptions and ultimately discovered that the EEI analysts had assumed in constructing their moderate growth scenario that, between 1975 and 2000 the average prices of electricity would fall by about 40 percent, from about 2.7 cents per kilowatt-hour to 1.6–1.7¢/kWhr (in 1975 prices).

It was already clear by 1976 when the EEI study was published, however, that the period of declining electricity prices was over. (See figure 4.) Indeed, because of the high capital costs of new nuclear and coal plants under construction, most industry forecasts at the time were projecting large electricity price *increases.*[12] As a result, when it was pointed out to the utility representatives on the Steering Committee that the EEI study had assumed declining real electricity prices, they were more than a little surprised, as the transcript of the 4 April 1977 meeting shows.

It would be pleasing to be able to report that, thanks to peer review, the Gordian knot of the breeder debate was cut and the panel agreed that the deployment of the breeder could be postponed. In reality, however, the Steering Committee continued to be split on that question and ultimately issued separate majority and minority reports.[13] The case for the breeder had been seriously undermined, however, by the challenge to the conventional wisdom concerning the future growth of the required nuclear-energy capacity, and this fact helped the Carter White House to resist great pressures over the next three years to continue subsidizing the commercialization of the breeder reactor.

Since early 1977 when the Steering Committee produced its report, the utility industry's average annual growth projections for the period of 1975–2000 have been dropping steadily: from 5.3–5.8% in the EEI's "moderate growth" scenario to 4.6% in late 1977, 4% in 1978, 3.9% in 1979, and most recently 3.5% in 1980.[14] This corresponds to a reduction of projected electricity consumption in the year 2000 by about 40%.

Official projections of US nuclear capacity have dropped still more rapidly during the same period—to less than 200 000 megawatts in the year 2000 and less than 460 000 megawatts in 2020,[15] while estimates of US uranium resources have increased.[16] As a result, it is now clear that US resources of high-grade uranium ore will last well beyond any reasonable planning horizon. Furthermore, the economics of the breeder now look quite unfavorable,[17] so that even in the absence of concerns about the proliferation of nuclear weapons, there would be no reason to pursue commercialization of this technology. The nuclear industry is still pressing the government to move ahead with a federally funded program to "demonstrate" breeder technology on a commercial scale, but the reasons being given now relate more to national prestige than national need.[18]

Consequences of "limited" nuclear war

One of the areas in which it is particularly difficult to do open peer review is defense policy. Occasionally, however, some internal debate bursts into the public arena, and outsiders can participate. This occurred in 1974 after James Schlesinger, then Secretary of Defense, argued in a secret hearing before the Senate Foreign Relations Committee that the US should be prepared to fight a "limited" nuclear war in which opposing nuclear-weapons delivery systems rather than cities or industries would be targeted. He argued that, while a full-scale nuclear exchange between the US and Soviet Union might be unthinkable, a limited one was not:[19]

> I am talking here about casualties of 15 000, 20 000, 25 000—a horrendous event, as we all recognize, but one far better than the alternative.

Some of the senators, Senator Case of New Jersey in particular, were quite astonished that *any* nuclear exchange could have such small consequences. As a result, the Department of Defense was asked to provide detailed calculations of the fatalities that would result from various Soviet attacks against US nuclear-weapons delivery systems. Secretary Schlesinger cooperated and 6 months later returned with the requested estimates. One of these drew special attention from the senators because it projected that almost a million US fatalities would result from a Soviet attack against just the 1054 US Minutemen and Titan missile silos—despite the fact that these silos are in relatively isolated locations in the Western US.[20] Figure 5, which is based on a figure originally prepared by Henry Kelly of the Congressional Office of Technology Assessment, shows the reason: Enormous swathes of lethal fallout would be laid out for many hun-

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dreds of miles downwind from the targets of such an attack.[21]

Senator Case was still not satisfied, however. He therefore persuaded the Chairman of the Senate Foreign Relations Committee to request that the Office of Technology Assessment convene a group of experts to review the Defense Department's calculations.

The OTA assembled a panel of prestigious nuclear-weapons analysts and this panel did in fact have a number of criticisms to make of the assumptions used in the DOD's casualty calculations. In particular the panel noted that the weapon yields and height of burst chosen in the DOD scenario (a one-megaton warhead airburst over each silo) would not maximize the probability of destroying the US missile silos. This put in question the purpose of the attack postulated by the DOD. The panel was also highly skeptical about the DOD assumption that, under the circumstances of a surprise attack by the Soviet Union, the US population would be able to make optimum use of existing civil defense fallout shelters.[22]

Once again the Office of the Secretary of Defense cooperated and recalculated the expected fatalities for more effective attacks on the missile silos, for less optimistic assumptions about fallout protection, and for various weather conditions. Assuming that 40 percent of the downwind population did not find refuge in fallout shelters, 18 million fatalities were estimated for the most effective attack considered (two 3-megaton weapons at each silo—one airburst and one ground burst.)[23]

This peer review therefore effectively challenged the idea that the US should consider "limited" nuclear war as a rational policy option. With the new Administration the debate on this matter has once again revived. Vigorous review of the analytical basis for US nuclear weapons policy is therefore needed now as much as ever.

Other reviews

It is important to acknowledge that peer review had more impact in the case histories that I have recounted here than is typical. The ingredients for success in each case was dedication and persistence on the part of both the reviewers and an important political actor who made certain that they were heard.

In the case of the Nuclear Regulatory Commission's Reactor Safety Study, it was Morris Udall who persisted over a period of years in pressing for a more adequate response from the NRC to the review sponsored by the APS and other organizations. In the case of the Energy Research and Development Administration's review of the breeder reactor, it was Jimmy Carter's White House that insisted that at least a minority of critics be added to the steering committee of utility and nuclear industry breeder supporters that ERDA had assembled. And in the case of the Defense Department's limited nuclear war casualty study it was Senator Case who arranged for Congressionally sponsored peer review.

When such special conditions are not present, large technical organizations ordinarily try to ignore unwelcome reviews. This is only to be expected. Thus, for example, after a public review of his new clothing, Hans Christian Andersen's emperor did not quickly admit his error.[24] After the assembled multitude, released by the child's voice, shouted out together "He has nothing on at all!"

> the emperor was angry and ashamed for he knew suddenly that they were

Scientists and the Politics of Technology

> The knowledge that the public possesses on any important issue is derived from vast and powerful organizations: the press, radio, and, above all, television. The knowledge that governments possess is more limited. They are too busy to search out the facts for themselves, and consequently they know only what their underlings think good for them unless there is such a powerful movement in a different sense that politicians cannot ignore it. . . . I think men of science should realize that unless something rather drastic is done under the leadership or through the inspiration of some part of the scientific world, the human race, like the Gadarene swine, will rush down a steep place to destruction in blind ignorance of the fate that scientific skill has prepared for it.
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> —*Bertrand Russell* (1960)

While the talents of scientists have been harnessed very effectively by our society for the development of technology, very few scientists participate as independent analysts in the political debates over what technologies should be developed. Nevertheless both interesting role models and opportunities exist.

One sort of activity is "public-interest science." Because there is relatively little funding available to support this sort of activity, most practitioners are volunteer citizen-scientists.[25] However, a few scientists have been able to pursue public-interest science as a full-time profession either at a university or on the staff of a national public-interest group. If a scientist in interested in being considered for such a position, it is a great help to have already established one's ability to contribute effectively to the policy-making debate as an "evening-and-weekend" public-interest scientist.

Some scientists find that their employers object to the nature of their participation in the public-policy debate, even when their activities are pursued entirely during their own time. While government managers are constitutionally forbidden to interfere in this way with the freedom of speech of their subordinates, protection of the freedom of speech of private sector employees from management retaliation is less developed. In any case, disapproval by management tends to have a chilling effect on the freedom of speech of scientists—a tragic loss to the national process of policy-making for technology. Perhaps we could use a "scientists lib" movement to counter this chilling effect.

Scientists can also contribute important insights to policy discussions *within* their organizations. They will only fully feel free to do so, however, if the organization respects and protects the right of its employees to dissent and even to "blow the whistle" when the organization's policies appear to be posing a danger to the welfare of the larger society. Abuse of this right must be subject to sanctions but the determination that an abuse has occurred must be arrived at by procedures that are manifestly fair.[26] In some cases involving occupational, public, or environmental safety, legal protections exist for whistle-blowers. However, the advice of one well-known whistle-blower still applies: "First line up a good lawyer then line up a good job."[27]

Congressional staffs have until relatively recently been quite deficient in technical expertise. This naturally weakened the ability of Congress to carry out its responsibilities in highly technical areas. The Congressional Science Fellowships were established in 1973 to strengthen Congress in these areas and to give scientists opportunities to become involved in national policy-making. Currently about 20 professional societies, including the APS and the American Association for the Advancement of Science, sponsor one-year Fellowships that provide scientists interested in policy issues an unusual amount of independence and a wide range of subsequent opportunities in policy related positions. In addition, Congress' Office of Technology Assessment, the Congressional Reference Service, and the State Department all sponsor one-year fellowships for scientists and engineers interested in policy analysis.

The National Science Foundation's Science for Citizens Program has over the past few years offered a number of grants for scientists to develop analyses of public-policy alternatives for citizens groups, museums, local-government organizations, and so forth. The new Administration has, however, proposed to eliminate this program along with much other independent policy analysis funded by the federal government.

These actions by the new Administration underline the fact that ultimately the responsibility for informing our society of the potentials and dangers of technology lies with individual scientists working with whatever resources are available.

right. 'But I will have to go through with the procession,' he said to himself, so he drew himself up and the lords in waiting tightened their hold on his mantle and stalked on.

Perhaps the emperor could not respond otherwise if he wanted to remain in office. Perhaps large organizations also would be weakened politically if they admitted their errors. This does not mean, however, that peer review has been ineffective when, despite harsh criticism, a bad policy is not immediately withdrawn. The review process educates many audiences—including both the peers and the organization which is pretending not to listen. Even an emperor cannot afford to play the fool too long. Andersen does not tell us what clothes the Emperor wore in his next procession, but probably they were a big improvement.

Fallout patterns from a hypothetical strike against US missile silos. The colored areas show regions within which one can expect more than half the population to be hospitalized. Within the shaded regions more than half the population that is indoors (but not in special fallout shelters) will die. (Based on a map by Henry Kelly, reference 21) Figure 5

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