Looking back on the Rasmussen report

1974 reactor safety study assembled some useful data, but it misled Congress and the public; such reports should be subjected to more timely scientific review

Frank von Hippel

The Nuclear Regulatory Commission (NRC) published the final report of its four-year, $5 million, *Reactor Safety Study* (RSS) in late 1975.[1] It is a massive document—including technical appendices it totals more than 2,400 double columned pages—and even now, more than a year after its publication, the technical review is still far from complete. The report has been a key document in the nuclear debate, however, ever since early 1974 when its conclusions were first cited in defense of nuclear power by AEC Chairman Dixy Lee Ray long before the study was completed.

The purpose of this article is to consider the usefulness of the *Reactor Safety Study* (or the Rasmussen report as it is more commonly called*) for policy-making purposes. In particular, its usefulness to decision-making in two critical areas will be considered:

- the national debate over the acceptability of nuclear power relative to other energy sources, and
- safety related decisions concerning nuclear power plant siting.

Surprisingly, despite its heavy use in the nuclear debate, it appears that the report in its current form is either highly misleading or virtually useless for these purposes. This conclusion underlines the importance of the public and the Congress having technical reports, on such highly politicized topics, put into perspective by peer review *before* they are accepted as a proper basis for policy.

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How useful is the *Reactor Safety Study* to those who wish to "raise the level" of the national debate over nuclear reactor safety? As we all know only too well, this debate is currently highly polarized. The public finds itself being told on the one hand that nuclear power is virtually fail-safe and, on the other, that if our society uses this energy source for the long term, it can look forward to the likelihood of catastrophes unprecedented in peacetime.

In these circumstances it would indeed be useful if we could have a study which could put each of the risks associated with nuclear reactors into some kind of perspective. In particular it would be important to know how often a major release of radioactivity from a nuclear power plant might occur, and how serious the consequences would be compared to those disasters which we have already experienced. It would be especially useful to have a comparison of the hazards associated with nuclear power plants with those associated with other energy technologies.

The NRC's *Reactor Safety Study* was supposed to accomplish most of these objectives.

One would have hoped that, once it was out, such a study would have had a tempering effect on the debate, that the reactor safety issue would have been put into better perspective, that the area of agreement between the nuclear opponents and advocates would have been expanded, and that all parties might be talking more often in the same language. Unfortunately, however, none of these things have come to pass. Instead of dampening the fire of controversy, the publication of the Rasmussen report has had the effect of adding fuel to it.

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*Norman C. Rasmussen, chairman of MIT's nuclear engineering department, was the part-time director of the study and has been its principal spokesman. The full-time supervisor of the study was the responsibility of Saul Levine, a high-level NRC official.

Why has this happened? In my view, the failure of the report to accomplish these objectives stems in large part from the way in which it was packaged. While the report contains a lot of material which can be used to put the risks from reactor accidents into perspective, it has been presented and publicized as having done something which it did not do, namely prove that the risks are negligible.

Consider, for example, the report's "Executive Summary." The *Reactor Safety Study* report itself, in all its 2,400 pages of detail, is virtually impenetrable to all but the "professional" reader. A 12-page Executive Summary was therefore prepared for those readers who would be interested in the conclusions of the report, but didn't have the time or the expertise to read even a significant fraction of the report itself.

In this summary, estimates of the frequency of reactor accidents of different levels of seriousness are presented graphically. Thus, for example, numbers are shown that indicate that thousands of dam failures, each killing a thousand people, should occur before one reactor accident occurs with the same number of fatalities (see Figure 1-1). Similarly, in a comparison of reactor accident hazards to natural catastrophes, it is indicated that the likelihood of a thousand people being killed by a reactor accident is approximately equal to that of the same number of people being killed by a meteor (see Figure 1-2).

If these graphs told the whole story correctly, one could only conclude that reactor accident hazards represent only a trivial addition to the hazards to which we are exposed every day and that perhaps those who worry about reactor safety should concern themselves with

Nuclear reactor accidents and natural catastrophes

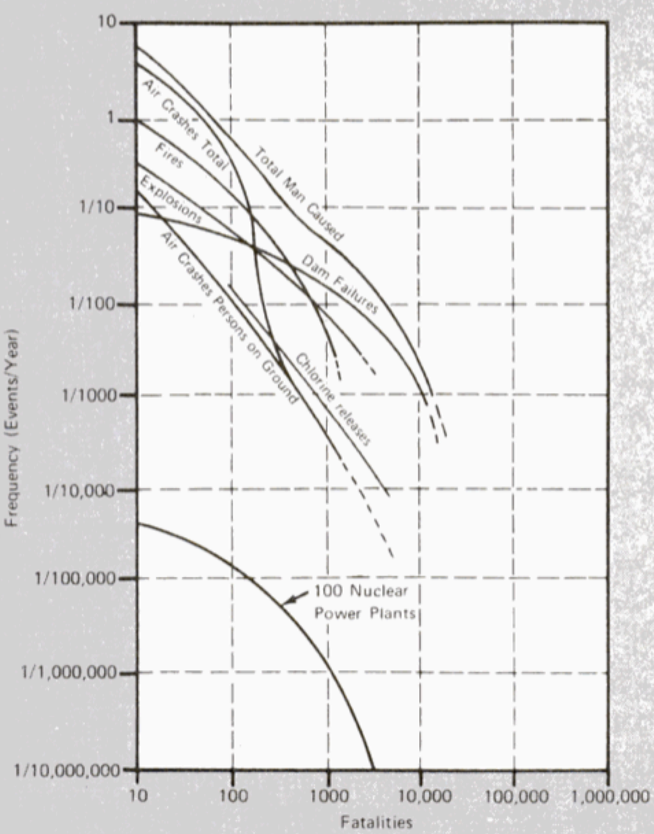

Figure 1-1. Frequency of fatalities due to man-caused events

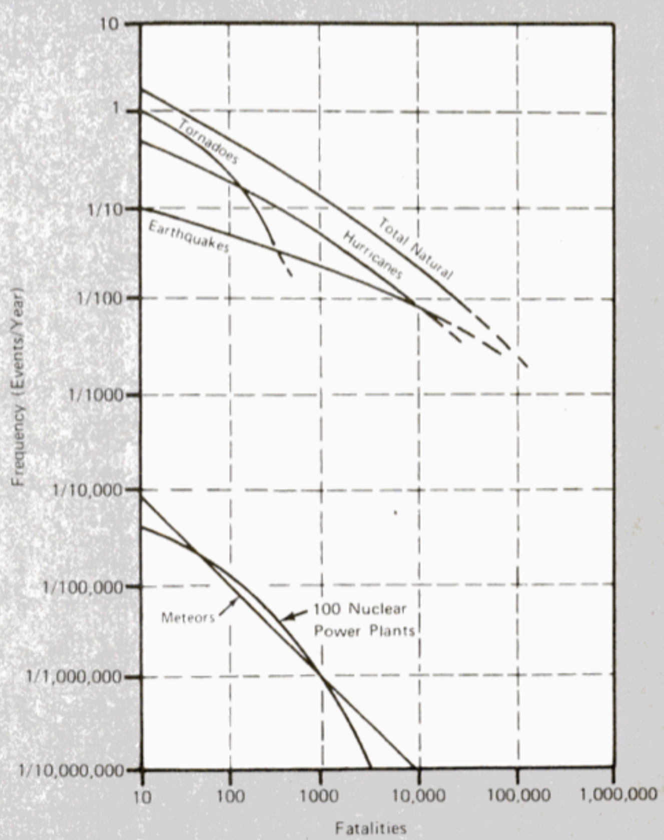

Figure 1-2. Frequency of fatalities due to natural events

These two figures from the "Executive Summary" of the NRC's Reactor Safety Study compare the risks of fatalities from reactor accidents to risks from man-caused and natural events. The accompanying article points out that these comparisons are deceptive; they show neither the most important consequences of a reactor accident nor the great uncertainties in the calculated probabilities of their occurrence.

TABLE 1

Long-Term Consequences of Nuclear Reactor Accidents Predicted at Same Level of Likelihood as the Ten Short-Term Fatalities[a]

Cancer deaths:	7,000
Genetic defects:	4,000
Thyroid tumor cases:	60,000
Square miles of land contaminated with radioactivity above acceptable levels:	3,000
Massive water contamination: Enough to contaminate Ohio River above maximum permissible drinking standards for more than a year.	

[a]The numbers in this table were obtained from the NRC, *Reactor Safety Study*, as follows:

Cancer deaths and thyroid tumor cases: Figures 5-5 and 5-6 in the body of the report show the probability distribution for latent cancer fatalities and thyroid tumor cases respectively per year. On page 92 of the report, it is stated that these rates would continue for a period extending roughly from 10 to 40 years after the reactor accident. To get total numbers of cancer deaths and thyroid tumor cases over these 30 years, therefore, the numbers shown in these figures should be increased thirtyfold.

Genetic defects: Figure 5-7 of the report shows the probability distribution for genetic effects per year. On page 93 it is stated that the total number of genetic defects is equivalent to this rate persisting for about 120 years after the reactor accident.

Land contamination: See Figure 5-9.

Water contamination: Based on the release of strontium-90 into a local body of water shown in Figure 3-6, Appendix VII. This release rate exceeds 100 curies per day for a period of approximately a year about five years after the accident. The maximum permissible concentration of strontium-90 in public drinking water is about 130 curies per cubic kilometer. The average flow of the Ohio river is about 0.6 cubic kilometers per day.

more important things. Unfortunately, however, these comparisons are deceptive. They show neither the most important consequences of a reactor accident nor the great uncertainties in the calculated probabilities of their occurrence.

Consider first the presentation of the consequences of reactor accidents. In the Executive Summary figures, the bottom axes are labeled "fatalities." In the body of the report these same curves for reactor accidents are shown with the less misleading caption of "early fatalities." The point is that the numbers shown include only those fatalities which would occur within a few weeks of the accident; they do not include the *hundreds* of delayed deaths from radiation-induced cancers projected in the Rasmussen report for *each* early death from a reactor accident. Thus, for example, one can find in the body of the report 7,000 cancer deaths predicted as occurring with the same probability as the 10 short-term fatalities shown in the summary figures.* Other major long-term consequences of reactor accidents (genetic defects, thyroid tumors, land and water contamination) predicted at this same level of likelihood are shown in Table 1.

Obviously, the long-term consequences of a reactor accident that caused 10 early fatalities would be considerably greater than the likely long-term consequences of a meteor impact which caused 10 early fatalities. To equate these two events, as the Rasmussen report did, is therefore highly misleading. Indeed it appears that it has even misled the chairman of the Nuclear Regulatory Commission, who told the audience last year at a convention of the Pacific Coast Electrical Association, that "the risks from potential nuclear accidents would be comparable to those from meteorites."[2]

Accident Probabilities

Consider now the question of accident *probabilities.* No uncertainties are shown on the curves where the Rasmussen group displays their computer results—yet, when you examine the calculations by which these predictions were obtained, you find enormous uncertainties:

- Whole categories of accident initiating events, such as earthquakes and fires, were dismissed without adequate analysis.
- Sabotage was explicitly not considered.
- There was no adequate analysis of the degradation of performance of emergency systems under accident conditions when the reactor building would be filled with superheated steam and water.
- The increase in component failure rates as the plants age was not taken into account.
- The design of only two reactors was looked at in detail; the results would therefore be vitiated if there were a real "lemon" out there somewhere.
- And, finally, when crucial numbers were not available, they were simply guessed. Different investigators might have guessed values ten to one hundred times larger or smaller.

It was for such reasons that the American Physical Society Light Water Reactor Safety Study con-

*There is considerable controversy about the validity of such predictions of cancers and genetic defects, since most of the "population radiation dose" would be delivered tens to hundreds of miles downwind at doses and dose rates low enough so that the increase in the prevailing incidence of these afflictions in the population downwind from the accident would be only a few percent. Because it is difficult to establish such effects statistically it is customary to estimate them theoretically by assuming that the probability of a cancer or a genetic defect resulting from a radiation dose is proportional to the dose, and then extrapolating down from measurements of effects observed in small groups who have received high doses. Some researchers argue that such a linear extrapolation will result in a gross overestimate of the effects while others argue that it will yield reasonable estimates. In any case the *Reactor Safety Study* in most of its published numbers reduced the predictions of the "linear hypothesis" by a factor of five at low doses and dose rates.

In the case of thyroid tumors, the doses received by the thyroids within approximately 100 miles downwind from a major release of radioactivity in a reactor accident would often be large enough to be in the dose regime where a significantly increased incidence of tumors has been observed in humans. This is because a large fraction of the radioiodines absorbed by the body would be concentrated in the small thyroid organ, resulting in it receiving a corresponding magnified dose.

cluded in its review of the NRC's Draft *Reactor Safety Study* report:

> Based on our experience with problems of this nature involving very low probabilities, we do not now have confidence in the presently calculated absolute values of the probabilities.[3]

In summary, therefore, it appears that we do not yet have a study which puts the risks from reactor accidents into correct perspective. For a report to do this, it would have to:

1. tell us what the full consequences of a reactor accident would be—to the degree that they can be determined,
2. tell us as much as is known about the chances of accidents of different degrees of severity—with full disclosure of the ranges of uncertainty of these estimates—and
3. compare, insofar as the ranges of uncertainty allow, the risks from reactor accidents with the other risks against which they must be balanced.

It should be stressed that the outcome of such an effort would not obviously be unfavorable to nuclear energy. The fact that the Rasmussen report is so misleading has naturally led many people to the conclusion that the nuclear industry has some terrible secret to hide. This is not necessarily the case. We are dealing here with an industry and regulators which have a long tradition of responding to public concerns with public relations campaigns rather than public information.

Siting Decisions

Recently, I have been asked by different states to provide information which would help them to develop their own positions on how large a low population buffer zone should surround nuclear power plants. They have decided to look into this question themselves because the Nuclear Regulatory Commission, for purposes of siting decisions, only considers the hazards to the surrounding population from "design basis" accidents less severe than those which would result from the meltdown of the reactor core.

In the simplest terms, the question put to me was: "How far away could early death from high radiation doses occur for different core meltdown accidents under various weather conditions?" The NRC's *Reactor Safety Study* addressed just this question in order to arrive at its numbers for the probabilities of different levels of consequences from reactor accidents. One would therefore expect to find in the Rasmussen report the information that the states need. In all of those 2,400 pages, however, there is only one graph which provides such information—for an unspecified accident for two different weather conditions.[4] In order to determine how the results depend upon the nature of the accident, the wind speed, the rate at which the radioactivity falls out, evacuation and sheltering arrangements, etc., one must reconstruct the entire computational machinery for oneself.

It is unfortunate that these results are not available in the Rasmussen report because it appears that the number of early deaths following a reactor accident could depend quite sensitively on the location of the site. Joel Yellin has made this point very effectively in his excellent review of the *Reactor Safety Study* report.[5] For one of two examples given in that report, Yellin averaged over wind directions around different nuclear power plant sites and found that the average number of early fatalities changed more than a thousandfold when he moved from the reactor site at Wiscasset, Maine, to the one at Zion, Illinois. Thus the accident which caused on the average about one death at the site in Maine would be expected to cause about 1,000 deaths if it occurred under the same weather conditions at the site in Illinois. In view of this result, it would seem that the NRC, state, and local authorities should have such information available to them when they are making siting decisions.

The fact that the report is so misleading led many people to the conclusion that the industry has some terrible secret to hide; this is not necessarily the case.

There is certainly adequate precedent for such information being made available: The U.S. Environmental Protection Agency, for example, has put out a handbook which allows regulators to calculate the groundlevel concentration of the pollutant which would result from specified releases from smokestacks of different heights under different weather conditions.[6] Similarly, the Defense Department and the Atomic Energy Commission have made available information from which civil defense officials may calculate the effects of nuclear weapons explosions under different conditions.[7]

Peer Review

Congress and the public both tend to be very diffident toward technical reports. After all, isn't science "objective" and haven't these reports been written by "experts"? Unfortunately, as the preceding discussion indicates, technical reports may have the same shortcomings as other forms of communication. They can be misleading, wrong or even irrelevant.

These are familiar facts within the scientific community and the mechanism of peer review has been developed to prevent the propagation of errors and to put "contributions" into proper perspective.

In the case of the *Reactor Safety Study*, the review mechanism was used by the authors of the study when a draft version of the report was circulated for purposes of review in late 1974. The peer review process was not used, however, when the final report was presented to Congress a year later as information relevant to Congress' decision on the renewal of the Price-Anderson Nuclear Indemnity Act. Rasmussen was invited to brief Congress' Joint Committee on Atomic Energy on the report, but no independent reviewers were invited. This is unfortunate because it apparently resulted in Congress being misled about the status of the *Reactor Safety Study*.[8]

At one point during the briefing Rep. Mike McCormack asked the following very important question: "To summarize, there is no substantive scientific group anywhere with whom you find lingering differences?" Rasmussen responded: "None that I am aware of."

Technically that statement was correct because at that time, despite repeated requests to the NRC, no substantive scientific group anywhere had been able even to get copies of the Rasmussen report for review. Only enough copies had been produced in the first printing to supply the Joint Committee, which had previously made the commitment to Congress that it would not bring the Price-Anderson Act up for renewal until the Rasmussen report had been completed.

Later, when the issue of peer review was raised before the House Rules Committee Rep. Melvin Price, a member of the Joint Committee, responded as follows:

> The final Report was almost identical to the original version. The only difference being one or two minor areas where they got together with the people who raised exception to figures and there was a final meeting of the minds on the figures.

The issue was thereupon shelved and Congress went ahead with the renewal of the Price-Anderson Act.

In the light of this unfortunate history and the general lack of understanding of the importance of peer review outside of the scientific community, it might be useful to cite briefly the results of a partial review of the draft *Reactor Safety Study* by a group sponsored by the American Physical Society (APS).

TABLE 2

Some Consequences of the American Physical Society Review of Draft Report of Reactor Safety Study

Accident effect	Change in final report
Whole body radiation dose to population downwind (cause of cancer and genetic defects)	Increased tenfold
Inhalation radiation dose to lungs of population downwind (omitted in draft as cause of cancer)	Now largest cause of cancer
Thyroid cases	Increased threefold
Long-term radioactive land contamination	Duration increased tenfold
Water contamination by strontium-90	Increased one-thousandfold

The APS Light Water Reactor Safety Study was an effort by a dozen technical people, with the actual work concentrated into the month of August 1974. The draft report of the *Reactor Safety Study* was only one of the objects of the brief APS study, yet even this limited review led to some very significant findings. The APS group found:

- that the *Reactor Safety Study* had grossly underestimated the "whole body" radiation dose to the population downwind by neglecting the dose from radioactive land contamination after the first day;
- that the radiation dose to the lungs from inhaled radioactivity was omitted entirely in the draft Rasmussen report as a cause of cancer;
- that the number of thyroid tumors which would result from the inhalation of radioiodine had been seriously underestimated;
- that long-term land contamination by radioactivity after an accident would have a half-life of about 10 years rather than the one year which had been assumed; the main source of potential radioactive water contamination from a reactor accident had been omitted.

When these omissions in the draft *Reactor Safety Study* report were corrected, the effect was far from minor (see Table 2). It took almost a year to convince the leadership of the *Reactor Safety Study* to accept these corrections but they ultimately were made in the final report—although, as has already been noted, the long-term consequences were dropped again when comparisons were made between the consequences of reactor accidents and other events.

Nevertheless, the experience of the APS group exemplifies the important role which peer review can play in the case of a technical report like this. Congress and the public should learn to insist on such a peer review process being completed and the results made public before a technical report is accepted as an appropriate basis for policy actions.

In fact, the review process is still far from complete in this case. Although the APS group examined in some depth that part of the report pertaining to the long-term consequences of a reactor accident, it did not look in detail at the analysis of accident-causing events nor did it review the calculations of early fatalities. It appears that, despite the excellent work which has been done by other groups in these areas, there is still much that remains to be done.

Even in the area of long-term consequences it would appear that another review is called for. The analysis of these effects has been completely changed and the space devoted to it in the Rasmussen report has been expanded approximately tenfold as a result of the APS critique. There are many new calculations which should be reviewed. For example, in view of the fact that natural processes would remove radioactivity (cesium-137 particularly) from the land much more slowly than was assumed in the draft report, the final report now assumes for a major release of radioactivity into the atmosphere that thousands of square miles of land and property would have to be decontaminated. An analysis is presented which concludes that it would be practical and economical to remove up to 95 percent of the radioactivity from such an area. This would be an heroic and unprecedented undertaking, and it is important that the assumptions made in this analysis be reviewed.

* * *

In summary, then, the *Reactor Safety Study* report has assembled a great deal of useful material and analysis; but its conclusions are presented in a highly misleading form. Furthermore, the report does not provide the information required for siting decisions. And, finally, the report has severely damaged not only the Nuclear Regulatory Commission's credibility but also its regulatory leverage. Since it appears to say that there is virtually no reactor safety problem, the industry can now use the NRC's own report as ammunition when it argues that no new safety improvements are needed.[9]

Where do we go from here?

First, it would appear that the peer review of the Rasmussen report must be completed. This may require substantial support from either government or foundation sources. The job cannot be done adequately by a few individuals working evenings and weekends, although such efforts can continue to play an important role.

Second, we need a study which can take the findings of the Rasmussen report, as corrected and extended, and put them into a more balanced perspective suitable for policy-making. Despite the recent proliferation of studies of nuclear issues, it appears that there is no group which is actually carrying out this important step.

Finally, it is to be hoped that in the future Congress and other governmental bodies will learn to insist that technical reports be subjected to peer review *before* they are used to determine policy.

Notes

1. Nuclear Regulatory Commission, *Reactor Safety Study* (WASH-1400 or NUREG-75/014, October 1975).
2. Marcus A. Rowden before the 59th Annual Convention of Pacific Coast Electrical Association, May 21, 1976. (NRC Press Release No. S-6-76.)
3. "Report to the APS by the Study Group on Light Water Reactor Safety," *Reviews of Modern Physics*, 47, Sup. No. 1 (Summer 1975), S5. See also Robert K. Weatherwax, "Virtues and Limitations of Risk Analysis," *Bulletin of Atomic Scientists*, September 1975, p. 29.
4. *Reactor Safety Study*, Appendix VI, Figure 13-7.
5. Joel Yellin, *The Bell Journal of Economics*, 7:1 (1970), 317.
6. D. Bruce Turner, *Workbook of Atmospheric Dispersion Estimates* (Washington, D.C.: Environmental Protection Agency, 1970).
7. Samuel Glasstone, ed., *The Effects of Nuclear Weapons* (Washington, D.C.: Department of Defense and Atomic Energy Commission, 1962).
8. The Congressional history reviewed here is summarized in a letter of Nov. 26, 1975 from Rep. Morris Udall to Speaker of the House, Carl Albert. The letter is reprinted in *Oversight Hearings on Nuclear Energy—The Price-Anderson Nuclear Indemnity Act*, hearing before the Subcommittee on Energy and Environment of the U.S. House Committee on Interior and Insular Affairs, Dec. 1, 1975, pp. 148-153.
9. Atomic Industrial Forum, "Statement on Reactor Licensing," Nov. 1976.

Editor's note: Professor Rasmussen was invited to respond to this article but declined to do so.