ETHICS AND PROFESSIONAL RESPONSIBILITY

WHAT IS ENGINEERING ETHICS?

Engineering ethics and professional responsibility are topics that have rapidly grown in importance and relevance to engineering during the last quarter of the twentieth century. As technology and its impacts have become more complex and far-reaching, the importance of responsible engineering decisions to employers and to the public have been underscored. Often these responsibilities conflict, resulting in ethical problems or dilemmas, the solutions to which, like other decisions engineers are faced with, benefit from a sound analytical framework.

Ethics is defined simply as "the rules and ideals for human behavior. They tell us what we ought to do (1)." In an engineering context, ethics is addressed in a number of ways.

There is a long intellectual tradition of moral thinking and moral theories. Indeed, *ethics* constitutes an entire branch of philosophy. In recent years, there has been growing interest among philosophers in applying moral theories to real-world problems, that is "applied ethics," especially in the professions. In addition to engineering ethics, much attention has been paid to ethics in other professional arenas, for example, business ethics, biomedical ethics, and legal ethics. These fields often overlap with engineering ethics, when, for example, engineers are involved in business decisions or in designing biomedical devices. Another related field of growing importance to many engineers and to society in general is computer ethics.

As individuals, engineers usually have a sense of personal ethics, influenced and molded by their upbringing, socialization, religion, and other factors, and are generally no different than other humans in this regard. All too often, however, engineers separate their personal sense of ethics from issues in the practice of engineering. Many feel that moral problems fall outside the scope of engineering, or should be left to managers and government officials to solve. It might be said that such engineers too readily "check their ethics" at the door to the office. In contrast, the field of engineering ethics has emerged to focus attention on ethical issues in engineering, and to better prepare engineers and engineering students to deal with such issues.

Some Engineering Ethics Issues

Although many cases in engineering ethics are highly publicized, usually those involving whistleblowing (discussed later), most issues in engineering ethics are not high profile, but confront the typical engineer in the everyday workplace. Engineering ethics issues include [adapted from (1)]:

- Public safety and welfare—a key concept in engineering ethics focusing on engineers' responsibility for public health, safety and welfare in the conduct of their professional activities. For example, engineering projects and designs often have a direct impact on public safety and the environment.
- Risk and the principle of informed consent—assessment of risk in engineering projects and the extent to which public input should be considered in engineering decisions. Technological controversies, pitting engineers and other technical experts against public interest groups and ordinary citizens, have grown in number and importance over the past two decades.
- Conflict of interest—a term for situations where engineers serve more than one client with conflicting interests or have a personal interest in a matter on which they are called upon to render a professional opinion. Often, even the appearance of such a conflict undermines the ability of engineers to carry out their assignments professionally.
- Integrity of data and representation of it—an issue of great importance because most engineering analyses rely to some extent on collecting reliable data. Falsification or misrepresentation of data has become a major issue in the ethics of scientific research and has played a role in many recent high-profile product liability cases.
- Whistleblowing—a term applied to a situation in which an employee "blows the whistle" on unethical or illegal conduct by a manager, employer, or client. Many high-profile engineering ethics cases have involved whistleblowing, which include actions within and outside of the organization where the engineer works.
- Choice of a job—employment choices entail a number of ethical decisions including whether or not the engineer chooses to work on military and defense applications, the environmental record of the potential employer, and the extent to which employers monitor the professional and personal activities of their employees.
- Accountability to clients and customers—an important issue concerning such concepts as trustworthiness, honesty, and loyalty, often overlooked in light of the atten-

tion given to the engineer's primary responsibility to the public.

- Plagiarism and giving credit where due—an issue that effects engineering students, their professors, and engineers and managers in the work place. Failure to give proper credit is not only dishonest, but affects morale and the integrity of engineering data.
- Trade secrets and industrial espionage—topics that underscore the ethical responsibility of engineers to their employers and clients, even when they move on to work for others. Computer software is an area of growing concern in this regard.
- Gift giving and bribes—bribes and their distant cousins gifts represent some of the most serious issues in engineering ethics. Virtually all engineers in the course of their professional careers must confront the issue of determining when gifts are acceptable.
- Fair treatment—an issue that applies to "civil rights" and relationships between superiors and subordinates. In addition to being ethically deficient in its own right, failure to treat others on merit often has a negative impact on engineering performance.

WHO DOES ENGINEERING ETHICS?

For the most part, consideration of engineering ethics takes place in two arenas: research and teaching and engineering practice. As previously mentioned, many philosophers have focused their research and teaching activities on engineering ethics and other areas of professional ethics. A common philosophical approach to engineering ethics is to employ moral theories, such as utilitarianism and duty/rights ethical theories, to solving moral dilemmas in engineering. Utilitarianism is an ethical system that deems an action morally correct if its outcome results in the greatest good for the greatest number of people. Duty and rights approaches to ethics, on the other hand, focus on actions themselves and whether or not individuals abide by duties to do good and avoid harm and act out respect for the moral rights of other individuals. Though these two types of moral theories often result in the same conclusion regarding a particular act, they might result in conflicting conclusions, for example, when an engineering project built to benefit the public at large results in evicting individuals without their prior consent.

Although some engineering educators disregard engineering ethics, especially philosophical approaches which they deem to be too idealistic and distant from engineering practice, a growing number of engineering educators are involved in research and teaching concerning engineering ethics. Most such engineers are from conventional engineering disciplines and are "self-educated" in philosophical approaches to professional ethics. Some, such as the author, are from nontraditional engineering disciplines that focus on public policy and/or societal issues in engineering. There has been collaboration between engineers and philosophers in both the research and teaching areas, much of which has been encouraged by funding from the National Science Foundation (NSF) and private foundations. Although there are few required courses in engineering ethics, a number of stand-alone elective courses have been taught for many years. There is increasing interest in incorporating engineering ethics concepts and cases in mainstream engineering courses, particularly in light of the proposed "Engineering Criteria 2000" of the Accreditation Board for Engineering and Technology (ABET), that calls for engineering students to have "an understanding of professional and ethical responsibility" (2). Similarly, the proposed Computer Science Accreditation Commission (CSAC) Criteria 2000 places increased emphasis on ethical issues in computing.

The significant amount of activity related to engineering ethics among engineers in industry is often neglected or played down in the scholarly literature. More often than not, these engineers become involved in such activities through the professional engineering societies. The most visible engineering ethics activity within the professional societies is the promulgation of Codes of Ethics. In this arena, engineers from industry interact with engineers from academia and, less often, with philosophers engaged in engineering ethics research and teaching. Although an increased trend in recent years has been to integrate research and teaching in engineering ethics with engineering practice, there is considerable need for further integration. The professional society, which provides a vital link between academia and engineering practice, thus plays a pivotal role.

ROLE OF PROFESSIONAL SOCIETIES IN ENGINEERING ETHICS

The code of ethics is the hallmark of a professional engineering society's stance on ethics. Although codes vary from one professional society to another, they typically share common features in prescribing the responsibilities of engineers to the public, their employers and clients, and their fellow engineers. Such characteristics as competence, trustworthiness, honesty, and fairness are also often emphasized in the codes (3). The IEEE Code of Ethics (4), adopted by the Board of Directors in 1990, is one of the more compact of the current codes, containing ten provisions totalling about 250 words.

In addition to maintaining a Code of Ethics, the professional engineering societies also generally have various committees and other bodies charged with treating ethical issues. The IEEE, for example, has two such committees at the Board of Directors level, the Member Conduct Committee (MCC) and the Ethics Committee. The MCC's purpose is twofold: to recommend disciplinary action against members accused of violating the code of ethics and to recommend support for members who, in following the code of ethics, have been put in jeopardy. The Ethics Committee, formed more recently, provides information to members on ethics and advises the Board on ethics-related policies and concerns. Ethics concerns also extend in some cases to the technical branches of the professional societies. The IEEE Society on Social Implications of Technology, for example, one of IEEE's thirty-seven technical societies and councils, has engineering ethics and professional responsibility as one of its major focuses. Other groups with similar interests include the Special Interest Group on Computers, Society of the Association for Computing Machinery, and Computer Professionals for Social Responsibility. Professional engineering societies also have other entities concerned with ethical issues within the scope of their activities. For example, committees charged with overseeing the publications of the professional society are often concerned with ethics in publishing, which relates to the responsibilities of editors, reviewers, and authors. Concern for engineering ethics even extends to student chapters of the professional societies. Some chapters, for example, have cooperated with their home departments in formulating academic codes of ethics modeled, in part, after the professional codes of ethics.

Professional societies are particularly important in engineering ethics because engineers are usually employed by large corporations, unlike professionals in other fields, such as law and medicine, who have traditionally enjoyed greater professional autonomy. As discussed later, however, the influence of corporations over the professional societies (5) has often resulted in less forceful stances on engineering ethics by the professional societies than some observers would like to see. Nevertheless, the professional society remains the only organizational force internal to engineering that can promote and nurture a sense of ethics and professional responsibility.

ENGINEERING AND SOCIETY

Complete understanding of the role of engineering ethics requires some introduction to the societal role of engineering. Although this is done in many ways, ranging from a historical treatment of engineering to a social constructionist's view of technology (6), here we consider only three aspects of the engineer's role in society: the way the engineer views the world, societal perceptions of engineers and engineering, and the relationship between engineering and business.

The Engineering View

A number of authors have described the characteristic "engineering view," some much more favorably than others. Samuel Florman, a civil engineer and author of several books that sing the praises of technology, characterizes the engineering view as consisting of such virtues as originality, pursuit of excellence, practicality, responsibility, and dependability (7).

In a more critical tone, Eugene Ferguson, a noted historian of technology who also studied engineering, decries what he calls the "imperatives of engineering," for example, system control, disregard for human scale, and fascination with technical problems. These imperatives, Ferguson argues, often result in engineering projects that do not address human needs (8).

A more descriptive view than either of these is found in Lichter's "core principles" of engineering that include practical efficiency, problem-solving in a constrained environment, optimal scientific and technical solutions, creative innovation, and development of new tools (9).

It should be noted that all three of these views, regardless of ideological slant, all characterize the engineering view to one extent or the other as focusing mainly on technical solutions to problems. This characteristic of the engineering view accounts, perhaps, for the reluctance of some engineers to stray into the uncharted waters of the social and ethical dimensions of engineering. The engineering culture clearly favors familiarity with technical approaches to problems—nontechnical problems and solutions are seen as the realm of management or politics (10).

The Engineering Image

The limitations of the characteristic engineering view, unfortunately, play into the popular image of the engineer as a one-dimensional person submerged in technical detail, a stereotype most engineers are quick to disown. Engineers rarely appear as characters in popular entertainment vehicles, and, when they do, they are either confused with scientists are portrayed in this one-dimensional fashion (11). For example, in the feature film *Homo Faber,* based on the book by Max Frisch (12) and originally released in the United States with the title *Voyager,* the protagonist is a globe-trotting civil engineer readily absorbed in gadgetry and technical discussions of risk, but who is adrift in discussions of the arts or in dealing with his own emotions, chance social encounters, and personal moral dilemmas.

Like all stereotypes, this image of the engineer is formed by a small element of the truth surrounded by shallow generalities. Unfortunately, the fact that engineers are often viewed this way plays a role in pigeonholing them when participating in decisions with ethical implications. For example, the infamous instruction during the Challenger incident (discussed later) to take off the engineering hat and put on the management hat, in part at least, reflects the notion that the engineering view is too narrow when it comes to considering "the big picture."

The Engineer as Professional

A third characteristic of the social role of engineering, and perhaps the one with the most significant implications for engineering ethics, is the relationship between engineering and business eloquently described by Layton (5). Layton depicts the engineer as part scientist and part business person, yet not really either, that is to say, marginal in both cases. This situation, which resulted from the coevolution of engineering as a profession and technology-driven corporations, sets up inevitable conflicts between the professional values aspired to by engineers and the business values of their employers. Roughly three-quarters of all engineers work in the corporate world, in contrast to other professions, such as law and medicine, where the model has been, at least historically, for professionals to work in private practice, serving clients or patients as opposed to employers. Although professionals value autonomy, collegial control and social responsibility, businesses value loyalty, conformity and, ultimately, the pursuit of profit as the principal goal. This tension is exacerbated by the fact that the career path of most engineers ultimately leads them into management. Consequently, engineers who hope to advance in the corporate hierarchy are expected to embrace business values throughout their careers. A further drawback of this situation, discussed in more detail later, is the extent to which business interests exert control over the professional engineering societies.

MORAL DILEMMAS IN ENGINEERING

Engineers on the Spot

A moral dilemma is defined as a conflict between two or more moral obligations of an individual in a particular circumstance. For example, an engineer's obligation to protect the public interest might conflict with an obligation to protect the trade secrets of an employer. As previously noted, moral dilemmas in engineering take on many forms, including such issues as conflict of interest, bribes and gifts, and failure to credit the work of others.

Perhaps the best known engineering ethics case involved the explosion of the Space Shuttle Challenger in 1986. This case includes a wide range of elements relevant to engineering ethics and professional responsibility, including protection of the public interest, conflicts between engineers and management, integrity of data, and whistleblowing.

The loss of the Challenger resulted from a failure in the design of the vehicle's reusable solid rocket boosters (SRB). In particular, the O-ring seal which prevented hot combustion gases from escaping through the joints of the SRBs failed as a result of very cold temperatures at the launch time. Engineers at Morton–Thiokol, Inc., the contractor responsible for the SRBs, had been concerned for some time about the ability of the joints to properly seal but had been unable to get Thiokol management or the National Aeronautics and Space Administration (NASA) to take the problem very seriously. On the eve of the Challenger launch, faced with unprecedented cold temperatures and the knowledge that the worst previous erosion of an O-ring seal had occurred during the coldest launch to date, the Thiokol engineers attempted to persuade their managers and NASA to postpone the launch until the temperature increased. Initially, the Thiokol managers supported their engineers. However, after NASA management expressed disappointment and serious doubts about the data presented and the judgment of the Thiokol engineers, the Thiokol managers, who were concerned with protecting a lucrative contract, overruled their engineers and recommended launch. At one pivotal point during an off-line caucus, the Thiokol vice-president of Engineering was told by one of his superiors to "take off your engineering hat and put on your management hat."

Following the disaster, in which all seven astronauts were killed, President Reagan formed a Commission to investigate the accident. During the subsequent hearings, several Thiokol engineers ignored the advice of their managers to stonewall and testified candidly about the events leading up to the disaster. The commission concluded that, in addition to a flawed shuttle design, there was a fatal flaw in NASA's decision making process. The late Nobel Prize winning physicist, Richard Feynmann, who served on the presidential commission, went even further in his appendix to the commission's report. In Feynmann's view, NASA's decision making process amounted to "a kind of Russian roulette" (13).

For their efforts, the "whistleblowing" engineers were reassigned and isolated within the company, a situation only corrected after the presidential commission learned of the circumstances. One engineer, in particular, Roger Boisjoly, who subsequently took disability leave from Thiokol and was ultimately fired, suffered the typical fate of the whistleblower, including being ostracized within the town where Thiokol was located, subjected to death threats, and apparently blacklisted within the aerospace industry.

FRAMEWORKS FOR ENGINEERING ETHICS

Moral Thinking and Moral Theories

Moral theories form the basis of traditional approaches to the philosophical study of ethics. For a theory to be useful, ethicists argue that it should be verifiable, consistent, and present a reasonable accounting of what is good (14).

Underlying moral theories is the concept that, to make moral judgments, a person must be an autonomous moral agent, capable of making rational decisions about what is the proper course of action in confronting a moral dilemma.

Philosophers often begin discussions of moral thinking [adapted from (15)] by dismissing three sorts of "theories" often employed by individuals, but which ethicists generally agree are not useful moral theories. The three rejected theories are divine command ethics, ethical egoism, and ethical conventionalism.

Divine command ethicists holds that a thing is good if God commands it. Philosophical arguments against this theory are quite complex. Suffice it to say, divine command theory must ultimately rest on faith and cannot be verified by purely rational means. In rejecting divine command theory, ethicists are drawing a distinction between religion and ethics. This is not to say that religion is irrelevant, but only that ethics as a rational system of moral decision making can be conceptualized apart from any considerations of religion.

Ethical egoism, which holds that a thing is right if it produces the most good for oneself, is easily rejected as a workable moral theory because it is not generalizable. In other words, if everyone operates solely out of their own self-interest, there is no basis at all for morality. This argument is not always easy for engineering students to grasp, especially because our economic system is based on a similar theory, that is, individual pursuit of profit benefits everyone in the long run. Here again, though, the point is that ethical systems and economic systems are not the same thing, and clearly do not always produce the same conclusions about whether or not an action is good.

Ethical conventionalism, also known as cultural relativism and situational ethics, holds that a thing is good if it conforms to local convention or law. This theory fails to provide a reasonable accounting of what is good. Numerous examples can be cited of actions that, though acceptable within the framework of the actors, are clearly morally unacceptable to most individuals. To argue for ethical conventionalism is to argue that ethics has no objective meaning whatsoever. This theory is quite popular, nonetheless, and often surfaces in discussions of international engineering ethics.

What then are the useful moral theories? The two most prevalent theories are utilitarianism, originally developed by Mill and Brandt, and duty-based theories which derive from Kant and Rawls. Rights-based theories advocated by Locke and Melden, which are closely aligned with duty-based theories, and virtue theories (Aristotle and MacIntyre) are also favored by some ethicists [adapted from (15)].

Utilitarianism is an ethical system whereby an action is considered good if it maximizes utility, defined as the greatest good for the greatest number of people. Act utilitarianism evaluates the consequences of individual actions, whereas rule utilitarianism, favored by most philosophers, considers generalizable rules, which result in the greatest good for the greatest number of people if consistently followed. Utilitarianism is a popular moral theory among engineers and engineering students. Indeed, it has its analog in engineering decision making in the form of cost-benefit analysis, wherein a project is deemed acceptable if its total benefits outweigh its total costs. It is also consistent with simplistic notions of democracy characterized merely by "majority rule." One problem with cost-benefit analysis and the utilitarian thinking on which it is based, however, is that the distribution of costs and benefits are not considered. A new highway or bridge, for example, may provide the greatest good for the greatest number. Those bearing the costs of relocation, however, may not share equally in the benefits of the project.

Utilitarianism's major competitors, duty- and rights-based ethical theories, take the distribution question head on by focusing not on an act's consequences but rather on the act itself. Individuals are thought to have duties to behave in morally correct ways. Similarly, people are moral agents who have basic rights that should not be infringed. In this manner, rights-based theories are the flip side of the more prominent duty-based theories. In each case, however, the focus is on the act itself rather than the consequences, as in utilitarianism. One problem with duty-based theories is how to handle situations with conflicting duties. Such situations frequently arise in engineering ethics, wherein engineers have duties to themselves, their families, their employers or clients, and the public in general.

A final moral theory is virtue ethics, which focuses on qualities such as loyalty, dependability, honesty, and the like, thought to be found in virtuous persons. Such theories often appeal to those with strong religious convictions because the virtues are similar to those expounded on in religious doctrine. Virtues also often frequently appear in the language of engineering codes of ethics.

One of the great challenges of engineering ethics is to learn how to distinguish the various types of moral reasoning and to know when to apply the different theories. For example, in most questions involving engineering projects, utilitarianism might be an adequate theory. However, if the projects or designs represent substantial risks to individuals who are unlikely to benefit from them, then duty/rights-based theories are more appropriate.

As discussed later, many contemporary philosophers hold the opinion that formal discussion of abstract moral theories is not necessary in doing applied ethics, and indeed is counter-productive by turning engineering practitioners away from considering ethics. Utilitarian and duty/rights concepts, it is argued, can and should be presented in lay person's terms. Indeed, such concepts are often implied in engineering codes of ethics.

Codes of Engineering Ethics

Codes of ethics serve various functions including education, encouragement of ethical behavior, the basis for disciplinary action regarding unethical conduct, and elevation of the public image of the profession (3). Indeed, many critics of codes of ethics charge that their primary purpose is to create a positive public image for the profession and that the codes are largely self-serving (16).

Although engineering codes of ethics have existed for about a century, only in the last several decades has responsibility for the public health, safety, and welfare gained prominence in the codes. Most modern codes, however, now state that this is the primary responsibility of engineers, thus conforming the major thrust of the codes closer to philosophical notions of ethics in both the utilitarian and duty/rights traditions. Nevertheless, provisions still remain in some codes that might be interpreted as merely self-serving.

It is not uncommon, for example, for codes to contain provisions barring public criticism of other members of the profession. (See, for example, article nine of the IEEE codes.) Unger (3), among others, is concerned that such provisions stifle dissent within the professional society. A famous 1932 case involving the American Society of Civil Engineers involved the expulsion of two members who publicly accused another member of participating in corrupt activities. Though vindicated by the outcome of a criminal trial, the engineers' memberships in the society were never restored.

Not all engineering codes of ethics are as succinct as the IEEE code. Perhaps the most extensive is the Code of Ethics for Engineers of the National Society of Professional Engineers (NSPE) (17), a multidisciplinary organization that represents registered professional engineers. The NSPE code, roughly 2,200 words long, includes four elements: a preamble and three sections entitled *"Fundamental Canons," "Rules of Practice,"* and *"Professional Obligations."* The code also contains brief commentary on a prior prohibition of competitive bidding that the NSPE was ordered to remove by the US Supreme Court in connection with antitrust litigation. Although the NSPE regards competitive bidding as a violation of professional standards, others, including the courts, have interpreted it as a self-serving measure designed to limit competition for engineering services. Rarely, however, have the courts become involved in settling such disputes over the codes, which are largely constructed and maintained by the professional societies themselves.

The IEEE and NSPE codes are representative of the two extreme formats in which codes are developed. Unger (3) cautions against codes which are either too short or too long. The danger in the former is the possibility of important omissions, and the lack of specific guidance to engineers, and the dangers of the latter include overprescription, thus leading to a code that is cumbersome to read and the possibility of loop holes if important issues are inadvertently omitted.

One potential weakness of engineering codes of ethics is their multiplicity. Nearly every professional society has its own unique code. This suggests to some a lack of a consistent sense of ethics among engineers and could create confusion in individuals who belong to two or more societies with conflicting codes. However, efforts to create a unified engineering code of ethics, through such organizations as ABET or the American Association of Engineering Societies, have failed heretofore.

Another important issue relating to codes of ethics is the extent of their applicability in different cultures. This issue is growing in importance as most of the major U.S. engineering societies are global in organization or becoming more so as time passes. A typical argument, for example, is that in some cultures bribery is an accepted, even expected, form of doing business. Such arguments are persuasive to many on practical grounds and an impetus for adopting the posture of ethical conventionalism. Others argue for the universality of codes of ethics. These are difficult, though not necessarily insurmountable questions. One way to gain greater understanding of these problems, which has been adopted by IEEE, is to ensure that the organization's ethics committee has adequate representation from regions other than the United States.

Support for Ethical Engineers

In many high-profile ethics cases discussed later, engineers and others who have blown the whistle on unethical behavior have often had to pay a high price for their ethical stance, including demotions, firings, blacklisting, and even threats to life and limb. Many believe that it is unreasonable to expect engineers to be "moral heroes" in this manner. Consequently, a great deal of attention has been focused on providing support for ethical engineers, with the notion that members of society have a collective responsibility for nurturing ethical behavior (18).

In recent years there has been a trend toward establishing management practices which encourage internal dissent within corporations. For example, many corporations now have ethics officers or ombudmen whose role is to provide a confidential channel for airing of ethical concerns within the company. Many of these programs have historically focused on legal compliance rather than ethical decision making, although there is a growing trend toward developing values-based programs more sensitive to ethical principles (19). It may be unrealistic, however, to rely too heavily on businesses to encourage ethical behavior. As a number of philosophers have noted, businesses are not moral agents, but rather are motivated by economic profit (18). Encouraging businesses to "do the right thing" usually means seeing to it that it is in their economic self-interest to do so.

One means of doing so is to enforce strong regulatory penalties for unethical behavior on the part of corporations. Unfortunately, since the early 1980s there has been a strong antiregulatory climate in the United States. And even when regulations exist, their enforcement often involves the corporation of the industries regulated. Another avenue is stronger product liability legislation, but here again the trend is in the opposite direction, the implications of which for engineering ethics are discussed at greater length later.

Another governmental approach for supporting ethical behavior by engineers and others is to establish stronger legal protection for whistle blowers. Although some existing state and federal laws provide support for whistle blowers in certain circumstances, a National Employee Protection Act, such as that proposed by the Government Accountability Project (20), would help to insure that all employees who become legitimate whistle blowers are shielded from employer reprisals.

The engineering community itself perhaps is in the best position to provide greater support of ethical conduct by members of the profession. Appropriate responses by the professional engineering societies include taking seriously the promulgation of engineering codes of ethics, providing legal and financial support for whistle blowers, and giving awards for noteworthy ethical conduct. Ultimately, however, to be effective, as Unger notes (3), the professional societies may need to seek means of sanctioning employers who punish their engineering employees for acting in the public interest.

The IEEE took a major step toward providing such support by establishing an Ethics Committee reporting directly to the Board of Directors that began operation in 1995. The foundation for this committee was laid by the activities of the Ethics Committee of the IEEE United States Activities Board. However, before 1995 ethics support at the Board level was left to the Member Conduct Committee which has a dual function of member discipline and ethics support and which, until recently, was largely inactive. Since its inception, the IEEE Ethics Committee has established an Ethics Hotline, promulgated guidelines for ethical dissent, and begun to draft more detailed guidelines for interpreting the IEEE Code of Ethics.

One problem with relying too heavily on the professional societies for providing support for ethical engineers is the level of influence, mentioned earlier, which business wields over professional societies. As Layton points out (5), many of the leaders of the societies are senior members who have moved from technical engineering into business management within their companies. In addition, many companies fund and support the participation of their employees in the professional societies.

Indeed, the activities of the Ethics Committee, particularly the hotline and efforts to establish an ethics support fund to aid engineers exhibiting ethical behavior have generated controversy and encountered resistance from some of the IEEE leadership. On the other hand, such resistance is often worn down by the persistent activism of professional society members, as witnessed, for example, by the IEEE's establishment of a Board level ethics committee and its early role in filing a friend of the court brief in support of whistleblowing engineers in the BART case (discussed later).

In closing this section it should be noted that calls for greater support of ethical engineers are not intended to suggest that engineers are not expected to exercise their own moral judgment (21). As suggested by Ladd (18), collective and individual moral responsibility are complementary rather than mutually exclusive.

CASES IN ENGINEERING ETHICS

The most popular tool employed in teaching engineering ethics is the case method. In this method, a detailed case study of a real or fictional event illuminates a moral dilemma and various approaches to its solution. Some well-documented, high profile cases involving engineers and engineering designs are discussed later. Documentation for these cases often includes book chapters (and sometimes entire books); journal articles; news accounts; and primary archives. The format lends itself to innovative pedagogies. For example, students are assigned to do supplemental research on the case or to play the roles of various participants in the case (22). Actual outcomes of the cases are critiqued by the teacher and students, and alternative scenarios, including those with more positive outcomes, are explored.

The BART Case

The BART Case from the early seventies, though somewhat dated, is of interest because of the significant role played by the IEEE. The case involves three engineers working on the design of San Francisco's Bay Area Rapid Transit System (BART) who became concerned about the safety of the system's automated control system for subway cars. Following unsuccessful efforts to have their supervisors rectify the problems, the three took their concerns to a member of the BART Board. Subsequently, the three were fired and blacklisted within the industry. A lawsuit by the three was settled out of court, but not before the IEEE filed a historic friend of the court brief in support of the engineers. Ironically, the concerns of the three were vindicated when a train overshot a station shortly after the system became operational, injuring several passengers. The case is useful in illustrating the unfortunate circumstances that all too often envelop whistleblowers. On a more positive level, the case illustrates the important role a professional society, such as the IEEE, plays in supporting ethical behavior by engineers.

The DC-10 Case

This famous case involves the crash of a Turkish Airline DC-10 in Paris in 1979 in which 346 people lost their lives, one of the worst airliner disasters in history. The accident resulted from the loss of control of the aircraft after an improperly closed cargo door blew open in flight, causing the cabin to decompress and the floor to collapse thus destroying the hydraulic controls that ran through the floor. An eerie precursor of the Challenger case, the DC-10 case is one in which a design problem was identified early in the production of the aircraft and recognized as the cause of a near disaster in another failure involving a plane of the same design, but still ignored or dealt with only in terms of a "band aid" fix. Players in the case include the aircraft manufacturer, McDonnell–Douglas, and fuselage subcontractor, Convair, both of whom sat on design changes to protect their economic interests, a Convair employee who wrote a warning memo that was suppressed by management, the Federal Aviation Administration who were slow to insist on design changes even after the flaw was identified, and Turkish Airlines, which provided inadequate training of the baggage handlers responsible for closing the door.

Hyatt Regency Walkway Collapse

In 1981 two suspended atrium walkways collapsed at the Hyatt Regency Hotel in Kansas City crushing hundreds of people who were crowding the lobby for a "Tea Dance." One hundred fourteen people died in the accident, and dozens more were seriously injured. An investigation revealed that the design of the supporting structures for the walkways had been altered by the steel fabricator but signed off for by the design architect-engineers. Moreover, the walkways, as originally designed, did not meet the Kansas City Building Code. The city inspectors were found lax in fulfilling their duties, and the design engineers were criticized for not following through on a commitment to check all of the roof connections following an earlier collapse of part of the roof. The case, which involved substantial litigation, is useful in illustrating the interplay between ethical responsibilities and legal issues. More importantly, the case resulted in a rare delicensing of the two principals of the design firm, who were stripped of their professional engineering licenses by the Missouri Board of Architects, Engineers and Land Surveyors following an extensive administrative hearing. The case thus suggests that stronger coupling between ethical principles and licensing requirements is called for.

The Bjork–Shiley Heart Valve Case

This case is one of many in a growing catalogue of product liability cases involving biomedical devices. Like the Hyatt case, it illustrates the often-complicated interplay between ethical and legal issues. It was determined that the artificial heart valve, manufactured by a company subsequently bought by industry giant Pfizer, Inc., had a structural failure that caused the death of more than 400 recipients. Evidence suggests that the manufacturer was not forthcoming with information about the flaw and, indeed, experimented with fixes in subsequent commercial versions of the valve. Lawsuits included claims by victims of actual heart valve failures, or their survivors, and by people who currently have the defective valves in place. In an interesting analysis, Fielder (23) argues that the failure rate of the valve is not all that unusual for this kind of device. Rather, he finds the manufacturer guilty of an ethical lapse in failing to be forthright about the flaws in the valve, a lapse, he argues, that caused the public to lose confidence in the product. The case is thus a very effective means of examining the role of risk assessment in engineering ethics and such issues as informed consent.

Although the high-profile cases mentioned here are useful in attracting the attention of engineering students and others interested in learning about engineering cases, the ethical dilemmas encountered by most engineers are typically more mundane. A significant amount of case development has occurred with respect to more commonplace events, including such issues as conflict of interest, trade secrets, and gift giving. For example, the NSPE's Board of Ethical Review (BER) publishes, for educational purposes, fictionalized reviews of actual cases brought to its attention. A number of the efforts aimed at developing cases that are more relevant to the everyday lives of engineers are discussed in more detail later in this article.

CRITIQUES OF ENGINEERING ETHICS

Criticism of engineering ethics ranges from condemnation of the very concept to critiques of the primary focus on individual moral dilemmas, the appropriateness of codes of ethics, and the use of abstract moral theories.

Samuel Florman (24) is a champion of the first view, arguing that ethics has no place in engineering. Engineers are obligated to serve their clients and employers, subject only to the laws of the land including regulations that prohibit dangers to humans and the environment. Florman's approach, which philosopher Deborah Johnson has labeled the "guns for hire" model of professional ethics (25), has few serious advocates among scholars and engineering practitioners concerned about ethics.

A more substantial critique, one recognized as valid by many engineers and philosophers, is of the traditional preoccupation of engineering ethics with specific moral dilemmas confronting individuals. This critique is perhaps best expressed by political philosopher Langdon Winner (26), who calls for greater attention in engineering ethics to macroethical issues related to the societal implications of technology as a complement to the traditional microethical approach that focuses on individual cases.

One response to this critique is to broaden discussions of engineering ethics so as to include the ethical implications of public policy issues of relevance to engineering, such as risk assessment and communication, sustainable development, and product liability (27). Engineers and engineering societies, for example, tend to denigrate public perceptions of risk, limit discussions of sustainable development to tradeoffs between economic growth and environmental quality, and lobby for sweeping product liability reform that would place manufacturers in a much stronger legal position than consumers. Rarely, however, are these debates informed by the ethical dimensions of such public policy issues. A number of important questions readily emerge from an ethical analysis of these issues. What role should informed consent play in the evaluation of public risk perception? What are the limitations of expertise in determining public policy regarding technological risk, and what are the ethical implications of such limitations? Why is the social equity dimension of sustainable development theory typically not given equal weight by engineers with the economic and ecological dimensions? Why are many visions of sustainable development incorporated in engineering discussions technocratic? How will relaxed product liability standards affect consumer safety and the atmosphere for internal dissent by engineers who are concerned about product safety?

Another level of criticism relates to the frameworks employed in considering engineering ethics. A number of philosophers are skeptical of the relevance and usefulness of engineering codes of ethics which they argue are largely self-serving, of little meaning when it comes to ethical reasoning and, indeed, a form of ethical conventionalism (16). On the other hand, other philosophers, such as Davis (28), place great stock in the usefulness of codes in engaging engineers in dialogue about ethical issues. Engineers, such as Unger (3), are staunch defenders of the utility of codes, while at the same time recognizing their limitations.

Conversely, as mentioned earlier, many, though by no means all, engineers have been critical of the utility of abstract moral theories in developing an understanding of engineering ethics. Recently, a few philosophers have also begun to challenge the predominance of ethical theory in coping with ethics in an applied setting. Whitbeck (29), for example, went so far as to argue that the problem-solving approach employed in engineering design is a useful paradigm for solving ethical problems as a strong complement to the theory-laden analytical reasoning traditionally employed by ethicists. Although gaining in popularity, such views still are in the minority, at least within the ranks of the philosophers engaged in studying engineering ethics.

Such debates, which can be both exciting and frustrating, underscore the relative immaturity of engineering ethics as a discipline. Most of the work in this area has emerged over the last quarter of the twentieth century. Engineering ethics will no doubt continue to grow and mature as we confront the problems and challenges of the twenty-first.

SOME CURRENT DEVELOPMENTS IN ENGINEERING ETHICS

World Wide Web

Many of the recent developments in engineering ethics have occurred in conjunction with the World Wide Web (WWW), which is an extensive and rapidly growing resource (30). The Web provides a convenient gateway to on-line instructional materials for engineering ethics courses or course units, resources for use by students and engineering practitioners, and archival information for research in engineering ethics.

Course materials and resources found on the Web include ethics centers; case studies and other instructional materials; course syllabi; codes of engineering ethics; ethics pages of professional societies; papers, articles and reports; and on-line journals and newsletters. There is also a wealth of primary source material relating to engineering ethics, including repositories of federal and state documents. The Web lends itself for use as a "living" course syllabus, with hypertext links to on- and off-site material containing course information and assignments.

A number of professional ethics centers have created home pages on the WWW, and other centers have been created specifically to take advantage of the Web's unique capabilities for disseminating information. These centers are usually staffed by experts in the field of professional and applied ethics and thus provide a "gatekeeper" function for the content on the websites. The most extensive engineering ethics center is The World Wide Web Ethics Center for Engineering and Science (31), formerly located at the Massachusetts Institute of Technology, but moved to Case Western Reserve University in the summer of 1997. This site, created with support from the NSF, contains diverse material, original and imported, on such topics as research ethics, codes of ethics, case studies, and corporate ethics. Though not formally designated as an ethics center, another valuable on-line resource is the Engineering Ethics site at Texas A&M University (32), that includes introductory essays on engineering ethics and several archives of case studies.

Codes of ethics are found at various places on the Web, including the ethics centers previously discussed. Most notably, the Center for the Study of Ethics in the Professions at the Illinois Institute of Technology (33) received funding from the NSF to make available on-line its entire library of professional ethics codes consisting of more than 850 documents.

Another on-line source of codes is the growing number of websites of the professional societies, which also provide information to the society's members and other interested parties regarding organizational procedures relating to ethical concerns. Indeed many societies, such as the NSPE (17) and the (IEEE) (4), have ethics pages located within their websites. Unlike the ethics centers, which are university-based, these sites offer information and perspectives on engineering ethics developed by the volunteers and staff of the professional societies themselves, an essential complement to the scholarly and educational focus of the content at university sites.

Case Development

In recent years a great number of case study materials have been developed and many of these are available on-line (30). The World Wide Web Ethics Center for Engineering and Science (31) includes more than thirty discussion cases based upon cases considered by the NSPE BER in such areas as public safety and welfare, conflict of interest, and international engineering ethics. This site also contains materials developed at the Center on such cases as the Space Shuttle Challenger disaster. The Engineering Ethics home page at Texas A&M University (32) includes three sets of case materials developed with NSF funding: (1) about a dozen engineering ethics cases and instructor guides for use in engineering courses, including several well-known cases such as the Hyatt Regency walkway collapse; (2) more than 30 cases and commentaries developed at Western Michigan University's Center for the Study of Ethics in Society, indexed by such topics as acknowledging mistakes, environmental and safety concerns, and honesty and truthfulness; and (3) about seventy numerical cases specifically designed for use in required courses in civil, chemical, electrical, and mechanical engineering. Many of these cases are presented in a text by Harris, Pritchard, and Rabins (34) and are also available on disk, some in interactive format. Gorman, Stocker, and Mehalik (35) have pioneered the use of multimedia in developing interactive case studies that raise ethical and societal concerns in engineering designs.

A number of philosophers, notably Pritchard (36), are calling for further development of cases focusing on "good works," that is, cases that demonstrate that making sound ethical judgments need not end with a whistle-blower being demoted or fired. One such notable incident is the case of William LeMessurier, the noted civil engineer who designed New York's CitiCorp Building. To his horror, LeMessurier discovered, after the building was in use, that it had not been properly designed to withstand hurricane force winds. Risking his professional reputation and considerable financial liability, LeMessurier went to his partners and to CitiCorp and insisted that immediate action be taken to strengthen the building's structural joints.

Engineering Education

Many of the initiatives previously discussed relating to engineering education have been influenced by the ABET Engineering Criteria 2000 which will set a new standard for engineering education at the dawn of the twenty-first century. Under ABET 2000, engineering programs will have to demonstrate that their graduates have, among other technical and social skills, "an understanding of professional and ethical responsibility" (2). Similarly, the proposed CSAC 2000 criteria mandate that graduates of Computer Science programs be exposed to broad "coverage of social and ethical implications of computing" (37). The rapid change occurring in the environment in which engineering takes place is also challenging engineering educators to expose their students to the ethical implications of such developments as internationalization, rapid computerization, and an increase in team-oriented engineering practice (38). Because it is unlikely that there will be many instances where required dedicated courses are taught in engineering ethics—indeed the ABET 2000 criteria eliminate the requirement for any specific courses in the humanities and social sciences—it will become more incumbent upon the engineering community to see to it that these issues are adequately handled in technical courses. Engineering educators, like their counterparts in industry, will thus be challenged to face the societal and ethical implications of engineering head on.

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EVALUATION, COMPUTER. See COMPUTER EVALUATION.
EVALUATION OF SOFTWARE. See SOFTWARE REVIEWS.
EVENT SIGNALLING. See INTERRUPTS.
EVOKED POTENTIALS. See ELECTROENCEPHALOGRAPHY.
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EXCHANGES, TELECOMMUNICATION. See TELECOMMUNICATION EXCHANGES.