Ethical Risk Assessment: Valuing Public Perceptions

Engineers are confronted with an array of moral issues and dilemmas as the complexity of modern technology results in equally complex efforts to assess the accompanying environmental and safety risks. The ethical responsibilities of engineers and the need for workable solutions to technological controversies dictate that engineers be able to discuss technological risk with the public. The openness required for meaningful risk communication, however, is often at odds with the prevailing engineering culture.

It was argued in [1] that for meaningful communication to occur between experts and the lay public on issues related to technological risk, substantive attitude changes are necessary on the part of experts, including engineers and other technical specialists, with respect to the relevance of public perception of risk. While that paper included a case study of risk communication in connection with "inherently safe" nuclear reactors, no attempt was made to relate the analysis to the ethical responsibilities of engineers or to the norms of engineering practice.

The purpose here is to examine the connections between engineering ethics, risk communication, and the engineering culture. First moral issues in risk assessment are reviewed and the ethical responsibilities of engineers with respect to risk assessment and risk communication are discussed. The conventional model of risk communication, which holds that only experts possess relevant risk information, is then critiqued, and the findings of social scientists and humanists with respect to the dual importance of expert and public risk information are reviewed. Following a discussion of the prevailing engineering culture, particularly as it relates to the problems involved in risk communication, some suggestions are made for transforming the engineering culture in a manner conducive to more meaningful discussion of risk.

Moral Issues in Risk Assessment

As modern technology and the assessment of environmental and safety risks become more complex, an increasing array of moral issues and dilemmas is created, including [2]:

1) the overlapping of political or normative judgments with scientific judgments;

2) the potential for manipulation of risk assessments to legitimize deployment of risky technologies;

3) the determination of the "value of life" used in risk assessment;

4) the imposition of risks upon others, particularly those less empowered (e.g. developing nations); and

5) the distribution of risks and consequences across geopolitical, cultural, or generational boundaries.

These points are illustrated by events such as the 1984 chemical leak in Bhopal, India, the 1986 explosion of the space shuttle, Challenger, and the 1986 accident at the Chernobyl nuclear power plant.

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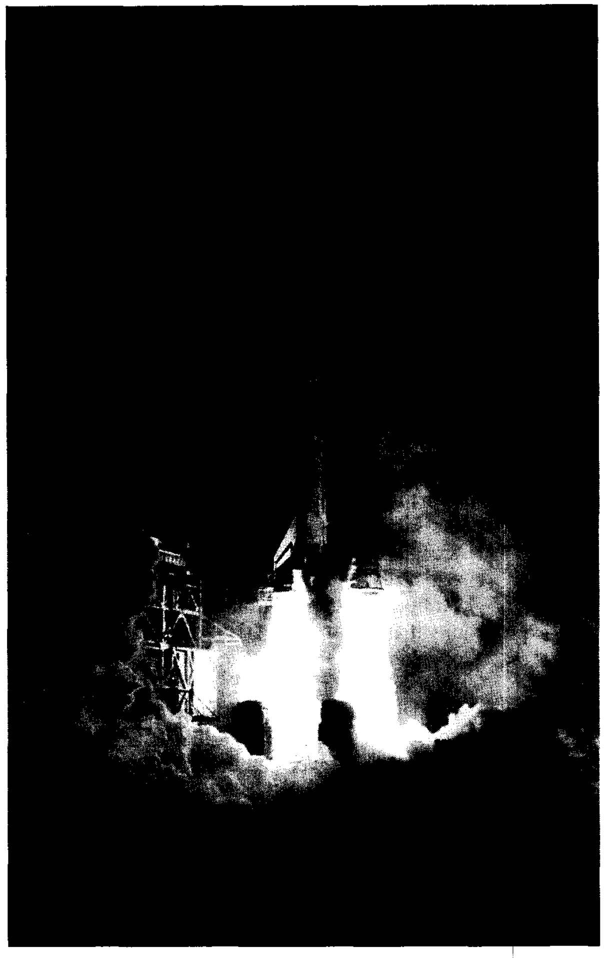
The overlapping of political or normative judgments with scientific judgments follows inevitably from the use of risk assessment in determining the acceptability of risks. The now-infamous remark of one Morton Thiokol executive to another during an engineering teleconference on the eve of the Challenger launch — "Take off your engineering hat and put on your management hat" — is a stark reminder both of how technical judgments regarding the amount of risk can become intertwined with value judgments regarding the acceptability of risk, and how risk decisions ostensibly made on technical grounds can be manipulated to camouflage economic or political reasons for imposing risks on others [3].

The "risk assessment" performed by the National Aeronautics and Space Administration (NASA) prior to the Challenger accident further illustrates how risk assessment can be misused to legitimize a risky technology. Although, at the time, no formal risk assessment techniques were employed by NASA in the space shuttle program, the agency estimated the risk to be very small when contributing to a study of the risk of flying a plutonium payload. And while the risk estimates were supposedly based upon "engineering judgment," the actual risk estimates of the working engineers were three orders of magnitude higher. [4]

Yet another example of the misuse of risk analysis is presented by the claims of engineers and others who promote a nuclear power renaissance based upon a new generation of "inherently safe" reactors [1]. Recognizing that the industry's current risk estimates for core-melt accidents are unacceptably high for any scenario that projects large-scale deployment of nuclear power, some experts have projected that the risks of future reactors will be as much as one hundred times lower than existing reactors. Such *ad hoc* risk analysis, while reflecting the experts' own notion of what the public will find acceptable, does not necessarily address the level of safety that is actually obtainable, or for that matter, publicly acceptable. The Three Mile Island and Chernobyl accidents have cast doubt upon the reliability of risk assessments pertaining to the current generation of reactors. Moreover, the new generation of reactors has yet to be demonstrated in a manner that even approaches commercial application. Highly optimistic projections of future safety improvements thus amount to not much more than wishful thinking, even when cloaked in the "respectability" of numerical estimates and accompanied by claims of inherent safety.

Determining the "value of life" is among the thorniest problems in risk assessment. Frequently, lives are valued based upon criteria such as economic worth or expected earnings, which translates into "life is cheap" in poorer neighborhoods or less-developed nations. This issue is clearly illustrated by the Bhopal case. Life in Bhopal was implicitly valued less than life in the United States — the safety equipment and emergency preparedness at the Bhopal plant were far less adequate than those at a similar facility



operated by Union Carbide in Institute, West Virginia [5]. The low valuation of life in Bhopal was made explicit in the legal arguments made by Carbide regarding the extent of the company's liability and in the actual settlement. Although nearly 3000 people died as a result of the Bhopal accident, the settlement was less than half the settlement agreed to in the case of the Exxon Valdez oil spill.

The Bhopal case also highlights the moral issues involved in the imposition of risk upon others, particularly those less empowered, as in the case of multinational corporations "exporting" risk to developing countries by building hazardous facilities abroad, by selling products in developing countries that are banned in the West on health or safety grounds, or by paying developing countries' governments for the disposal of hazardous waste.

While the direct impacts of the Bhopal catastrophe by and large were contained within the local community, the Chernobyl accident illustrates how such impacts are not always limited by geopolitical, cultural, or generational boundaries [2]. Significant amounts of radioactive fallout from Chernobyl were deposited throughout Europe and the then Soviet Union. Ironically, perhaps the most serious damage was done to a people who have very little to do with complex contemporary technologies such as nuclear power. The Lapps of northern Scandinavia, whose culture revolves around the herding of reindeer, were devastated when much of their herds had to be destroyed due to ingestion of radioactive cesium that had been deposited on the lichen that made up the reindeer's diet. Radioactive fallout from Chernobyl also raises the possibility that future generations will be adversely impacted by the shortcomings of today's technologies.

The points mentioned so far by and large deal with the value judgments made in the use of risk assessments, or put another way, in determining acceptable risk. A number of these examples also illustrate, however, that contrary to the conventional wisdom within the technical community that the process of risk assessment is entirely objective, value judgments can and often do enter into the process. The risk evidence in the Challenger case was perceived differently by the Thiokol engineers, who relied to a great extent on past experience and their engineering judgement, than by the NASA and Thiokol managers, who insisted that there was no hard and fast data that justified scrubbing the launch. The uncertainties involved in evaluating the risks of nuclear power are valued differently by technical specialists, who argue that "inherent safety" reduces risk and uncertainty, and a public skeptical of such claims as a result of previous accidents and near-misses. Determining the "acceptability of evidence of risk," then, can also involve moral questions [6].

In summary, determination of the acceptability of risk and of risk evidence is a value laden process, accompanied by a wide array of moral issues and dilemmas. By virtue of their significant role in the process of technological development, engineers are inevitably involved, directly or indirectly, in risk assessment and risk management and, hence, must be prepared to examine the values these judgements incorporate and wrestle with the accompanying moral issues [7].

Engineering Ethics and Risk Assessment

Although engineering ethics codes have existed for a century, it is only during the past thirty years that such codes have been revised to include explicitly the notion that engineers have a responsibility for protecting the public safety, health, and welfare. The first "fundamental canon" of the code of ethics of the National Society of Professional Engineers (NSPE), for example, holds that engineers shall:

Hold paramount the safety, health and welfare of the public in the performance of their professional duties.

Likewise, the first pledge contained in the current code of the Institute of Electrical and Electronics Engineers (IEEE) states that IEEE members agree:

to accept responsibility in making engineering decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.

The evolution of such codes reflects a growing acknowledgment on the part of professional engineering societies that engineers have both a professional and a moral responsibility for the public safety and welfare [8]. In this respect, ethics codes have also become more consistent with traditional moral theories in both the utilitarian and rights/duties traditions [7].

The moral issues raised by risk assessment have significant implications regarding the professional responsibilities of engineers. Since, as we have seen, the scope of such issues is not limited to technical matters, their ultimate resolution, in addition to technical expertise, also requires the judgments of experts in management and public policy [7]. In addition, since most technological risks are borne by the public, and since societal values are relevant in the evaluation of risk, the judgments of nonexperts are also legitimate components of risk assessments.

The concept that the public should have an active role in the assessment of risk is consistent with the IEEE code of ethics, the fifth pledge of which states that IEEE members agree:

...to improve the understanding of technology, its appropriate application, and potential consequences....

Improving understanding of technology, however, is not a one-way process. In order to fully understand technology and its consequences, engineers must be informed with respect to nontechnical perspectives on technology [8]. Indeed, as I have argued elsewhere [1], for successful communication about risk to take place between engineers and the public, engineers must develop a sensitivity to and respect for the differences between expert and nonexpert perception of risk. Unfortunately, such sensitivity is not widely apparent among engineers, even among those who have addressed the problem of risk communication.

Two Models of Risk Communication (1)

The conventional view of risk communication, held by many engineers, is that risk communication need consist merely of "educating" the public to endorse expert judgment concerning which risks are acceptable and which are not. Under this model of risk communication, the experts have a corner on the truth of the matter; the only problem is to see that the public is properly informed of the experts' views. Nonexperts (and even experts in other fields) are seen as incapable of understanding the problem, and of making rational risk decisions. The role assigned the public under this model of risk communication is a passive one: listen and learn from the experts. Success is measured by how well the message gets across, and whether or not the public accepts the judgments of the experts [9], [10].

This view of risk communication is so imbued in the engineering culture that it is readily endorsed by most engineers and technologists who turn their attention to addressing the problem of risk communication. Markert, for example, has argued [11]:

Since only a few persons truly understand new technologies, most of us are dependent on those few "experts" to present us with all the facts regarding safety. Prudent control and management of risk demands a high level of technology awareness unclouded by emotional biases. It appears that the most effective risk management decisions will be made only when the risks are clearly communicated.

The conventional model of risk communication is also exemplified by the risk messages contained in discussions of advanced, "inherently safe" nuclear reactor designs. By implying that accidents are impossible, the term "inherently safe" epitomizes the conventional model of risk communication with the experts assuring the public that all is well. Implicit in its use is the notion that the public wants zero risk, and, therefore, the solution is to give them "inherent safety." Although increased public acceptance of nuclear power is a stated goal of the planners of the new nuclear power era, one wonders whether the public would ever accept a claim of inherent safety by an industry whose credibility has been so heavily damaged by the failures of the first era [12].

In contrast to the conventional model, an emerging view of risk communication recognizes that nonexperts are also in possession of relevant risk information, thus necessitating an exchange of information between experts and the public if effective communication about risk is to occur [10]. Under this broader definition of risk communication, success is measured by the level of increase in understanding of risk problems by all of the involved parties [9]. This two-way, interactive model of risk communication follows from research in the behavioral and social sciences which has indicated that while experts and the public view risk in fundamentally different ways, each has something valuable to offer to the understanding of risk.

To date, most of the work on the perception of risk has been done by psychologists who have determined that people employ mental strategies, known as heuristics, as aids in decision making in the face of uncertainty. While the use of heuristics is essential to avoiding a life frozen with indecision, use of these mental strategies also introduces systematic biases in the way we evaluate risks. Such factors as difficulties in judging probabilities, sensational media coverage, and personal experiences often lead us to underestimate or overestimate risks [13]. The well-known gambler's fallacy (the longer I play a game of chance, the more likely I am to win) is an example of a heuristic which would cause one to underestimate risk. Television coverage of an airline crash and a close relative suffering from a rare disease are events which could lead to overestimation of risk. Significantly, experts can also fall victim to the same sort of biases, particularly when they are in the realm of applying intuition as opposed to dealing with available data [13].

The conventional model holds that only experts possess relevant risk information.

Using a technique known as the psychometric paradigm, psychologists have also determined that the concept of risk has a different meaning to experts, who usually focus on the probability of fatality from a given activity, than it does to members of the lay public, who also tend to factor in qualitative characteristics of hazards such as catastrophic potential, lack of control, and delayed harm [13]. Psychometric research has also indicated that the risks that are least understood and most dreaded by the public — such as those posed by nuclear power and other potentially catastrophic technologies — often have a very high "signal potential" regarding the indirect impacts of environmental pollution or technological accidents [13]. Many engineers, for example, view the Three Mile Island nuclear accident, in which there were no apparent deaths, as testament to the safety of nuclear power. The impacts of the accident, however, have rippled throughout the industry and the economy. Had more attention been paid by industry and government experts to the public's perception of the risks involved, the accident and its costly indirect impacts may have been prevented.

Some psychologists and risk analysts have viewed these findings as justification for the conventional model of risk communication. They view the public perception of risk as irrational, when compared to the rational judgment of experts. In order to close this gap, the experts' information must be transferred to the public [10]. Slovic [13], on the other hand, argues that psychometric research implies a broader conception of the risk communication process:

> *...there is wisdom as well as error in public attitudes and perceptions. Lay people sometimes lack certain information about hazards. However, their basic conceptualization of risk is much richer than that of the experts and reflects legitimate concerns that are typically omitted from expert risk assessments. As a result, risk communication and risk management efforts are destined to fail unless they are structured as a two-way process. Each side, expert and public, has something valid to contribute. Each side must respect the insights and intelligence of the other.*

Substantive attitude changes are necessary on the part of experts.

Slovic's statement highlights the fact that there are practical reasons for engineers to become better informed regarding the public's attitudes toward risk. The broader understanding we have about how people evaluate risk, and how they respond to the continued development of technology in the aftermath of accidents, the more likely we are to prevent accidents with costly direct and secondary impacts. The impacts of the cases previously cited — Three Mile Island, Chernobyl, Bhopal, and Challenger — could have been reduced or eliminated entirely if the warnings contained in lay risk perceptions had been heeded as valid supplements to expert risk judgements. By reducing complexity of system design, improving operating procedures, siting facilities in a more prudent manner, and leveling with the public about the uncertainties contained in quantitative risk models, the proponents of technological development will benefit from a safer operating record and far greater public support.

Moreover, engineers have a *moral* obligation to acknowledge the dual importance of expert and public risk information. We not only expect professionals to be experts in their field; we also expect them to know their limitations. Engineers thus have a professional obligation to recognize and acknowledge the limits of scientific rationality and the value of public perception of risk [14].

Risk Communication and the Engineering Culture

There is both a practical necessity and an ethical imperative for engineers to become actively engaged in risk communication efforts that incorporate an understanding of and respect for public perception of risk. This calls for nothing less than a transformation of the engineering culture.

The prevailing engineering culture is readily recognized from both inside and out. Engineers are no-nonsense problem solvers, guided by scientific rationality and an eye for invention. Efficiency and practicality are the buzzwords. Emotional bias and ungrounded action are anathema. Give them a problem to solve, specify the boundary conditions, and let them go at it free of external influence (and responsibility). If problems should arise beyond the workbench or factory floor, these are better left to management or (heaven forbid) to politicians.

These attributes of the engineering culture are succinctly summarized by Lichter's "core principles" of engineering [15]:

1) A concern for the efficiency of practical means;

2) A commitment to concrete problem-solving, constrained to some necessary degree by time and available resources;

3) The pursuit of optimal technological solutions based on scientific principles and/or tested technical norms and standards;

4) The pursuit of creative and innovative designs;

5) And the development of new tools for the accomplishment of each of these.

Given the preoccupation of engineering with efficiency and merely technical solutions, to the neglect of all other criteria, it is not surprising that the conventional view of risk communication, which devalues lay perception of risk, is reinforced by the current engineering culture.

For example, perhaps the biggest obstacle in persuading engineers to listen more carefully to the concerns of the public is the overwhelming bias toward quantification in their evaluation of risk [1]. As the Challenger and "inherently safe" reactor examples illustrate, merely assigning numbers to the decision parameters in a technological problem doesn't change the fact that value choices are often made by experts at the expense of the people affected by technology. Closing the gap between expert and public perception of risk thus implies closing the gap between the quantitative and the qualitative. And this, in turn, implies changing the engineering culture so that questions of enduring human value are at its core [15], even when such questions can only be dealt with qualitatively.

In other words, a complete understanding of risk assessment and the problems of risk communication is not possible without an integration of technical concepts with concepts drawn from the humanities and social sciences. In particular, meaningful participation in risk communication efforts by engineers requires significant attitude changes on their part with respect to the relationship between expert and public [1]. For example, engineers should value, on an equal footing with scientific and technical rationality, other ways of knowing and expressing. Engineers should also have a commitment to *listening* to others, and to incorporating alternative points of view into the search for technical solutions to problems. Such attitude changes cannot be expected until knowledge gained through study of the humanities and social sciences is relocated from the margin of engineering to its essence [15].

If a meaningful transformation in the engineering culture is to occur, significant change must take place within engineering institutions. The most important of these institutions are the places where engineers first become immersed in the culture — the engineering schools.

Transforming the Engineering Culture

Several options are available for remaking the engineering culture through transformation of engineering education. A number of educators have recently called for increased emphasis in the engineering curriculum upon the relationship between technology and social, political, economic, ethical, and legal concerns [16]-[19]. Most agree that the typical practice of selection of a few elective courses in the humanities and social sciences does not adequately facilitate the making of connections between engineering and other modes of inquiry.

A solution that does not rely on isolated humanities and social science courses for emphasizing the relationships between technology and society is the development of engineering courses which incorporate the study of these relationships [20], [21]. For example, in order to prepare engineering students for meaningful communication with the public regarding risk, such topics as the role of engineering in society, engineering ethics, safety, risk assessment, and the professional responsibilities of engineers should become standard fare within the engineering curriculum, along with increased emphasis on communication skills [16].

Another option worth pursuing is increased interdisciplinary education for engineers [22]. In recent years, a new field has emerged in the area of Science, Technology, and Society (STS) studies. Although much of the recent interest in STS by the engineering community has been aimed at increasing the "technological literacy" of liberal arts students, the STS field has a strong tradition of integrating technical perspectives with perspectives on technology drawn from the humanities and social sciences for the benefit of both engineering and liberal arts students [23]. Indeed, the STS model is ideally suited for the development of courses that include material from a variety of perspectives on such topics as technological catastrophes, ethical responsibility, risk assessment, and risk communication [12].

Innovative approaches to teaching engineering students, such as collaborative learning [24], are also called for. Collaborative learning includes various processes by which students engage in peer learning in semi-autonomous small groups. The benefits of collaborative learning include improved student performance and enthusiasm for learning, development of communication skills, and greater student appreciation of the importance of judgment and collaboration in solving real-world problems such as those relating to safety concerns and the ethical responsibilities of engineers. In an interdisciplinary setting, collaborative learning has the added benefit of exposing engineering students to the concerns and biases of peers who lack technical training, but who nonetheless have a stake in the outcome of engineering decisions, thus enabling the difficulties of risk communication to be modeled in the classroom.

In addition to engineering schools, other institutions must contribute to a transformation of the engineering culture. The professional engineering societies can play a critical role in creating an engineering culture more conducive to effective risk communication by:

1) taking a lead role in promoting the educational reforms previously discussed;

2) providing stronger support and protection for engineers who apply ethical principles in the exercise of their professional judgment [8], [15]; and

3) initiating efforts, such as forums and journals, that recognize the dual importance of public attitudes toward risk and expert judgment [14].

Educational materials such as the video *Gilbane Gold*, produced by the National Institute for Engineering Ethics founded by NSPE, and "How to Be a Good Engineer," a guide to engineering ethics presentations available from IEEE's United States Activities Board, are examples of how professional societies can facilitate meaningful discussion of risk and other ethical issues confronting engineers. Significant changes in the engineering culture will also require the cooperation of their corporate employers [15]. As the cases mentioned in this paper illustrate, shortcomings in the conventional model of risk communication have created many problems both for corporations and for the advancement of technology; acknowledging and accepting the importance of the public's role in risk decisions would be beneficial to corporations as well as their engineering employees.

Finally, the role of the individual engineer in transforming the engineering culture should not be overlooked. As with other ethical issues, engineers need to approach the problem of risk communication with what Werhane [25] calls "moral imagination":

...to try to change one's habits, or ask oneself weird questions, to try in some way to place oneself in a different perspective so as to regard events from another point of view.

Valuing other ways of knowing and expressing, as well as listening to the views of others, are essential prerequisites if engineers are to become effective risk communicators [1]. While it may be difficult to imagine an engineering culture in which this is possible, all engineers have a professional and moral responsibility to do so, and to work toward a transformation to such a culture.

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