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Uncertainty, Reassurance and Nuclear Safety

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Introduction

The safety of nuclear reactors remains a key public issue in Ontario. In December 1986, in part as a response to public concerns raised by the accident at Chernobyl, the Ontario government commissioned a study of reactor safety, the Ontario Nuclear Safety Review (ONSR). The study was conducted by Dr. Kenneth Hare, a geographer who is now Chancellor of Trent University. The author of the present paper served as staff scientist, with the responsibility of coordinating the scientific work of the Review.

The ONSR report, *The Safety of Ontario's Nuclear Power Reactors* (hereafter "the Report"), was released in April 1988. The complete report consists of five volumes, the first of which is 288 pages long. A summary document, in the form of a report to the Minister of Energy, consists of 41 pages.

Despite the length of the Report, only its Major Conclusion (a highlighted central message contained in the executive report) of 48 words has been cited in various documents since published by the Ministry of Energy (Ontario Ministries, 1988) and Ontario Hydro (Ontario Hydro, 1989). The conclusion (Hare, 1988) states that:

> The Ontario Hydro reactors are being operated safely and at high standards of technical performance. No significant adverse impact has been detected in either the work-force or the public. The risk of accidents serious enough to affect the public adversely can never be zero, but is very remote.

I argue in this article that, although I agree with the overall findings contained in the main body of the Report, the reassuring words of this conclusion should not be taken as an adequate basis for judging that nuclear power is safe. I take this position for two important reasons. First, the degree of certainty in the conclusion taken by itself is not supported by the substance of the Report, with the result that someone who reads the conclusion without seeing more of the Report is misinformed. Second, the type of uncertainties that arise in reactor safety cannot be adequately resolved by the technical and scientific examination considered in the ONSR. The latter reason is a consequence of inherent limitations on the scientific approach when it is applied to solving vexing political problems. Both issues — the problem of communicating the results of technical and scientific analysis applied to policy problems and the fundamental limits of such applications — are quite general. The ONSR merely provides a timely illustration.

Limitations of Traditional Scientific Approaches to Environmental Issues

Jerome Ravetz has characterized the traditional view of science in the policy process as follows:

> The public, through some political machinery, expresses a concern that some particular purposes are being frustrated or endangered, say through the lack of clean water. Administrators then devise or promote devices and systems, physical technology, or administrative agencies to perform particular functions whereby these purposes may once again be protected. For this they need information about the natural process involved in the problem; for which they turn to the scientists. The scientists provide the necessary facts (either from the literature, or produced by research to order) which either determines the appropriate solution, or at least sets boundaries within which the normal processes of political bargaining can take place. In that way, the problem is solved or, at least, effectively resolved in political terms (Ravetz, 1985).

Applying the traditional scientific approach to policy problems involving environmental harm presents a thorny challenge

The success of such investigations is presumably in part due to the cooperation and respect accorded to the investigators and the comprehensiveness of the information with which they are presented. In some situations the model has worked rather well. A recent example is the investigation of the Challenger space shuttle accident (Presidential Commission, 1986). It can be observed in this case, however, that the determination of the cause of the

accident and the identification of the responsible agents involve quite narrow terms of reference. Environmental problems present a much thornier challenge. When the harm is difficult to prove and the consequences of action are uncertain, different types of issues appear on the political agenda and they can make the model referred to above ineffective. In these situations it is more likely that values will be in dispute and will be incoherently expressed and that the base of scientific knowledge from which to work will be very incomplete. The time constraints on making a decision may also be quite different.

What happens when one approaches a problem that unavoidably involves "incomplete science" within the traditional policy process as characterized here? The assumption of the model is that the scientific review should "stick to the facts" and avoid explicit discussion of values. It is further assumed that the judgment will provide a clear answer to the problem in question. These goals then have implications for the investigation. They will generally mean that the terms of reference have to be narrowed sufficiently to exclude incomplete scientific issues and that uncertainties have to be de-emphasised in order that the principal conclusion of the investigation not be brought into question.

The scientific portion of the analysis is assumed to be value free

The difficulty involved in having to deal with facts and values simultaneously when making decisions on environmental issues has led some to treat the analytical problem as a dichotomy. The portion of the analysis viewed as scientific is treated as if it were value-free; values are to be taken account of in the portion which confronts actual decisions. The latter portion is then viewed as involving a special type of uncertainty — "political uncertainty." Consider as an example of this view the following statement by the Royal Commission on Lead in the Environment (Royal Society, 1986):

> The Commission's approach has been determined by the skills and experience of its members, and by a conviction that all of us share — that objective weighing of scientific evidence is a better way to judge an environmental issue than is an exchange of threats or rebuttals. We have sought a consensus on this issue. We found what we knew must be there: a common agreement that all Canadians must be protected against environmental toxins. But we also found widespread differences of opinion about how dangerous a toxin lead was in the special conditions of Canadian life. Our report addresses that question.

Certainly "an exchange of threats or rebuttals" does not sound promising as a way to exercise judgment in contrast to "the objective weighing of scientific evidence." The latter is seen as a refuge from apparently irresolvable political differences and perceived misunderstandings. Presumably the authors of the statement believed that much of the "widespread difference of opinion" over the dangers of lead was due to insufficient scientific

analysis, or misunderstood scientific analysis, or the use of biased analysis by some of the protagonists in the debate. Thus they could argue that much of the question was resolvable through science. At the same time, they appear confident that they can handle the political uncertainty involved in the question, for they have found agreement that all Canadians must be protected from toxins.

The characterization of uncertainty involved in the above example is intended to establish the autonomy of science and the judgments made by scientists in the policy process. It is, of course, true that, if science simply provided facts, scientists could exercise their trade without regard to the political context. I believe, however, that "the objective weighing of scientific evidence" can require scientists to become judges and make judgments, often in the face of incomplete research and significant uncertainty.

An important category of difficulty arises when some aspect of a policy dispute is over the way scientists interpret evidence to arrive at their judgments. In situations in which both the nature of evidence and the value judgements required to use the evidence in decisions are under dispute, the scientist will often find it difficult to avoid the overlap between technical and political judgment. The problem involves both technical and political uncertainty. When this happens, analytical conclusions can appear more certain to a non-technical audience than they really are. If the existence of this kind of overlap is admitted, the autonomy of the scientific decision-making process, and hence its authority, has become more limited.

In the presence of such uncertainties, any scientific judgment is subject to criticism. Indeed, scientific approaches to dealing with the very concept of uncertainty have been criticized.[1] However, the ambiguities noted above often enable scientists to avoid criticism of their conclusions. In this way uncertainty can be inadvertently suppressed.

The suppression of uncertainty has two important political aspects. First, there is a rhetoric of certainty that discourages the consideration of tradeoffs. Second, uncertainty concerning safety can be used in debate to shift the burden of proof to those who perceive the potential for harm by insisting upon an unattainable standard of proof before action becomes necessary.[2]

A key limitation on the use of a traditional scientific approach to environmental issues is the way that uncertainty is managed. As shall be illustrated, uncertainties appear in the consideration of many technical issues that concern tradeoffs between hazard

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1/ For a critique of scientific approaches to dealing with uncertainty in a policy-making context, see Schrecker (1984).

2/ See, for example, Schrecker (1984), pp.26-37.

and cost. "Scientific" judgment on these issues may well not question the tradeoffs that are made. Furthermore, if the political legitimacy of a scientific review needs to be supported, a rhetoric of certainty may be used to obscure uncertainties that might better be dealt with through a broad political input.

Ontario Nuclear Safety Review

Ontario Nuclear Safety Review involved a traditional scientific approach

The Ontario Nuclear Safety Review can be viewed as an attempt to address the reactor safety issue with a traditional scientific approach. The terms of reference for the Review were spelled out in a letter from the Ontario Energy Minister. In it the Minister made abundantly clear that the ONSR was intended to be a review of the technical and scientific aspects of nuclear reactor safety. Dr. Hare was instructed to "draw on a full range of scientific and technical advice" through the commissioning of technical reports from consultants and to invite "submissions from interested groups on the scientific and engineering dimensions of nuclear safety" (Kerrio, 1988). Indeed, the report is subtitled "A Scientific and Technical Review" (Hare, 1988).

The intent of these terms of reference was to exclude consideration of political judgements. The ONSR was established to investigate how well or poorly the reactor was designed, or operated, and how effective the emergency plans might be. In my view, any improvement in safety devices, in operating procedures or in provisions for emergency plans would not have met many of the fundamental objections of those opposed to nuclear power. The Review was defined so as to address a narrower technical set of safety issues, rather than the broader questions concerning public acceptance of nuclear power.

Thus described, the Ontario Nuclear Safety Review certainly took a traditional scientific and technical approach to the public policy problems regarding nuclear reactor safety. If the characterization of the traditional approach presented above is accurate, an examination of the treatment of uncertainty in the Review should reveal some of the limitations of this approach. In the next section, the management of uncertainty in nuclear reactor safety and some of the tradeoffs between hazard and cost revealed by the Review will be discussed. Following this, various conclusions of the Report will be examined to show how the confident tone of the principal conclusion is contrary to many of the other conclusions.

The Management of Uncertainty

Differences in the interpretation of data can indirectly reveal information about value-tradeoffs

Ironically, though differences in values are set aside when a traditional scientific approach is adopted for the study of an environmental issue, differences over the interpretation of data

can indirectly reveal information about the value-tradeoffs between hazard and cost that are being applied. Judgments made by experts in the context of their specialized technical studies, which have supposedly been separated from value-questions, reveal choices that merit wider political consideration. Thus an examination of uncertainty, even in a technical context, can form part of a broader debate on nuclear safety.

There were numerous instances in which these kinds of normative choices were revealed in the Ontario Nuclear Safety Review. This paper considers only two examples. In the first, the criteria for selecting accident analysis cases are considered. The second concerns a particular example of legitimately different opinions over tradeoffs between hazard and cost.

Accident Analysis

Given the complexity of a nuclear power station, and the possible combinations of things that could go wrong, accident analysis requires a process of selection of possible events for detailed analysis.[3] One of the avowed purposes of the analysis is to determine the robustness and effectiveness of the reactor's safety systems to prevent an accident from becoming a threat to human and environmental health. The cases that are analyzed for licensing purposes are considered to be conservative; that is, they are examples of the "worst case" of each type of accident considered. Some conceivable accidents are not analyzed because their likelihood is judged to be too remote (Ontario Hydro, 1987, Sec. 4.2.1).

The reactors at Pickering A have only one special safety system for shutting down in case of an accident. Reactors built subsequently have two. Safety analysis was performed when they were licensed in the early 1970s. It considered the consequences of a failure to shut the reactor down should the reactor power begin to rise. The analysts concluded that, although there would be serious damage to the reactor, very little of the radioactive material would escape to the environment (Ontario Hydro, 1971). By the late 1970s it was realized that the original analysis was out of date. An Ontario Select Committee on Energy asked that it be redone.[4] Ontario Hydro refused to do such a study and the Atomic Energy Control Board (AECB) did not see the necessity for the analysis to be redone. One reason given was that analytical tools were not then sufficiently developed to produce reliable answers.

The accident at Chernobyl, the event that precipitated the ONSR, changed matters. First, French nuclear scientists had con-

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3/ This is sometimes called the Design Basis set (AECL, 1987).

4/ Select Committee (1980) Recommendation X, p.37.

cluded that the enormous energy release caused by the explosion at Chernobyl was large enough to blow apart any containment (MacLachlan, 1987). It seemed to me to be possible, **at least in principle**, that a reactor in Ontario might do the same thing if its power were to increase out of control and its shutdown system were to fail. There had been many improvements in the tools used to analyze such events. The time had come for a new analysis.

Commissioner Hare decided that such a study should be done. Senior officials of Ontario Hydro were initially upset by this decision. They argued that the results would be too uncertain to be reliable. When this was seen to have no effect on the decision, additional arguments were advanced. A senior manager urged the Review's Advisory Panel that it was unwise to do the analysis **because** the predicted consequences would be similar to Chernobyl. A scientist at Argonne Laboratory, not directly involved in the project, contacted this author to express his concerns. He argued that to undertake such analysis was politically foolhardy and could undermine the public acceptance of CANDU.

Nevertheless, attitudes did change within Ontario Hydro and its staff members began to cooperate with Argonne Laboratories, the consultants hired by the Review. The results of the analyses ultimately turned out to be much more favourable than those expected by some experts who had initially been apprehensive (Ontario Hydro, 1988a).

Relating this episode to the issues considered in the present paper, the unavailability of adequate analytical tools was used by Ontario Hydro staff as an argument against performing an analysis that they thought would have led to an unfavourable result; specifically, they felt that undue emphasis would be placed on unreliable analyses of low-probability events. As a result, Ontario Hydro did not examine in depth an event that its own analysts believed would have very severe consequences. The AECB did not require Hydro to redo the analysis and did not reconsider its position until after the Chernobyl accident (AECB, 1987).

By avoiding re-analysis, both Hydro and the AECB avoided reconsidering the tradeoff between hazard and cost. For if, as some scientists believed, the consequences of accidents would be significantly more severe than any that had been considered, the need for further safety requirements would have had to be revisited. As Bryan Wynne writes (Wynne, 1988, pp.10-11):

Conflict over the boundaries between technical sovereignty and policy values

> Here I think is a possible explanation of the fundamentally political experience which many people amongst public groups have of technical expertise which is exercised with impeccable technical competence and good faith. It is not so much a matter of arguing whether such technical claims are right or wrong, but whether they embody implicit visions of the proper degree of audience access to internal uncertainties and disagreements which that audience fundamentally repudiates. Such conflicts are not for the technical

> expert to resolve, as tends to happen currently, because they are not about the Technical **Content** of claims; they are about the proper boundaries between technical sovereignty and policy values, and this is legitimately a matter for wider political negotiation. [original emphasis]

The denial of audience access to the internal uncertainties and to the reasoning that goes into expert judgment means that the audience for a technical statement, a report or a technology assessment will never be troubled by discussions over policy values. But they are likely to be affected by the values actually applied, for these values have practical consequences, namely the level of hazard and the associated cost actually chosen in the policy decision involved.

Conflicts Over the Management of Uncertainty

Conflicts over the treatment of uncertainty arose between intervenors and Ontario Hydro. One of the submissions presented by Energy Probe was a well-researched paper on the safety hazards presented by the aging and obsolescence of reactor equipment (Slee, 1988). The authors argued that many of the safety-related design changes made by Ontario Hydro to its reactors were needed because of the proven inadequacy of the present design. If this is so, they argued, it then seems sensible to require that the obsolescent equipment be replaced and, furthermore, that the "backfitting" be done promptly with equipment that will do what it was proclaimed to do. They also argued that, considering the uncertainties which have turned up in safety analysis that show equipment to be obsolete, old reactors should be upgraded to meet the standards of new reactors.

Ontario Hydro took a quite different view of these matters. They argued (Ontario Hydro, 1988b) that Energy Probe's recommendation:

> is not required, is not achievable and is counterproductive. Ontario Hydro uses the original safety criteria as the minimum basis for continued operation. It is also policy to improve safety to the extent practical regardless of compliance with minimum standards and to upgrade existing plants where new insights show the original standards were unacceptable. The result of the recommendation would be that new safety developments would be harder to pursue.

The treatment of uncertainty is central to the disagreement between the two positions. Energy Probe argued in their paper that better equipment on newer stations is not merely a matter of adding "deluxe" features solely as additional economic protection against damage: rather the more stringent criteria were instituted to deal with uncertainties revealed by more careful research into reactor safety problems. Ontario Hydro's attitude was that expenditures to reduce these uncertainties are not nec-

essary to protect the public adequately. Installing such features on older plants would be a frivolous and unnecessary cost.

It should be clear from this example that the debate, even in this relatively technical area of safety, is not really about "the technical content of claims" or about the technical competence of Ontario Hydro or Energy Probe. Rather the treatment of uncertainty embodies assumptions about what constitutes acceptable safety and that, as Wynne argues, is a legitimate matter for political negotiation.

The tradeoffs made by scientists need to be considered as an essential part of the political process

This is not to say that tradeoffs are unacceptable; nor that choices from among the tradeoffs made by AECB and Ontario Hydro are necessarily wrong. On the contrary, tradeoffs are unavoidable. But it is important to emphasize that the tradeoffs made by scientists need to be considered as an essential part of the political process, rather than as part of scientific evidence which is not subject to wider discussion.

Of course, in principle the AECB is the agency through which this balancing act takes place. I believe, however, that the Board's procedures provide insufficient public input into the process.[5]

Conclusions as Reassurance

The principal conclusion of a report is of paramount importance from the point of view of communicating results to a wide audience. It is the main message received by the public, and possibly by some decision-makers as well. The Major Conclusion of the Report, quoted in the introduction to this paper, is a reassuring message about reactor safety. It has been cited by the Ontario Ministry of Energy (Ontario Ministries, 1988) and by Ontario Hydro (Ontario Hydro, 1989) to support their argument that the CANDU nuclear option should remain open. It is clear that the confidence conveyed by the statement plays a role in the political process that keeps the nuclear option open.

A careful examination of the Report, however, reveals that the recommendations of the Commissioner were more ambiguous than the principal conclusion highlighted at the beginning of the Report might lead one to believe. It is useful to examine each part of the conclusion in relation to other statements in the Report that qualify it.

The first sentence says that "Ontario Hydro reactors are being operated safely and at high standards of technical performance." However, the Report also identifies numerous problems with Ontario Hydro's operating practices and the Commissioner concluded that, although no one problem seriously threatened safety, together they suggest that "an overhaul of operational safety culture would be in Ontario Hydro's interest — and therefore the

5/ See, for example, Schrecker (1988) and Adams and Jerrett (1987).

public's" (Hare, 1988, p.v).

The second sentence says that "No significant adverse impact has been detected in either the workforce or the public." While this is true, it is also noted that for workers "it is ... too early for all latent cancers to have been revealed" (Hare, 1988, p.xvi). Regarding public exposure, it is noted that "no comparable study of public impact" of radiation exposure had been carried out. Noting the results of a British study that suggests a possible association between lymphoid leukaemia and radiation exposure,[6] the Commissioner argued that "every effort should be made by epidemiological means to establish whether children and young adults in communities near reactors ... show increased leukaemia incidence or other morbidities."[7]

The third sentence states that "The risk of accidents serious enough to affect the public adversely can never be zero, but is very remote." Elsewhere, noting that a severe accident cannot be ruled out, the review did conduct an analysis of the consequences for a "worst case" type of accident. It was necessary to use US information since comparable Canadian data were not made available to the Review. This case, combined with unfavourable wind conditions, predicted 9700 deaths and extensive land contamination. Thus the conclusion of the Report places emphasis on the low probability and deemphasizes the magnitude of the consequences of such an event. Note that both the technical uncertainty of the probabilities and the potential for differences in evaluating the consequences (distinct issues according to the traditional view described above) are not mentioned.

Communicating a principal conclusion more fully

The above discussion leads one to think of ways in which the principal conclusion of the Report could be modified in order to reflect more adequately some of the provisos raised in the body of the Report. In the following revised version of the conclusion, quotations from other sections of the Report appear in italics; added connecting words and paraphrasing of other information from the Report appear in square brackets.

> The Ontario Hydro reactors are being operated safely and at high standards of technical performance, [although] *an overhaul of Ontario Hydro's safety culture is needed.* No significant adverse impact has been detected in the work force, [although] *it is too early for all latent cancers to have been revealed.* No significant adverse impact has been detected in the public, [although no studies have been undertaken in Canada]. [While accidents involving fatalities and the contamination of land were considered, and] the risk of accidents

6/ Note that the latest study suggests that workplace exposure, rather than releases to the environment, may be the cause. (Gardner *et al*, 1990).

7/ Hare (1988), pp. xvi-xvii. The AECB is conducting such a study. The first phase showed a greater number of leukaemias than would have been expected but the number was small enough that the excess was likely due to chance.

> serious enough to affect the public adversely can never be zero, [such risk] is very remote, [although not precisely known].

The purpose of rewriting the conclusion in this way is not to demonstrate that the original conclusion is wrong, but rather that it is open to interpretation. The modified conclusion better reflects the Report's contents and recommendations.[8] The original conclusion, cited on its own, amounts to a strong endorsement of present practice.

Conclusion

If a closer examination of nuclear safety shows that important uncertainties exist, and the ONSR report contains many provisos that are at odds with the confident tone of its principal conclusion, why is the tone of the conclusion so firm and certain? In my view, the answer can be found in the political role that such scientific reviews play. Bryan Wynne has described this process as a "ritual of reassurance" undertaken to reaffirm commitments to nuclear power.

It is fundamentally important to recognize that the issue of the safety of nuclear power cannot be resolved by scientific investigation. As Wynne writes of the Sizewell B inquiry (Wynne, 1988, p.2):

> Such matters are in the end simply indeterminate, and although much useful and necessary examination of them was carried out, they cannot be said to be **resolved** by this technical examination. They can only be resolved eventually by political commitment and history.

The Review revealed that important uncertainties exist and that there are important tradeoffs between hazard and cost. The balancing of these tradeoffs requires input from concerned members of the public and their political representatives as well as scrutiny by experts.

Ontario Hydro, in its recently released long-term plans, proposed to build three new nuclear generating stations over the next 25 years. The public hearings on these plans to be convened by Ontario's Environmental Assessment Board could provide an opportunity for that broader input, if the Board chooses to consider nuclear safety as a priority issue. Its failure to do so would undermine the legitimacy of the nuclear enterprise.

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8/ Of course, if the conclusion had been written in the first instance with these qualifications in it, it would have been structured differently to accommodate considerations of writing style and more effective communication.

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