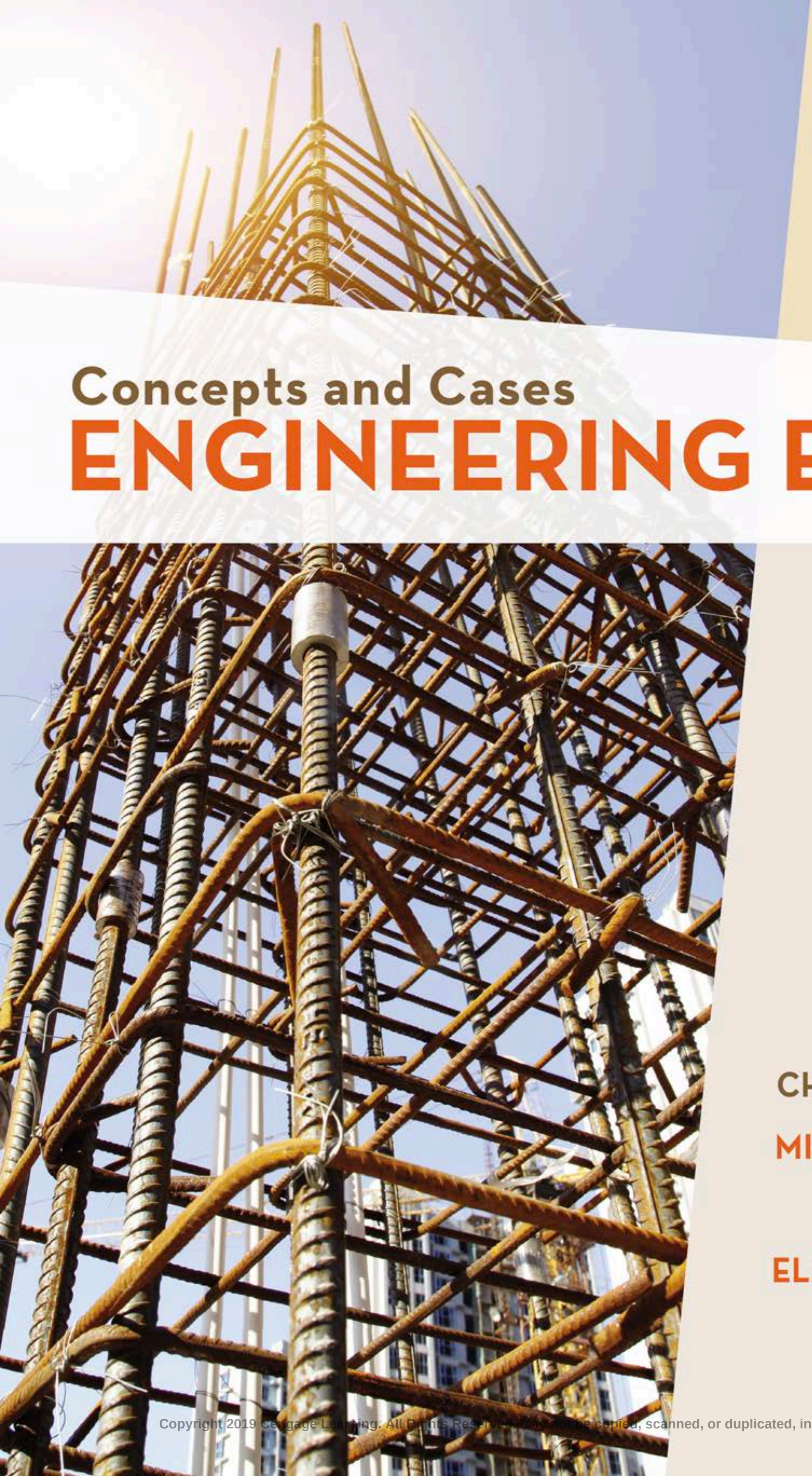
Sixth Edition

Concepts and Cases

ENGINEERING ETHICS



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Engineering Ethics: Concepts and Cases, **Sixth Edition**

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PREFACE

WE ARE HAPPY TO INTRODUCE the sixth edition of *Engineering Ethics: Concepts and Cases*. We have both added and deleted material throughout the book. One new feature is the introduction of boxes in every chapter. The boxes serve to break up the textual material and to either summarize ideas already discussed or to introduce ideas not covered elsewhere. Some chapter rearranging and renumbering is noted in the summary below. For example, the chapter in the fifth edition "The Social and Value Dimensions of Technology" has been removed; however much of the ideas in that chapter are discussed in the new Chapter 1 and elsewhere.

Here is a summary of some of the major additions:

- Chapter 1 (Engineers: Professionals for the Human Good) begins with a discussion of professional identity and continues with three accounts of the nature of professionalism. The special concern of engineering for human welfare, well-being, or quality of life is given greater emphasis, along with a discussion of what this means.
- Chapter 2 (A Practical Ethics Toolkit) contains revised accounts of utilitarianism and the analogy between the use of ethical theory in applied ethics and the use of models in engineering. For the first time, we provide an extensive discussion of virtue ethics and show how it can be useful in applied ethics.
- Chapter 3 (Responsibility in Engineering) shifts the discussion of impediments, or obstacles, to responsibility from Chapter 7 in the fifth edition, to this chapter. This revised chapter now contains considerations of how virtues can assist engineers in dealing with these impediments.
- Chapter 4 (Engineers in Organizations) is a reworking of the fifth edition's Chapter 7 in ways that make clearer how the working environment of engineers in organizations gives rise to special responsibilities for engineers as employees. The chapter also explores tensions between these organizational responsibilities and responsibilities engineers have by virtue of being members of a profession.
- Chapter 5 (Trust and Reliability) is a reworking of the fifth edition's Chapter 5 and places greater emphasis on the importance of virtues in grounding the trustworthiness of engineers in regard to their relationships to the public, their employers, clients, and the engineering profession itself.

- Chapter 6 (The Engineer's Responsibility to Assess and Manage Risk) is revised to include a more focused delineation of the engineer's responsibilities to assess and manage risks in two major tasks commonly handled by engineers: design of products or engineered systems, and operation of engineered systems.
- Chapter 7 (Engineering and the Environment) has been substantially revised and now contains an account of the development of the environmental movement, including its international dimension, and a more extended discussion of sustainability and the potential conflict between sustainability and economic development. The implementation of environmental concerns in both engineering and business is given a more extended treatment. The chapter also considers how the virtue of respect for nature can be developed.
- Chapter 8 (Engineering in the Global Context) features a new discussion of whether engineers outside Europe and North America think of themselves as professionals and whether they should be considered professionals. The statements of international engineering organizations are given greater prominence.
- Chapter 9 (New Horizons in Engineering) is a new brief chapter designed to highlight some of the important challenges that will face engineers of the future as well as areas where evolving technology offers promise. The chapter encourages the reader to anticipate the kinds of ethical challenges that will be faced by future engineers as they address those challenges and implement evolving technologies. One constant is that engineers of the future will still need a good understanding the ethical responsibilities of the profession in order to best serve the public.
- Cases. Several new, contemporary cases have been added and several others from the fifth edition have been deleted. Newly introduced cases include studies of problems with Toyota's drive-by-wire software, the Tesla Model S "Autopilot" semi-autonomous driver assist system, Volkswagen's emissions cheating scandal, and lead contamination in the municipal water supply in Flint, Michigan. In addition, some existing cases have been updated to reflect new facts or legal findings that have emerged since the publication of the fifth edition.

CHAPTER ONE

Engineers: Professionals for the Human Good

Main Ideas in This Chapter

- **A person's profession is a part of her personal identity.**
- **According to several prominent accounts, engineering is a profession, although the absence in a jurisdiction of a requirement for registration in order to practice engineering weakens its professional status in that jurisdiction.**
- **Engineering codes and other statements from leaders of the engineering profession impose on engineers an obligation to promote the public good, sometimes interpreted as well-being and also as welfare or quality of life.**
- **Promoting the well-being of the public includes not engaging in professionally prohibited actions, preventing harm to the public, and actively promoting the public's well-being.**
- **In designing for well-being, engineers must keep in mind the social context of engineering and technology, and the need for a critical attitude toward technology.**

DRIVERLESS CARS ARE IN OUR future. It is easy to understand why, given the advantages they offer. They promise a significant reduction in traffic collisions, increased access of the elderly and disabled to automobile transportation, lower fuel consumption, and major increases in traffic flow. On the other hand, they raise many social, legal, and ethical questions. Perhaps the most obvious question is who should have responsibility for accidents. The first fatal accident of a driverless car occurred in Williston, Florida, on May 7, 2016. The occupant of the Tesla driverless car was killed when a tractor-trailer made a left turn in front of the car. The car went under the truck's trailer without applying the brakes, evidently because neither the autopilot nor the driver noticed the white side of the trailer against a brightly lit sky. Where should moral responsibility and legal liability lie in this case? Investigation revealed that the driver did not operate the Tesla according to instructions, and that Tesla did not deploy a system capable of identifying situations in which the driver was not "prepared to take over at any time." And how realistic is it to install an autopilot system and then tell the driver she must be able to take over at any time?

Liability and responsibility are not the only questions raised by driverless cars. How safe are they? What kinds of information should be given to drivers before they purchase or use these vehicles? How should the potential problems of hacking and terrorism be handled? (A driverless car filled with explosives could be like a drone on the highway.) What about the potential loss of driving-related jobs? Should there be retraining for other jobs?

Many of these questions have appeared in other forms and other contexts before. Technology almost always raises new moral and social issues—or, most commonly, old issues in new ways. Questions of responsibility are not unique to driverless cars. They arise in the context of so-called engineering accidents, such as the loss of the Challenger and Columbia space vehicles. Moral issues also arise in thinking about the duties of engineers in such areas as the relationship of technology to the environment and handling risk properly. The issues are important to engineers not simply because engineers have usually created the technologies involved, but because engineers are professionals, and the concept of professionalism has a strong moral component. The two components of professionalism are (1) expertise in a certain area (accounting, law, medicine, engineering, etc.) and (2) adherence to moral guidelines, usually laid out in a formal code of ethics. Failure in either of these two areas means one is deficient as a professional. This book is about the second component of professionalism. We hope you are ready to begin your journey of discovery into the moral or ethical dimension of engineering.[1]

1.1 YOUR PROFESSION IS PART OF YOUR IDENTITY

If you were asked to identify or describe yourself, how would you do it? You might give your name and family affiliation, and maybe your place of residence. If you are employed, you would probably give your occupation. "I am a salesperson for Blue Jeans, Inc." "I am an executive with Safety First Corporation." If you are a professional, giving your profession would probably be especially important to you. "I am a cardiologist in private practice." "I am an accountant with Jones, Brown and Smith." "I am a civil engineer with Galendo Engineering."

If you are an engineer—and the chances are good that, if you are reading this book, you are an engineer or an engineering student—your professional identity will become an important part of your conception of *who you are*. To get some sense of the power of professional identity, just ask yourself: "How does it *feel* to be an engineer?" If you are not yet a degreed engineer, ask yourself: "Will I *feel* differently about myself when I get that degree?" The answer to this question is probably "yes." You will of course give a deep sigh of relief, now that you have finally "done it." And you will be proud of yourself, now that you are a true professional. But there is something deeper. See Box 1.1 for an account of how professional identity develops.

BOX 1.1 Three Stages in the Development of Professional Identity

- ***Independent Operator***. Professionalism is meeting fixed and clearly defined guidelines and expectations that are external to one's character.
- ***Team-Oriented Idealist***. Rather than identifying professionalism with fixed rules and behaviors, professionalism is seen as conforming to the expectations of other professionals, especially of the exemplary type.
- ***Self-Defining or Integrated Professional***. Rather than identifying professionalism with external expectations of one's peers, one has integrated his personal values with those of his profession. Professional values are a part of who one is. This stage is often not fully achieved until mid-life.[2]

1.2 WHAT IS A PROFESSION?

What, then, is a profession? The use of "profess" and related terms in the Middle Ages was associated with a monk's public "profession" of a way of life that carried with it stringent moral requirements. By the late seventeenth century, the term had been secularized to apply to those who "professed" to be duly qualified to perform certain services of value to others. Three approaches to professionalism are especially important in understanding the concept, and can be useful in understanding professional identity.

First, there is the Sociological Account, which holds that there are characteristics especially associated with professionalism. See Box 1.2 for one widely known list of such characteristics.

BOX 1.2 Characteristics of a Profession

1. Extensive period of training of an intellectual character, usually obtained at a college or university.
2. Possessing knowledge and skills vital to the well-being of the larger society.
3. A monopoly or near-monopoly on the provision of professional services, and considerable control over professional education and the standards for admission into the profession.
4. An unusual degree of autonomy in the workplace.
5. A claim to be regulated by ethical standards, usually embodied in a code of ethics, that promotes the good of the public.[3]

A second way to understand professionalism is the Social Contract Account. On the Social Contract Account, professionals have an implicit agreement with the public. On the one hand, professionals agree to attain a high degree of professional expertise, to provide competent service to the public, and to regulate their conduct by ethical standards. On the other hand, the public agrees to allow professionals to enjoy above-average wages, to have social recognition and prestige, and to have a considerable degree of freedom to regulate themselves. The idea of such an implicit contractual relationship, if taken seriously, imposes a powerful sense of obligation on a professional or a developing professional.

A third account of professionalism is offered by philosopher Michael Davis, who defines a profession in the following way:

> A profession is a number of individuals in the same occupation voluntarily organized to earn a living by openly serving a moral ideal in a morally permissible way beyond what law, market, morality, and public opinion would otherwise require.[4]

Davis' definition highlights the facts that a profession is not composed of only one person, that it involves a public element, that it is a way people earn a living and is therefore usually something that occupies them during their working hours, that people enter into it voluntarily, and that it involves a morally desirable goal, such as curing the sick or promoting the public good.

1.3 ENGINEERING IS A PROFESSION

Engineering is clearly a profession by all three accounts. There are a few rough edges to the fit, but this may be true with all professions. First consider the Sociological Account. Becoming an engineer requires high level of training at the college or university level. Engineering is vitally important to the public. Just as one cannot imaginea modern society without the services of lawyers and doctors, one cannot imagine our society without highways, computers, airplanes, and many other technological artifacts designed by engineers. Engineers have considerable control over the curriculum in engineering schools and the standards for admission to the profession. Control is usually exercised through the influence of professional societies and other professional organizations. The engineering profession does not have complete control over the practice of engineering, because, in some countries, such as the United States, one does not have to be a registered professional engineer (PE) in order to practice engineering. In fact, in the United States, only about one-third of engineers are registered with their state licensing boards. Further, the so-called industry exemption exempts engineers whose services are not directly offered to the public.

To continue, while engineers who work in business and public organizations may not be as autonomous as lawyers or doctors who have their own practice, they probably have more autonomy than most nonprofessionals, if only because nonengineers do not have enough technical knowledge to give more than general direction to engineers. Finally, engineers, like other professionals, have ethical codes that are supposed to regulate their conduct for the public good. Cynics may claim that professional codes are mere window dressing, designed to disguise the fact that professionals are primarily out to promote their own economic self-interest. While there is some truth to the claim, we believe ethical considerations are taken very seriously by most engineers and other professionals.

The question whether engineers should have to be registered in order to practice engineering is especially important for the professional status of engineering. It is also controversial in the engineering profession itself. See Box 1.3 for a summary of some of the arguments.

We believe the "YES" arguments are stronger and that the exemption from universal registration weakens engineering professionalism. It is not, however, a fatal weakness. A licensed PE must "sign off" on most public-works projects, and most business would probably want their engineering work to be performed by a degreed engineer, if not a PE.

The engineering profession also satisfies for the most part the conditions set by the Social Contract Account, although, again, it fits some aspects of the account better than others. Engineers in general have a high level of professional expertise and render competent service. Engineers also have ethical codes, but the loss of PE registration as a penalty for unethical conduct does not prohibit an engineer from professional practice, as in most other professions, since engineers are not required to be licensed to practice. So perhaps it can be said that the engineering profession does not have the same ability to enforce ethical sanctions as some other professions. Nevertheless, a severe ethical violation can tarnish the reputation of an engineer and possibly subject the engineer to legal penalties.

On the other side of the social contract, engineers do command attractive wages and considerable social status. Because most engineers work in large organizations, they may not have as much freedom in the workplace as professionals who are in private practice; but lawyers and physicians increasingly are also employed by large organizations, so this difference can be exaggerated. Our conclusion must be, then, that, by the first two standards we have used, engineering fits into the category of

BOX 1.3 Should Engineers Have to Be Registered to Practice Engineering?

NO. Registration Should Not Be Required to Practice Engineering.

- Registration might increase the cost of engineering services, because the costs of registration would be passed on to clients and customers.
- Registration might make certain types of cooperation between engineers and nonengineers on the same project difficult, because registration would prohibit nonengineers from doing engineering work.
- Engineers already must be licensed in order to "sign off" on work that directly affects the public.

YES. Registration Should Be Required to Practice Engineering.

- Some countries already require registration to practice, and the types of problems described above have not appeared to be serious.
- The distinction between work that does and does not affect the public is not clear, since most engineering work affects the public in some way.
- Registration might increase the professional autonomy of engineers in the workplace, because engineers could more easily resist management requirements to violate professional standards. An engineer could say, "Complying with your requests might lead to the revocation of my license, and other engineers would face the same problem if they complied with your request."

"profession," although there are a few rough edges in the fit, especially with regard to the lack of a requirement for universal registration.

Look back at the Michael Davis' definition of a profession. We believe you will conclude that engineering satisfies this definition as well.

1.4 A PROFESSION WITH A DIFFERENCE: THE PRIMACY OF THE PUBLIC GOOD

In addition to not requiring registration, engineering has another feature that differentiates it from most of the other major professions: the clear primacy of the obligation to the good of the public, as opposed to the good of employers, clients, and patients. To see this difference, contrast engineering with law, medicine, and accounting.

The "Preamble" to the 2013 Model Rules of Professional Conduct of the American Bar Association says, "A lawyer, as a member of the legal profession, is a representative of clients, an officer of the legal system, and a public citizen having special responsibility for the quality of justice." Looking at the order of priorities, the obligation to clients appears to be primary, a conclusion which may be justified by the nature of the adversary system of justice in the United States. In the adversary system, each client has a lawyer who advocates her interests, and the contest in court, regulated by the relevant laws, is supposed to produce a just outcome. This at least is a common justification for the claim that lawyers owe their primary obligation to their clients.

The "Preamble" to the 2001 Code of Medical Ethics of the American Medical Association begins by saying that the provisions in the code are "developed primarily for the benefit of the patient." It goes on to say that the physician must hold "responsibility to patients foremost, as well as to society, other health professionals, and self." Here, obligations to the patient take first place. As in the legal profession, the physician is the advocate of the patient and his or her rights. Even if the patient has committed a crime, the physician must in general be devoted to treating the medical needs of the patient, rather than being concerned with legal or even moral issues. There are a few exceptions to this rule, such as the obligation of physicians to report child abuse, but exceptions are few and far between.

Finally, under "The Public Interest," section .02 of the code of the American Institute of Certified Public Accountants says that a distinguishing mark of a profession is responsibility to the public but goes on to list *"clients"* as the first member of the public, along with "credit grantors, governments, employees, investors, the business and financial community, and others...." The first place given to clients, as well as the italics, indicates the primacy of client loyalty.

Prior to the 1970s, engineering codes also listed loyalty to clients or employers as the first responsibility of engineers. The first canon of the 1912 code of the American Institute of Electrical Engineers, for example, says that "engineers should consider the protection of a client's or employer's interests his first professional obligation…." The first canon of the 1963 code of the American Institute of Chemical Engineers says that an engineer should "serve with devotion his employer, his clients and the public." Note here that employers and clients appear to take first place.

In the 1970s, a profound shift of emphasis took place. The primary obligation of engineers shifted from clients and employers to the public. This shift may have been foreshadowed by an earlier code. The 1828 charter that established the Institution of Civil Engineers in the United Kingdom defines engineering as "the art of directing the great sources of power in nature for the use and convenience of man." At the time of this code's writing, the expression "use and convenience of man" was often associated with utilitarian thinking and thus implied an obligation to maximize the good, and this good may have been the general public good, as it was in utilitarian thinking.[5] Whatever may have been the case with this early code, engineering codes are now clear that the primary obligation of engineers is to the public. As an example, the first of the Fundamental Canons of the code of the National Society of Professional Engineers (NSPE) says that engineers shall "hold paramount the safety, health, and welfare of the public."

This change was not supported by everyone in the engineering profession. In October of 1978, shortly after the change in priorities occurred, engineer Samuel Florman wrote a well-known criticism of the change in priorities.[6] Florman notes that engineering codes have traditionally focused on "gentlemanly conduct rather than concern for public welfare" and expressed dismay that "the deceptive platitude that the professional's primary obligation is to the public..." should trump an "employer's wishes or instructions..."

Florman provides several arguments to bolster his opposition to giving priority to the public. One argument is that this new way of thinking could produce organizational chaos. He fears that "ties of loyalty and discipline would dissolve, and organizations would shatter." Every engineer would follow her own conscience, instead of allowing managers to decide issues, based on laws and judicial decisions. Determining the will of the public "can become weak if there is too much reliance upon morality." He concludes this first argument by saying, "Engineers are obliged to bring integrity and competence to whatever work they undertake. But they should not be counted upon to consider paramount the welfare of the human race."

Florman's second major argument is that engineers are not qualified by training to make ethical and policy decisions. This is not their area of expertise. He insists that "engineers have neither the power nor the right to plan social change." Engineers are not trained in social policy issues, environmental issues, and other topics relevant to making decisions about the public welfare, nor have they been given this right by law. Rather "professionals should serve," not lead in these areas. To be sure, business, government agencies, and citizens' groups should have access to engineering expertise, but engineers should not take the lead in making policy decisions.

Both of Florman's arguments contain an undeniable element of truth. He is certainly correct in wanting to avoid organizational chaos and in holding that engineers should in general be loyal employees. He is also correct in his claim that engineers are not trained in many areas relevant to the assessment of the social consequences of technology. In addition to the areas he mentions, we could add that engineers are also not trained in psychology, sociology, and economics.

Nevertheless, we believe that further considerations cast doubt on Florman's arguments. First, Florman seems to believe that engineers should obey managers, no questions asked, unless it is clear that they are being asked to disobey the law. If this is the case, engineers would have no need of a code of ethics and probably should not be considered professionals at all. Whether or not this conclusion would disturb Florman, it would disturb many engineers. Second, Florman apparently assumes that organizational dissent weakens an organization, but differing opinions and viewpoints often make an organization more creative and enable it to anticipate problems before they cause trouble. Nowadays, some managers welcome differing viewpoints and encourage employees to bring up criticisms. Third, engineers often see problems before managers do, and understand them better. Being more "on the ground" and involved more intimately in design and testing than managers, they can alert managers to issues that should be considered.

How and to what extent engineers are obligated to concern themselves with the public good is a complicated question of enormous importance. It is, we believe, an area where the position of the engineering profession is still evolving. Think of the question of engineering obligations with regard to the environment and the social effects of technology. We pursue this issue only in the most general way here, but much of the rest of the book is devoted to the question, "How should engineering be devoted to the public good?"

1.5 WHAT IS THE PUBLIC GOOD?

Even if we grant that engineers have an obligation to the public good, we can still ask what the public good is. The most general answer to this question is spelled out in many codes, and the answer is that engineers should "hold paramount the safety, health, and welfare of the public," as the NSPE code states. Probably, the most fundamental term here—and certainly the most ambiguous and controversial—is "welfare."

The term "welfare" appears to have several equivalents in engineering codes, such as "well-being" and "quality of life." The Preamble to the NSPE code says that "engineering has a direct and vital impact on the quality of life for all people." The code of the Association for Computing Machinery obligates its members to "contribute to society and human well-being" (I.1). This same section says that well-being includes a safe natural environment. One of the "Guidelines" to Canon 1 of the code of the American Society of Civil Engineers affirms that engineers should utilize "their knowledge and skill for the enhancement of human welfare and the environment." Finally, part of the introductory statement of the code of the Institute of Electrical and Electronics Engineers states that its members recognize "the importance of our technologies in affecting the quality of life throughout the world."

Assuming the equivalence of these terms, we shall take "well-being" as our term of choice and say that *promoting the well-being of the public is the primary responsibility of the engineering profession*.

1.6 BUT WHAT IS WELL-BEING?

No doubt, engineers have always assumed that their work contributes to the human good or what we have now called human well-being, but, until recently, little explicit consideration has been given to this goal. One reason for the increased interest in well-being is that the term itself has been the focus of considerable public and academic discussion. Some countries, such as the United Kingdom, France, Canada, and Australia, are measuring the well-being of their citizens, with a view to basing national policy on the results.[7] It is even conceivable that engineers may one day be asked in some formal way to determine the well-being impact of their work, just as they now are often asked to determine the environmental impact.

The mandate to engineers to promote human well-being or quality of life in their professional work is clear, but more guidance about the nature of well-being is needed. A simple equivalence of well-being (or welfare or quality of life) with material well-being is not supported by psychological research. Psychologist Martin Seligman maintains instead that the five elements of well-being include positive emotion, enjoyment of activities in which one can be absorbed, connection to something larger than oneself, accomplishment in projects or work, and positive relationships.[8] There is, if anything, even more agreement on what constitutes the closely related concept of happiness. According to a poll conducted by the British Broadcasting Corporation, the factors that promote happiness include human relationships (47%) and health (24%); the remaining factors being work fulfillment (2%); community and friends (5%); spirituality (6%); money and financial situation (7%); and a nice place to live (8%).[9]

These ideas, however, may be somewhat difficult to relate to engineering. One possible way around this issue which may sometimes be useful is to take advantage of the widely discussed Capabilities Approach (CA). Two important developers of the CA were Nobel Prize winner in economics Amartya Sen and philosopher Martha Nussbaum. According to Sen and Nussbaum, we do not have to determine what well-being is, but rather step back a little and ask what conditions are necessary for the realization of some of the most commonly recognized elements of well-being, regardless of how individuals or even experts may define it. In his "Foreword" to the National Academy of Engineering's (NAE) presentation of the 20 greatest engineering achievements of the twentieth century, astronaut Neil Young put it this way. Even though each of us may have our own concept of what comprises "quality of life," we can probably agree "that certain living conditions are essential to a preferred quality in our own lives."[10] If we look at the capabilities suggested by CA writers that are most closely related to engineering, we get a clue as to what some of these living conditions might be: having food, shelter, and water, having satisfying human relationships (communication, the Internet), having free movement and expression (highways, air travel, the Internet, telephone, etc.), and having a satisfactory relationship to the natural world (environmental preservation).[11]

Whether or not we use the CA, we shall be considering the relationship of engineering to well-being (or its conditions) throughout much of the rest of this book. In the next three sections, we discuss three types of engineering activity identified by codes or other engineering authorities and show how they relate to the theme of promoting human well-being.

1.7 PROHIBITED ACTIONS

Many precepts in ordinary or nonprofessional ethics identify actions we should not do. Ethical precepts prohibit such actions as dishonesty, stealing, and murder. Prohibitions are also a prominent part of professional ethics, including engineering ethics. Approximately 80 percent of the code of the NSPE is taken up with statements that are, either explicitly or implicitly, prohibitive in character. See Box 1.4 for some examples.

Even many provisions of the NSPE code that are not explicitly negative are actually prohibitive in character. Section II.1.b states that "engineers shall approve only those engineering documents that are in conformity with applicable standards." In other words, engineers shall *not* approve engineering documents that are *not* in conformity with applicable standards. This is not the same as saying that engineers *shall* approve all engineering documents that are in conformity with applicable standards. Presumably, there are other criteria that would need to be satisfied for approval of an engineering document to be *required*.

Many other provisions of the code, such as the requirement that engineers notify the appropriate professional bodies or public authorities of code violations (II.1.f), are "policing" provisions and thus are essentially prohibitive in character. Even the requirement that engineers be "objective and truthful" (II.3.a) is another way of stating that engineers must not make biased and deceitful statements. Similarly, the provision that engineers shall continue their professional development (III.9.c) is another way of saying that engineers shall not neglect their professional development.

BOX 1.4 Examples of Prohibited Actions from the NSPE Code

- Do not reveal privileged information (II,1,c)
- Do not associate with dishonest professionals (II,1,d)
- Do not aid the unlawful practice of engineering (II,1,e)
- Do not accept compensation from two parties on the same project (II,4,b)
- Do not participate in governmental decisions related to your own work (II,4,d)
- Do not solicit work from a governmental body on which a member of your firm has a position (II,4,e)
- Do not falsify your qualifications (II,5,a)
- Do not give bribes (II,5,b)
- Do not be influenced by conflicting interests (III,5)
- Do not unjustly injure the reputation of another engineer (III,7)

There are several good reasons for the prohibitive tone of the NSPE code and many other engineering codes. First, it makes good sense that the first duty of moral agents, including professionals, is to refrain from harming others. Before doing good, one should not do harm. Second, the codes are largely formulated in terms of rules that can be relatively easily enforced by penalties, either of the societies or perhaps by law, and it is easier to enforce rules that specify what is prohibited than rules that require, or at least encourage, more open-ended and positive objectives. A rule that requires engineers to "avoid conflicts of interest" is relatively easy to enforce, at least in comparison to a more open-ended requirement such as the requirement that engineers "hold paramount the safety, health, and welfare of the public."

Without reviewing each of these provisions in detail, it is easy to see how refraining from certain actions on the part of engineers can contribute to the well-being of the public. Protection from harmful actions is an essential prerequisite for well-being, no matter how it is defined. Taking just three examples, if engineers (1) are dishonest, (2) have their professional judgment corrupted by conflicts of interest, or (3) do professionally incompetent work, their clients or employers are harmed, because they are not given the benefit of honest, fair, and competent judgments. This limits the ability of clients to use the services of engineers to further their own goals and purposes.

1.8 PREVENTING HARM TO THE PUBLIC

Engineers are obligated not only to abide by code prohibitions, thereby refraining from causing harm, but also, under some circumstances, to actively prevent harms caused by technology or by other engineers. Prevention of harm usually involves (1) identifying and disclosing potential harms and (2) attempting to prevent them. Such actions, even though perhaps fundamentally negative, also have a positive dimension, since they often involve courage, and it often requires considerable effort to oppose and prevent harms to the public. In any case, they both protect and promote well-being.

Some codes are more specific than others about the obligations of engineers to actively prevent harm. Canon 1 of the code of the Institute of Electrical and Electronics Engineers says that its members commit themselves "to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to *disclose promptly factors that might endanger the public or the environment* [emphasis added]."

The NSPE's Board of Ethical Review appeared to recognize the category of preventive action in its decision on case 82-5, which was submitted by one of its members.[12] In this case, an engineer was terminated because he repeatedly protested his employer's actions, believing the employer was wasting taxpayer money on a defense contract. The Board cited section II.1.a. of the NSPE code operative at that time, which reads:

> Engineers shall at all times recognize that their primary obligation is to protect the safety, health, property and welfare of the public. If their professional judgment is overruled, under circumstances where the safety, health, property, or welfare of the public are endangered, they shall *notify their employer or client and such other authority as may beappropriate* [emphasis added].

It also cited section III.2.b of the code as formulated at that time, which stated:

> Engineers shall not complete, sign, or seal plans and/or specifications that are not of a design safe to the public health and welfare and in conformity with accepted engineering standards. If the client or employer insists on such unprofessional conduct, they shall *notify the proper authorities and withdraw from further service on the project* [emphasis added].

These two provisions underline the obligation of engineers not only to refrain from harming the public, but to actively protect the public from harm. Citing the reference to the "welfare" of the public, the Board concluded that the engineer had a right "as a matter of personal conscience" to continue to protest his employer's actions, but did not have an obligation to do so.

Two of the most famous cases in engineering ethics have a strongly preventive theme. Engineer Roger Boisjoly attempted to prevent the 1986 launch of the Challenger, a launch which resulted in the destruction of the vehicle and the loss of the crew.[13] Seventeen years later, engineer Rodney Rocha attempted to persuade managers to arrange for photos of possible damage the Columbia sustained when it was launched. This action might have prevented the loss of the vehicle and crew.[14] If we consider the astronauts in these two examples to be members of the "public," as surely they were, these examples also illustrate the attempt to protect the public from harm. Actions illustrative of preventive ethics do not have to involve such high-stakes actions, however. An engineer may simply believe that redesigning a product can make it safer or that calling the attention of management to a problem might prevent some later problem.

1.9 PROMOTING WELL-BEING: ASPIRATIONAL ETHICS

Although engineering codes of ethics place great emphasis on the importance of refraining from certain kinds of behavior (prohibited actions) and engaging in behavior that prevents harms, such provisions do not adequately capture the more positive aspects of engineering. We call this more positive component of engineering ethics *aspirational ethics*. The aspirational component can take many forms, ranging from actions that are obligatory—since engineering codes require engineers to promote human well-being—to those that go beyond the obligatory. In the next chapter, we shall call such actions *supererogatory*, or actions that are praiseworthy, but go beyond what is required. We begin with some examples of aspirational conduct that go beyond what is obligatory for engineers.

Engineer Bernard Amadei founded Engineers Without Borders (EWB-USA) in 2001. A very compassionate man, Amadei was profoundly affected by the poor living conditions in underdeveloped countries, such as the absence of clean water. In many cases, undergraduate engineers could design and build water supply systems that would enable such people to have a better life. Engineering students in EWB are responsible for many projects throughout the world that have enhanced human well-being.

EWB-USA is an organization primarily for engineering students and professionals who want to use their expertise to promote human welfare, especially, but not exclusively, in less developed countries. In a typical example of the organization's work, engineering students from the University of Arizona chapter developed a water supply and purification project in the village of Mafi Zongo, Ghana. The project's aim was to supply 30 or more villages, with approximately 10,000 people, with safe drinking water. In another project, engineering students from the University of Colorado installed a water system in Muramka, a Rwandan village. The system provides villagers with up to 7,000 liters of safe water for everyday use. It consists of a gravity-fed settling tank, rapid sand filters, and a solar-powered sanitation light.[15] The many Engineers Without Borders websites at colleges and universities around the world feature a wide range of projects aimed at providing technical and engineering assistance to impoverished areas.

Other engineers and like-minded people have advocated ideas and projects that also illustrate aspirational ethics. Engineer P. Aarne Vesilind and Robert Textor have come up with the term "Peace Engineering" as a label for ideals such as global environmental management, sustainable development, and seeking greater economic justice.[16] In another example, the Colorado School of Mines has created a program in "Humanitarian Engineering" which is devoted to research and design intended to improve the well-being of poor and marginalized communities around the world. Several other universities, including Dartmouth and Ohio State, also have Humanitarian Engineering programs.

Examples of aspirational action are not confined to work in underdeveloped regions. Engineers not infrequently engage in projects that go far beyond what employers or codes require, and they do so out of a desire to promote the human good. Even after his retirement, engineer Carl Clark devoted extensive time to the development of air bags for car bumpers, and wearable air bags for the elderly to prevent broken hips. Much of his work was done on his own time and without pay. Unfortunately, the air bags were eventually patented by someone else.[17]

1.10 ASPIRATIONAL ETHICS AND THE NATIONAL ACADEMY OF ENGINEERING

Most engineers probably believe that their work promotes human well-being and that it is required of them as engineers to promote well-being. A call to use technological innovation for the human good is evident in perhaps the most prestigious organization in American engineering. In an unpublished speech in 2000 by the former president of the (NAE, on the occasion of its selection of the 20 greatest engineering achievements of the twentieth century, Dr. William A. Wulf described the criterion for selecting the achievements as "not technological 'gee-whiz,' but how much an achievement improved people's quality of life." He went on to say that the achievements selected are "a testament to the power and promise of engineering to improve the quality of human life worldwide."[18] Box 1.5 gives the NAE list of twentieth-century engineering's greatest achievements.

BOX 1.5 NAE's List of the Greatest Engineering Achievements of the Twentieth Century

- Electrification
- The automobile
- The airplane
- Water supply and distribution systems
- Electronics (vacuum tubes, transistors, etc.)
- Radio and television
- Agricultural mechanization
- Computers
- Telephones
- Air-conditioning and refrigeration
- Highways
- Spacecraft
- The Internet
- Imaging (especially in medicine)
- Household appliances
- Heath technologies
- Petroleum and petroleum technologies
- Laser and fiber optics
- Nuclear technologies
- High-performance materials

Recognizing the fundamental role that the technological innovations of engineers will have in determining the course of society in the twenty-first century, in 2008, the NAE formed a committee of distinguished engineers to discuss what they referred to as the Grand Challenges of engineering for the twenty-first century. The list was accompanied by a call to engineers to dedicate themselves to ensuring the future in the face of finite resources, increasing population, and a current rate of consumption that is unsustainable. We believe that the world's cadre of engineers, as part of their obligation to promote human well-being, should seek to put their engineering knowledge to work in meeting these grand challenges. Box 1.6 gives the list of the 14 Grand Challenges.

BOX 1.6 NAE's List of the Grand Challenges for the Twenty-First Century

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

Recognizing that preparation for engineering careers should begin long before the college years, NAE also established a K–12 mission to create an awareness of the NAE Grand Challenges at the precollege level and to encourage students to pursue careers in engineering. This mission includes the development of technical literacy and the motivation that is necessary to successfully address these Grand Challenges. It also aims to "educate the populace on the engineering mindset and the role of engineering in address Grand Challenges and improving the quality of life."

1.11 DESIGNING FOR WELL-BEING: THE SOCIAL CONTEXT OF ENGINEERING

The primary way in which engineers improve well-being is through design. In designing for well-being, engineers must keep many things in mind. In this and the following section, we discuss two important themes that should govern design: *technology functions in a social context* and *engineers must adopt a critical attitude toward technology.*

Technologies always function in a social context, and in this context, they have consequences for good or ill. Another way to state this same idea is to say that *engineering is a type of social experimentation.*[19] Engineering innovations—whether consumer products, bridges, or buildings—are "tested" on members of the public. Think again about the autonomous car. Whether this innovation will promote well-being, all things considered, can be known only after it is placed in the social context in which it will function. The autonomous car clearly has many advantages, but it also raises some serious issues. Whether the advantages will outweigh the disadvantages can only be determined by performing the "social experiment" of immersing the car in its social context, which is composed of physical objects and tools, knowledge, inventors, operators, repair people, managers, government regulators, and the like.[20] The social context comprises a two-way causal relationship: technology affects society and the social context influences the development of technology. Let's begin with the effect of technology on society.

Technology affects our behavior in many ways. Speed bumps, for example, virtually force us to drive more slowly. The invention of the printing press had an enormous impact on European civilization and was a major factor in the Protestant Reformation. It is difficult to deny the effects of the development of the technology of warfare on the conduct of warfare itself. Technology also obviously affects the jobs we hold. Some jobs have been diminished in numbers due to technology, such as jobs for bank tellers and travel agents. Others have been created, such as computer programmers.

Technology has also affected our social relationships in many ways, sometimes affecting people in different generations differently. For many young people, the elapse of several hours with no cell phone call or text message prompts them to wonder whether their friends still care about them, but for many of an older generation, the absence of such communications is a welcome relief. Many young people feel that they are not in a genuine romantic relationship until they are "Facebook official," but older people find this hard to understand. Regular use of social networking sites such as Facebook, MySpace, and Bebo almost certainly has an effect on human relationships. As is often the case, the technologies probably affect even our definitions of crucial terms—in this case, what it means to have a "friendship" or "relationship." We have already mentioned some of the ways in which the autonomous car can affect jobs and other elements of the social context.

Social forces also direct the development of technology. One way to understand this is acquainting ourselves with the rapidly growing field of Science and Technology Studies (STS), a discipline created by sociologists, historians, and philosophers. Detailed investigations of technology have shown that there are usually several workable solutions to a technical problem and that social and value factors often determine which solution is adopted. Sociologists of technology Trevor Pinch and Wiebe Bijker illustrate this theme with the early history of the bicycle.[21] The early evolution of the bicycle had two "branches": a sportsman's bike with a high front wheel that was relatively unstable and a more utilitarian version with a smaller front wheel that was more stable. The sportsman's version was designed for speed and was especially attractive to young athletic males. The utilitarian version was more appropriate for pleasure riding and ordinary transportation. Eventually, the utilitarian design came to be more widely accepted, and the high-wheeled bike disappeared. Most people evidently decided that producing a sportsman's toy was not as important as producing a useful means of transportation.

On a still more subtle level of analysis, STS researchers have found that even concepts that are usually thought to have a purely technical definition often have a social and value dimension. For example, what constitutes "effective functioning" or "efficiency"—especially important terms in technology—is not determined wholly by technical considerations, but also in part by social considerations. In engineering, the efficiency of a device is taken to be a purely quantitative ratio of energy input and energy output. However, in practice, whether a device is considered to "work well" is a product of the character and interests of a user group.[22] Child labor was in some ways more "efficient" than the use of adults, but when it was decided that the use of child labor was immoral, children were no longer taken into account as a possible source of more efficient labor. The use of child labor was no longer considered in determining "efficiency." Instead, children were redefined as learners and consumers, not laborers. These so-called technical concepts, then, have a social dimension.

A similar process seems to be occurring in many areas related to the environment. Standards for consumption of gasoline are changing. Even if it is more "efficient" to build automobiles by older standards or to use less environment-friendly standards in other areas, society will almost certainly continue to change the standards in favor of the environment. Many design standards that were once controversial no longer are, and design standards already incorporate many safety and environmental considerations that probably cannot be justified economically or even by a consideration of trade-offs. Society has simply made certain decisions that are no longer in dispute. They become part of the definition of what it means to design a product, such as an automobile. Can you think of ways in which social forces have influenced the evolution of the autonomous car and an evaluation of its advantages? What about the increasing size and importance of the elderly population? What about increasing population densities and traffic congestion?

1.12 ADOPTING A CRITICAL ATTITUDE TOWARD TECHNOLOGY

Some scholars hold that technological development has a life of its own that can only minimally be controlled by individual humans or even society at large. For example, the steamship was developed from prior wind-driven vessels, and diesel-powered and atomic-powered vessels could not have been developed apart from steamships. There seems to be something inevitable about the progression itself and the order in which it occurred. Furthermore, many people believe that if a technology (good or bad) can be developed, it will be developed, and there is little we can do about it. This position, *technological determinism,* has been rejected by most scholars in favor of the view that humans can influence the direction of technological development. But if there is freedom to direct the course of technological development, how *should* it be directed? *Technological optimists* believe that most technological development promotes well-being and should be encouraged. Consider the situation in India.[23] The country seems finally poised to experience the kind of explosive economic development necessary if the millions who live on less than $1/day are to escape poverty. Remarkable increases in mobile phone connections, shopping malls, and prime office space are only a few examples of growth, and the IT industry, which barely existed in 1991, has the potential to do for India what automobiles did for Japan and oil for Saudi Arabia.

Technological pessimists, on the other hand, while not opposing all technological development, want to enter a cautionary note. In India, for example, the development which technological optimists praise may weaken or destroy many aspects of traditional life, such as close-knit families and community ties that have great human value. Philosopher Albert Borgman illustrates how technological development can be responsible for the loss of a complex network of relationships by contrasting the fireplace with the modern furnace.[24] The fireplace was once a focal point for family life. The family gathered there for conversation and storytelling. Often the father cut the wood, the children brought in the wood, and the mother built the fire. The centrality of the fireplace to family life is not something new. In ancient times, the hearth was the place where the household deities dwelled and important ceremonies, such as marriages, were conducted. Contrast the fireplace with the modern furnace, from which heat appears without effort and without the involvement of family members. Similar considerations apply to the traditional family meal as contrasted with a microwave meal. At the traditional meal, the mother prepared the food, which might have been raised in a family garden in which the whole family worked. Mealtime was a time for grace and discussion of the experiences of the day, thus linking family members with each other and the transcendent. All of this is lost when we "grab a bite" on the run from a microwave dinner and eat it in solitude.

The truth lies between technological optimism and pessimism. Creators of technology must recognize that technology can have both desirable and undesirable aspects, and that designers should try to maximize the desirable aspects and minimize the undesirable aspects. This requires a critical attitude toward technology. Consider the example of social networking, where the critical attitude is needed. Philosopher Shannon Vallor recognizes the "psychological and informational value of social networking sites for people with serious illnesses, for victims of violent crime, or those suffering and alienated in other ways."[25] However, she raises concerns about the influence of these same technologies on what she calls the "communicative virtues," especially in their early development in young people. These virtues include patience, honesty, empathy, fidelity, reciprocity, and tolerance, and they are the ones necessary, she thinks, for the development of effective and satisfying interpersonal relationships. She worries that the Internet may not be conducive to the development of such virtues.

Vallor focuses on three of the communicative virtues. Patience is an important virtue for sustaining close relationships. One must be willing to remain in communication with a friend, even when it may sometimes be boring or irritating to do so; but on the Internet, we can always say "gotta run" or just click the person off. Honesty in personal relationships is the willingness to offer one's authentic self in relationship with another, but social networking sites offer opportunities for massive misrepresentation of oneself, which is incompatible with genuine friendship. Finally, empathy or compassion, although crucial for genuine relationships, usually requires an encounter with the embodied presence of another person, enabling us to see bodily expressions of pain, anger, disgust, or caring. The best expressions of sympathy and compassion may be physical touching and embrace, none of which is possible in online relationships.

The answer to the problems posed by social media is neither to get rid of them nor to view them uncritically. Some way must be found, Vallor believes, to minimize these negative effects while preserving the undoubted benefits. It is up to the creators of technology and others to solve this problem. Whether or not Vallor's concerns are well founded—and only empirical research can determine this—it is reasonable to suppose that social networking technology has affected interpersonal relationships in some way.

1.13 GETTING DOWN TO CASES

Professionals are men and women of practice. As a physician once said to one of the coauthors, physicians are "tied to the post of use." The same is true of engineers. While professionals are required to master large amounts of intellectually challenging material, the ultimate aim of professional knowledge is to deal with "use," with concrete problems that arise in professional practice. Something similar applies to the ethical dimension of professionalism. Professionals do not encounter the ethical dimension of their work in the form of abstract dilemmas, but in the form of cases which must be resolved or dealt with in some way in order to get on with the task at hand. Because of the centrality of cases in all areas of professional work, this book contains many cases—at the beginning of the chapters, in the body of the chapters themselves, and in the appendix.

Cases serve several important functions: (1) Through the study of cases, we learn to recognize the presence of ethical problems, even in situations where we originally saw only technical issues. (2) Studying cases is the best way to develop our skills in ethical analysis. Cases stimulate the moral imagination by challenging us to think of possible alternatives for resolving them and to think about the consequences of those alternatives. (3) A study of cases shows us that the codes of ethics, however useful, cannot provide ready-made answers to many of the cases generated by professional engineering practice. Cases can convince us that there is no substitute for developing our own ethical skills, and that in some cases, the codes themselves should perhaps be revised. (4) Cases can show us that sometimes the world of practice presents us with dilemmas that are not easily resolvable and that professionals may disagree about what is right.

1.14 CHAPTER SUMMARY

By several widely accepted accounts of professionalism, engineering is a profession, although, in contrast to most professions, one does not have to be registered in order to practice. Most engineers, like professionals generally, probably increasingly identify with the values of their profession as they experience more of professional life. One of the professional values in engineering is the obligation to promote the good (welfare, well-being, quality of life) of the public. According to contemporary engineering codes, this obligation takes precedence over loyalty to clients and employers.

Determining what constitutes the good or well-being of the public can be controversial, but almost any conception of well-being requires that people have food, shelter, water, satisfying human relationships (including a way to communicate with others, such as telephone), free movement, and a relationship with the natural world that is not in a state of degradation. Engineering is probably involved in all of these conditions of a satisfactory life.

In carrying out the obligation to promote the public good, engineers must honor certain professional prohibitions, such as not taking bribes or having conflicts of interest, and attempt to prevent harm to the public that is caused by technology. Engineers have also recognized an obligation to promote the well-being of the public. They also, from time to time, engage in nonobligatory actions, such as participating as students in projects sponsored by Engineers Without Borders or developing technologies that promote well-being. In pursuing their professional projects, however, engineers must keep in mind that engineering always functions in a social context, and they must adopt a critical attitude toward technology.

NOTES

1. In this text, we use the terms "moral" and "ethical" interchangeably.
2. Muriel J. Bebeau and Stephen J. Thoma, "Moral Motivation in Different Professions," in *Handbook of Moral Motivation*, eds. Karin Heinrichs, Fritz Oser, and Terence Lavat (Rotterdam: Sense Publishers, 2013), pp. 475–498.
3. Ernest Greenwood, "Attributes of a Profession," *Social Work*, July 1957, pp. 44–45.
4. Michael Davis, "Is There a Profession of Engineering?" *Science and Engineering Ethics*, 3, no. 4, 1997, p. 417.
5. C. Mitcham and D. Munos, *Humanitarian Engineering* (San Rafael, CA: Morgan and Claypool, 2010), pp. 3–5.

6. Samuel Florman, "Moral Blueprints," *Harper's Magazine*, October 1978, pp. 30–33.
7. Susan A. David, Ilona Boniwell, and Amanda Conley Ayers, *The Oxford Handbook of Happiness* (Oxford: Oxford University Press, 2013), p. 3.
8. M. E. P. Seligman, *Flourish* (New York: Free Press, 2011), pp. 16–20.
9. Geoff Mulgan, "Well-Being and Public Policy," in *The Oxford Handbook of Happiness*, eds. Susan A. David, Ilona Boniwell, and Amanda Conley Ayers (Oxford: Oxford University Press, 2013), pp. 517–532.
10. George Constable and Bob Sommeerville, *A Century of Innovation* (Washington, DC: Joseph Henry Press, 2003), p. vi.
11. There is a vast literature on the CA. See especially Martha Nusbaum, *Women and Human Development: The Capabilities Approach* (Cambridge, UK: Cambridge University Press, 2000), pp. 78–80.
12. The NSPE's Board of Ethical Review consists of engineers who are members of the NSPE and who apply the NSPE code to cases submitted by members in order to arrive at a judgment about the case.
13. See the Rogers Commission's *Report to the President by the Presidential Commission on the Space Shuttle Challenger Accident* (Washington, DC, June 6, 1986), pp. 772–773. For Boisjoly's own account of the *Challenger* disaster, see his "The *Challenger* Disaster: Moral Responsibility and the Working Engineer," in *Ethical Issues in Engineering*, ed., Deborah Johnson (Englewood Cliffs, NJ: Prentice-Hall, 1991), pp. 6–14.
14. For a detailed account of Rocha's efforts, see James Glanz and John Schwartz, "Dogged Engineer's Effort to Assess Shuttle Damage," *The New York Times*, September 26, 2003, pp. A1, A16.
15. See the Engineers Without Borders website at http://www.ewb-usa.org.
16. P. Aarne Vesilind, *Peace Engineering: When Personal Values and Engineering Careers Converge* (Woodville, NH: Lakeshore Press, 2005), p.15.
17. For further discussion of this and other examples of what Pritchard calls "good works," see Michael S. Pritchard, "Professional Responsibility: Focusing on the Exemplary," *Science and Engineering Ethics*, 4, 1998, p. 222.
18. William A. Wulf, "Great Achievements and Grand Challenges," revised version of a lecture given on October 22 at the 2000 annual meeting of the National Academy of Engineering, p. 1. Used with permission.
19. Mike W. Martin and Roland Schinzinger, *Ethics in Engineering*, 4th ed. (Boston: McGraw-Hill, 2005), pp. 88–100.
20. Val Dusek, *Philosophy of Technology: An Introduction* (Malden, MA: Blackwell, 2006), pp. 32–36.
21. Trevor J. Pinch and Wiebe E. Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, eds. W. E. Bijker, T. P. Hughes, and T. Pinch (Cambridge, MA: MIT Press, 1987), pp. 17–50.
22. Dusek, *Philosophy of Technology: An Introduction* (Malden, MA: Blackwell, 2006), p. 205.
23. Most of this account is taken from "Now for the Hard Part: A Survey of Business in India," *The Economist*, June 3–9, 2006, special insert, pp. 3–18.
24. Albert Borgman, "Focal Things and Practices," in *Readings in the Philosophy of Technology*, ed. David M. Kaplan (New York: Roman and Littlefield, 2004), pp. 115–136. Taken from Albert Borgman, *Technology and the Character of Contemporary Life: A Philosophical Inquiry* (Chicago: University of Chicago Press, 1984).
25. Shannon Vallor, "Social Networking Technology and the Virtues," *Ethics and Information Technology*, 12, 2010, pp. 157–170.

CHAPTER TWO

A Practical Ethics Toolkit

Main Ideas in This Chapter

- **The first task of ethical analysis is to sort out the issues in a case into four categories: factual issues, conceptual issues, application issues, and moral issues.**
- **The line-drawing method is a way of comparing a controversial situation with uncontroversial ("paradigm") ones in order to determine what should be said about the controversial situation.**
- **The creative-middle-way approach is a way of resolving moral problems involving competing moral demands by coming up with courses of action that satisfy as many moral demands as possible.**
- **What are sometimes called "moral theories" or "approaches" to moral thinking are attempts to identify the fundamental idea(s) in common morality. They are not always necessary for resolving a moral problem, but, when they are, it is better to use more than one approach.**
- **The utilitarian approach finds the fundamental idea of common morality to be the imperative to maximize overall well-being. There are several ways of applying the utilitarian approach.**
- **The respect for persons (RP) approach finds the basic idea of common morality to be the imperative to act so as to respect humans as free and equal moral agents. There are several ways of applying the RP approach.**
- **The virtue ethics approach finds the basic idea of common morality to be the imperative to act in the way the virtuous person would act. It supplies concepts for understanding moral motivation and development and gives guidance when moral and professional rules provide insufficient direction.**

IN 1993, IT WAS PUBLICLY REVEALED that Germany's Heidelberg University had in the past used more than 200 cadavers, including those of 8 children, in automobile crash tests. This revelation drew immediate protests in Germany. Rudolph Hammerschmidt, spokesperson for the Roman Catholic Bishop's Conference, objected. "Even the dead possess human dignity. This research should be done with mannequins," he said. ADAC, Germany's largest automobile club, issued a statement saying, "In an age when experiments on animals are being put into question, such tests must be carried out on dummies and not on children's cadavers."

In reply, the university claimed that, in every case, relatives granted permission, as required by German law. It added that although it had used children in the past, this practice had been stopped in 1989. The rationale for using cadavers is that data from such crash tests are "vital for constructing more than 120 types of instrumented dummies, ranging in size from infants to adults, that can simulate dozens of human reactions in a crash." The statement claimed that such tests have been used to save many lives, including those of children.

Similar testing has also been conducted in the United States at Wayne State's Bioengineering Center. Robert Wartner, a Wayne State spokesperson, indicated that the testing has been done as a part of a study by the federal government's Centers for Disease Control. However, he added, "Cadavers are used only when alternative could not produce useful safety research."

Clarence Ditlow, head of the Center for Auto Safety, a Washington, DC, public advocacy group, said that the center advocates three criteria for using cadavers in crash testing: (1) assurance that the data sought by the tests cannot be gained from using dummies, (2) prior consent by the deceased person, and (3) informed consent of the family.[1]

2.1 INTRODUCTION

This case illustrates how technology raises important moral and social issues. Here, we can see a conflict between the safety and well-being of the public, which apparently can be enhanced by the use of cadavers, and concerns about the dignity of the cadaver. As we shall see later in this chapter, these moral considerations correspond to two different and sometimes conflicting moral approaches. If we take the code of the National Society of Professional Engineers (NSPE) as representative of other engineering codes, it is clear that simply referring to a professional code is not sufficient to resolve some issues in engineering. To be sure, the first "Fundamental Canon" of the NSPE code says that engineers must "hold paramount the safety, health, and welfare of the public." But does this directive imply that cadavers should be used for crash testing, or does the consideration of human dignity (rarely mentioned in engineering codes) override considerations of health, welfare, and safety in this case? In addressing many issues in engineering ethics, we need ethical resources or methods to supplement the codes.

These methods should be thought of as analogous to tools in a toolbox. Carpenters have many tools at their disposal: hammers, screwdrivers, saws, and so forth. For some tasks, a hammer is appropriate, for others, a screwdriver, and for others, the saw. The carpenter must learn which tools are appropriate for a given task, and this knowledge comes only with experience.

We begin with tools for analyzing a moral problem into its components. Most moral problems contain one or more of the following components.

2.2 DETERMINING THE FACTS: FACTUAL ISSUES

We cannot discuss a moral problem intelligently apart from a knowledge of the facts that bear on the problem. We have designated questions about what the facts are as *factual issues*. We might think that the facts of a situation are always beyond dispute, but this is often not the case. To understand the status of facts in a moral controversy, consider the following three claims about factual issues.

First, *many apparent moral disagreements turn out to be disagreements over the relevant facts.* In looking at the case at the beginning of the chapter, you may be asking yourself: "Is it really the case that important factual information that will save lives can only be gained from crash testing with cadavers?" Many people (although certainly not all) would agree that if vital information can be gained *only* by the use of cadavers, then cadavers should be used, but people might legitimately disagree over whether cadavers are really necessary.

Second, f*actual issues are sometimes very difficult to resolve.*In this case, for example, it may be difficult or even impossible to determine with certainty whether using information from testing cadavers produces a significant decrease in accidents, as opposed to using information from other sources, such as computer simulations or testing with dummies.

Third, *sometimes we must make decisions about important moral issues, even though some of the relevant factual issues cannot be resolved.* Suppose there is simply no way to confirm or deny the claim that cadaver testing results in a higher level of safety. How shall we decide what to do? Should we put greater emphasis on respecting the bodies of dead humans or obtaining data that may save lives? In this case, the controversy shifts to a more direct consideration of moral issues.

2.3 CLARIFYING CONCEPTS: CONCEPTUAL ISSUES

Responsible moral thinking requires not only attending carefully to facts but also having a good grasp of the key concepts we are using. That is, we need to get as clear as we can about the meanings of key terms. For example, "public health, safety, and welfare," "conflict of interest," "bribery," "extortion," "confidentiality," "trade secret," and "loyalty" are key terms for ethics in engineering, but their meanings are not always obvious. We call questions about the meanings of terms *conceptual issues.* If people disagree about the meanings of such terms, they may be unable to resolve arguments which make reference to them, even if they agree about all of the facts and moral assumptions. For example, an engineer's action might be a conflict of interest according to one definition of the term, but not a conflict of interest by another definition of the same term.

It would be desirable to have precise definitions of disputed terms; but like most terms in ethics, their meanings are somewhat open ended. In many cases, it is sufficient to clarify our meaning by thinking of *paradigms,* or clear-cut examples, of what we have in mind. We might, for example, think of an uncontroversial case of a conflict of interest, such as an engineer's specifying bolts from a company he owns, even though the bolts are the most expensive and lowest quality on the market. From this example, we can draw out a definition of a conflict of interest: a situation involving a conflict between a professional obligation (e.g., specifying the best product at the best price) and a private interest (e.g., promoting the interests of a firm one owns).

In the case at the beginning of the chapter, the concept of "human dignity" is crucial. Similarly, the concept of "informed consent" is important in determining whether the cadavers were obtained with the proper kind of consent.

2.4 DETERMINING HOW CONCEPTS APPLY: APPLICATION ISSUES

When we say that the use of cadavers in crash testing violates "human dignity," we are saying that the concept of "respecting human dignity" cannot be correctly applied to the practice of using cadavers for crash testing. This is a claim about an *application issue*, that is, a claim about whether a given term or expression applies to an individual action, or a general practice. Since application issues have to do with whether a concept applies to or "fits" a situation, disagreements over application issues can occur when there is disagreement over (1) the meaning of the concept to be applied (conceptual issue), (2) the facts to which the concept is to be applied (factual issue), or (3) whether the concept applies in the situation (application issue). In this case, one conceptual issue is how we should define "human dignity." A factual issue is whether cadavers are necessary to obtain some types of information relevant to auto safety. An application issue is the question whether using cadavers for testing can be considered an example of respecting human dignity.

2.5 LINE DRAWING

So far we have been looking at three analytical techniques for sorting out moral controversies into categories. Now we are ready to look at a way of resolving moral issues.

Keep in mind that sometimes a moral judgment is justified as soon as an application issue has been decided, especially when the application issue involves a concept that we can call "morally laden." When we have established that an action is a "lie," or is "murder," or "bribery," we have, under ordinary circumstances, already decided that an action is wrong, because lying, committing murder, or bribery are ordinarily wrong. In other words, to resolve the application issue is to justify a moral judgment about the action. However, sometimes lying, murder (or at least killing), or bribery might have to be balanced against other important moral considerations. Then, we have a true moral issue in the sense defined in Box 2.1

Consider the following example. Victor is an engineer in a large construction firm. Although he will not make the final decision, he has been assigned the task of recommending which welded steel studs should be used for the construction of a large apartment building. After some research and testing, he decides to recommend ACME steel studs for the job. On the day after Victor's recommendation was made, an ACME representative visits him and gives him a voucher for an all-expense paid trip to the annual ACME Technical Forum, which meets in Jamaica. The trip will have considerable educational value, but will also include day trips to the beach and other points of interest.

BOX 2.1 Components of a Moral Problem

- **Factual Issues.** Questions of fact relevant to the resolution of a moral problem.
- **Conceptual Issues.** Questions about the meanings of terms relevant to the resolution of a moral problem.
- **Application Issues.** Questions about whether and how a term applies in a situation.
- **Moral Issues.** Questions about how conflicting moral considerations relevant to the resolution of a moral problem should be weighed or balanced.

BOX 2.2 Paradigm Case of Bribery

Gift size	Large ($10,000)
Timing	Before decision to buy
Reason	Personal gain
Responsibility	Sole
Product quality	Lowest in the market
Product cost	Highest in the market

If Victor accepts, has he been bribed? In answering this question—an application issue—it is useful to begin by coming up with a clear-cut, unproblematic case of a bribe. We have referred to such cases as *paradigm cases*. Here is a paradigm case of a bribe. Suppose a vendor offers an engineer $10,000 to get the engineer to recommend the vendor's product to the engineer's company. Since all of the facts we need are not supplied in the narrative, we must make some assumptions. Filling in some facts not given in the narrative with reasonable assumptions, we can say that several aspects of the situation—we shall call them *features*—are relevant in making this situation a paradigmatic bribe. The gift is substantial; it is offered before the engineer's decision on which product to recommend; the engineer accepts the offer for reasons of personal gain; the engineer has sole responsibility for the decision as to which studs to specify; the vendor's product is the most expensive on the market; and it is of questionable quality. This is, without question, a bribe. Box 2.2 shows a useful graphic way of representing a paradigm case of a bribe.

We can also construct a paradigm at the other extreme, one which depicts a situation that is clearly *not* a bribe. In most cases, this can be done by simply negating the characteristics of the paradigm bribe. Thus, a paradigmatic nonbribe would be a situation in which the gift is very small (perhaps a pen worth two dollars); it is offered after the engineer's decision on which product to recommend has been made; the engineer does not personally gain from the decision; the engineer does not make the final decision on whether to buy the steel studs; and the vendor's product is the highest quality and lowest price on the market.

Now we can return to Victor's situation. We can call his situation a *test case*, because it is a case in which the question whether Victor's action is a bribe is controversial and must be tested by comparing it with paradigm bribes and nonbribes. In the case of each feature, we can place an "X" on the continuum between the two paradigms to indicate whether a given feature of the test case is closer to the paradigm bribe or the paradigm nonbribe. It is also useful to put circles around a few of the "Xs" to indicate features you think have special importance in evaluating this test case. Box 2.3 provides a useful graphic representation of these issues.

As Box 2.3 suggests, the test case is by no means a paradigm bribe and probably should not be considered a bribe. Nevertheless, it comes close enough to a paradigm bribe with regard to several features—especially gift size—to raise some concern.

BOX 2.3 Line-Drawing Analysis of Whether Accepting the Vendor's Offer is a Case of Bribery

	Paradigm Bride	*Test Case*	*Paradigm Non-Bribe*
Gift Size	Large	__(x)__________	Small
Timing	Before	__________(x)__	After
Reason	Personal	_______x_______	Professional

So far, line-drawing has been applied to an application issue, namely whether Victor's accepting the vendor's offer should be considered accepting a bribe. Since we have concluded that Victor's action is not a bribe, the analysis so far does not give Victor a definitive answer to the question whether he should accept the vendor's offer. This is because, even if accepting the offer is not accepting a bribe, other reasons for not accepting the offer might be relevant.

A second line-drawing exercise might help decide whether Victor should accept the offer, all things considered. The opposing paradigms would be a situation in which accepting the offer would not be morally justifiable and a situation in which accepting the offer would be morally justifiable. The features might include whether accepting the offer confirms to industry-wide practice, whether accepting the vendor's offer would conform to company policy, whether really useful information will be offered at the Technical Forum, whether it will be generally known that the offer of the trip was made after the decision to purchase the vendor's product, and whether accepting the vendor's offer might influence Victor or others to make unethical decisions in the future. Just as we had to make some assumptions in the first decision, assumptions will have to be made here. Given the absence of sufficient facts, performing this analysis will involve many assumptions. We leave it to the reader to perform this analysis and come to a conclusion, based on the assumptions made.

2.6 CONFLICTING VALUES: CREATIVE-MIDDLE-WAY SOLUTIONS

Here is a case involving conflicting values, making it a moral issue as defined in Box 2.1.

Brad is in the second year of his first full-time job after graduating from Engineering Tech.[2] He enjoys design, but is becoming increasingly concerned that his work is not being adequately checked by more experienced engineers. He has been assigned to assist in the design of a number of projects that involve issues of public safety, such as schools and overhead walkways between buildings. He has already spoken to his supervisor, whose engineering competence he respects, and he has been told that more experienced engineers check his work. Later, he discovers to his dismay that his work is often not adequately checked. Instead, his drawings are stamped and passed on to the contractor. Sometimes the smaller projects he designs are under construction within a few weeks after his designs are completed.

At this point, Brad calls one of his former professors at Engineering Tech for advice. "I'm really worried that I'm going to make a mistake that will kill someone," Brad says. "I try to overdesign, but the projects I'm being assigned to are becoming increasingly difficult. What should I do?" Brad's professor tells him that he cannot ethically continue on his present course because he is engaging in engineering work that surpasses his qualifications and may endanger the public. What should Brad do?

Brad's case illustrates one of the most common conflicts faced by engineers, one in which his obligation to his employer seems to conflict with his obligation to the public. Both of these obligations are clearly mandated by the codes. The NSPE code requires engineers to "hold paramount the safety, health, and welfare of the public" (Canon 1) and also to "act in professional matters for each employer or client as faithful agents or trustees" (Canon 4). Brad also has a legitimate interest in preserving and promoting his own career and protecting the interests of his family, if he has one.

Because of the multiple conflicting values, Brad should attempt to find what we call a "creative middle way" that would satisfy as many of these conflicting obligations as possible. In carrying out the search for a creative-middle-way solution, it is helpful to arrange courses of action in serial order, beginning with the one that would most satisfactorily honor all three of the obligations, and continuing to options that would not honor all of the obligations. Here are some possible courses of action:

1. Brad could go to his supervisor again and suggest in the most tactful way possible that he is uncomfortable about the fact that his designs are not being properly checked, pointing out that it is not in the firm's interests to produce designs that may be flawed. If the supervisor agrees to provide more adequate supervision, Brad could resolve the problem and keep on the best of terms with his employer. Brad could thus honor his obligation to the safety of the public, to his employer, and to himself and his career. This would be an ideal creative-middle-way solution.
2. Brad might talk to others in the organization with whom he has a good working relationship and ask them to help him persuade his supervisor that he (Brad) should be given more supervision. This solution is almost as good, because it would resolve the problem, but it might tarnish the supervisor's reputation with his other employees and perhaps with the public. While satisfying Brad's obligation to the public, it might not as satisfactorily honor the obligation to his employer and himself.
3. Brad could find another job and then, after his own employment is secure, reveal the information to the state registration board for engineers or to others who could stop the practice. While protecting his own career and the public, this option does not promote his employer's interests.
4. Brad might tell his supervisor that he does not believe he can continue to engage in design work that is beyond his abilities and experience and that he might have to consider changing jobs. This solution involves a confrontation with his employer. This solution might not cause the employer to change his bad practices and might harm Brad's career. It might also harm the reputation of the supervisor with his other employees.
5. Brad could go to the press or his professional society and blow the whistle immediately. This would protect the public, but possibly damage his career prospects and certainly severely damage the supervisor's business.

You can think of other possibilities as well, such as continuing in his job without protest or finding another job without protest. If the first obligation is to protect the public—as the codes enjoin—these options would be unsatisfactory. Perhaps only the first two options could be considered really satisfactory creative-middle-way solutions, because they satisfy the most important demands, and the first option is the more desirable of the two.

As this example illustrates, finding a creative-middle-way solution is often the best way to resolve a moral problem with important, but conflicting, moral considerations. It also illustrates the need for creativity, because it may take some creative work to think of good solutions.

2.7 COMMON MORALITY

We have seen that the work of the practical ethicist is analogous to the work of a carpenter who uses whatever tools are appropriate to the task at hand. A hammer is sometimes appropriate, but at other times, the carpenter needs a saw or a screwdriver. Like a skilled carpenter, the practical ethicist must have a command of all of the available tools and use whatever is appropriate for the situation. The methods of line drawing or finding a creative middle way may be sufficient, but sometimes something more is needed. In order to resolve some moral issues—especially those involving larger social policies—we must look more deeply into the moral ideas that lie at the basis of our moral judgments.

The most obvious place to look is the stock of common moral beliefs which most people in our culture, and perhaps people generally, accept. We call this set of beliefs *common morality*. Several summary accounts of the basic precepts of common morality exist; as you might expect, they are similar.

The first account is by philosopher W. D. Ross, who constructed a list of basic duties or obligations, which he called "prima facie" ("at first sight," or "before closer inspection") duties. In using these terms, Ross intended to convey the idea that although any given duty is usually obligatory, it can be overridden by another duty in special circumstances. He disclaimed finality for his list, but he believed it was reasonably complete. His list of prima facie duties can be summarized in Box 2.4.

Engineers, like others, probably share these moral beliefs, and many of them are reflected in engineering codes of ethics. Most codes enjoin engineers to be faithful agents of their employees, and this injunction is reflected in the duties of fidelity (R1) and gratitude (R2). Most codes require engineers to act in ways that protect the health, safety, and welfare of the public, and this obligation is reflected in the duties of justice (R3) and beneficence (R4), and especially in the duty not to injure others (R6). Finally, most codes encourage engineers to improve their professional skills, a duty reflected in R5.

BOX 2.4 Ross's Prima Facie Duties

- R1. Duties resting on previous acts: (a) Duties of fidelity (to keep promises and not to tell lies), (b) Duties of reparation for wrong done
- R2. Duties of gratitude (e.g., to parents and benefactors)
- R3. Duties of justice (e.g., to support happiness in proportion to merit)
- R4. Duties of beneficence (to improve the condition of others)
- R5. Duties of self-improvement
- R6. Duties not to injure others[3]

Another attempt to formulate many of the basic elements of common morality is the list of 10 "moral rules" formulated by philosopher Bernard Gert. His list is shown in Box 2.5.

BOX 2.5 Bernard Gert's 10 Moral Rules

- G1. Don't kill.
- G2. Don't cause pain.
- G3. Don't disable.
- G4. Don't deprive of freedom.
- G5. Don't deprive of pleasure.
- G6. Don't deceive.
- G7. Keep your promise (or don't break your promise).
- G8. Don't cheat.
- G9. Obey the law (or don't disobey the law).
- G10. Do your duty (or don't fail to do your duty).[4]

Ross's prima facie duties and Gert's moral rules overlap each other considerably. Moral rules G1–G9, for example might be seen as specifications of Ross's duty not to injure others. The wrongness of lying and promise breaking appear on both lists. R2–R5 seem to be of a more positive nature than Gert's moral rules, which focus on not causing harm. However, Gert also provides a list of 10 "moral ideals," which focus on preventing harm. In fact, the moral ideals can be formulated by introducing the word "prevent" and changing the wording of the rules slightly. Thus, the moral ideal corresponding to "Don't kill" is "Prevent killing." For Gert, the moral rules specify moral requirements, whereas the moral ideals are aspirational. Nevertheless, there is a difference of emphasis. While Gert believes that the primary requirements of common morality are negative and prohibitive, Ross gives preeminence to positive duties.

Everyone recognizes that moral precepts and rules have exceptions. We have already seen that Ross calls his duties "prima facie," but he does not explain how we go about deciding when an exception is justified. There are two ways.

First, when moral duties or rules conflict, we must decide which precept is more binding in a given situation.[5] Usually, it is wrong to lie, but if the only way to save an innocent person from being murdered is to lie to the assailant about that person's whereabouts, then most would agree that lying is justified. How is this exception justified? According to Gert, if we are willing for this exception to be widely practiced—if we are willing for others also to lie in similar circumstances—then the exception is justified.

This exception is based on a widely held moral idea that we shall encounter later: *we must be willing for others to do what we do in similar situations.* This principle, called the *Universalization Principle*, while an idea of great importance in common morality, is not always easy to apply. People can disagree as to when a situation is really "similar" and when one should be willing to universalize. Nevertheless, the principle is an important one in ethics.

Second, exceptions can be made to moral duties or rules when our conscience intervenes. Suppose a young man is called into military service, but sincerely believes that killing others is wrong, even to defend one's country. He might understand the obligation not to kill in war to follow from a duty not to injure others. In this situation, many nations, including the United States, allow an exception to the presumed duty to defend one's country, based on "conscientious objection." The moral justification is that if this young man is forced to defend his country by killing, he is being forced to do what he deeply and sincerely believes to be wrong; and, according to

BOX 2.6 Types of Moral Judgments

1. **Permissible.** One is morally permitted, but not morally required, to perform an action. An engineer might decide to take a job with Company X rather than Company Y, but both actions are permissible. It would also be permissible to take neither job.
2. **Impermissible.** An action that one is morally required not to do. An engineer must not be a part of an undisclosed conflict of interest.
3. **Obligatory.** An action one is morally required to do. An engineer must disclose an actual or a potential conflict of interest.
4. **Supererogatory.** An action that is praiseworthy if one does it, but not morally required. An engineer designs a parking lot for a nonprofit organization without charging a fee. Sometimes we call these actions ones that go "above and beyond the call of duty."

common morality as ordinarily understood, one should never do what he or she deeply and sincerely believes to be wrong.

Such exceptions must be handled carefully and sometimes cannot be allowed. We may believe that the young man is mistaken, and that an implicit obligation as a citizen to defend one's country follows from the general duty to keep promises. And we certainly cannot allow a person to follow up on a presumed obligation to kill those who disagree with him on political or religious grounds, even if such a belief is deeply and sincerely held. Nevertheless, a certain freedom to make exceptions to duties or moral rules on the basis of conscience is a part of common morality.

2.8 ADDITIONAL ELEMENTS OF COMMON MORALITY

Several other elements are a part of common morality as generally understood and are useful in practical moral analysis.

First, moral judgments can be of several types, which are enumerated in Box 2.6. We can say that, from the standpoint of common morality, there are four types of moral judgments. See Box 2.6.

Second, moral statements can usefully be divided into three levels of generality described in Box 2.7.

BOX 2.7 Three Levels of Moral Judgments

1. **Particular Actions.** Judgments about the moral acceptability or unacceptability of an action. "Engineer Mike should not have specified bolts made by a firm in which he has a vested interest."
2. **General Practices or Classes of Actions.** Judgments about the moral acceptability or unacceptability of more general types of action. "Engineers should never engage in undisclosed conflicts of interest." The duties of Ross and the rules of Gert fall into this category.
3. **Very General Moral Principles or Criteria.** Statements that provide criteria for determining whether any action or class of actions is right or wrong. "Actions are right insofar as they promote utility or human well-being."

Third, determining the *intent* behind an action is of great importance in common morality. In the law, which follows common morality here, whether you kill someone deliberately, as in first-degree murder, or accidently, as in an unavoidable traffic accident, is crucial in determining moral blame. Similarly, whether engineers do something intentionally (as was apparently the case in the attempts of Volkswagen officials to deceive governmental regulators) or unintentionally (even if negligently) is of central moral and legal importance.

2.9 IS THERE A PLACE FOR MORAL THEORIES?

We have now reviewed several methods in practical ethics: line-drawing, creative middle ways, and an appeal to duties or rules, along with the Universalization Principle. Are there any other useful methods? Philosopher Michael Davis suggests eight questions or "tests" that rely on our commonsense morality, but also reflect some of the concepts in moral theories or approaches that we discuss later. (See his tests in Box 2.8.) Thus, they offer an appropriate transition to the moral theories, or what we shall often call "approaches," to moral thinking, because the latter term emphasizes their partial and incomplete nature.[6]

BOX 2.8 Davis' Eight Moral Tests

- **Harm Test.** Does this option do less harm than any available alternative?
- **Publicity Test.** Would I want my choice of this option published in the newspaper?
- **Defensibility Test.** Could I defend my choice of this option before a Congressional committee, a committee of my peers, or my parents?
- **Reversibility Test.** Would I still think my choice of this option is good if I were one of those adversely affected by it?
- **Virtue Test.** What kind of person would I become if I chose this option often?
- **Professional Test.** What would my profession's ethics committee say about this option?
- **Colleague Test.** What would my colleagues say when I describe my problem and suggest this option as my solution?
- **Organization Test.** What would the organization's ethics officer or legal counsel say about my option?

In some situations, these questions may be sufficient to guide us in resolving a moral issue, and when they are, they should be used. But other questions can arise. How should I go about deciding whether I would want my decision to be made public? On what grounds would I defend my decision before a Congressional committee? Would my colleagues or ethics officer be right in agreeing or disagreeing with my action?

Here are some further questions not related to Davis' tests. Think of the case at the beginning of this chapter. You notice that if you begin by thinking about respecting cadavers you seem to come to one conclusion and that if you think about the lives that might be saved by using the cadavers in crash tests, you come to another conclusion. Why are there such different approaches to moral decision making? Is one superior to the other? Consider some other questions, for example, why should we keep promises, or refrain from injuring others, or refrain from deceiving others?

2.10 MORAL THEORIES: APPROACHES AS MODELS

In the remainder of this chapter, we look at three theories or approaches that shed light on these and other questions. Before doing this, we shall make a case for what we believe are useful analogies between ethical theories or approaches and models in engineering and computer science. Let's begin by considering the following two examples:

Example 1. A Materials Model. Modeling is a technique familiar to engineers. For example, we often model the behavior of a material as "linearly elastic," meaning the stress is linearly proportional to the strain, $\sigma = E\varepsilon$. Sometimes this theory about the behavior of a material is simply not accurate, however. Sometimes we must model the material as nonlinear or perhaps with time-, temperature-, or rate-dependent properties. That doesn't mean that the linear elastic material model is "wrong," but only that it is not applicable or sufficiently accurate for the particular material in the particular situation under consideration. As part of their professional training and experience, engineers come to understand this kind of problem. They learn how to recognize this deficiency and to understand that a different model might be more appropriate.

Example 2. An Online Bookstore. Suppose computer experts are designing computer programs to operate an online bookstore. They quickly discover that several programs are needed: one to model the elements used and the relationships between them (books, authors, invoices and payment options, etc.), one to model the sequence of steps in the ordering process (designation of a book, placing an order, processing order, etc.), and one to model the costs involved in operating the online bookstore (costs for each step, various options, etc.). They also notice that the models can lead to incompatible conclusions. For example, one sequence of steps in the ordering process may be the most user-friendly, but too expensive. In the event of such conflicts, a process of *reconciliation* must be used to produce a final design.

Notice several analogies between these examples and the way moral theories are employed in practical or applied ethics.

First, just as the equation for stress reveals a principle widely applicable in science and engineering, so ethical theories reveal widespread patterns of moral thinking. Recalling the cadaver example, both the value of promoting the public good (a utilitarian approach) and the value of protecting the dignity of cadavers (an RP approach) are important and widely accepted ways of moral thinking.

Second, just as the stress equation may not be adequate in some situations, sometimes a generally valid moral principle is simply not relevant in a particular moral analysis. We shall see, for example, that sometimes the utilitarian approach may be more relevant to a moral analysis, and sometimes virtue ethics or RP approaches may be more relevant. This is not because the other approaches are wrong, but only that they are not as relevant to the situation at hand as another approach. They do not capture moral considerations that are helpful in a given analysis.

Third, just as several approaches are useful in the online bookstore example, sometimes several ethical models are necessary to adequately analyze and resolve a moral dilemma. In the cadaver example, both the utilitarian and RP approaches are necessary in order to understand the moral considerations underlying the controversy.

Fourth, just as in the online bookstore example, the programs for the ordering process and economic analysis may suggest different conclusions, so different ethical analyses may suggest different conclusions. (Remember the cadaver example at the beginning of the chapter.) More generally, well-being, respecting individual dignity, and the ethical ideas in virtue ethics may not produce the same conclusions.

Fifth, just as the differing conclusions in the bookstore example require reconciliation, so differing conclusions suggested by the different ethical approaches may require reconciliation. As you might expect, sometimes the differing lines of reasoning from the various approaches converge on the same conclusion, and then they reinforce each other. When the conclusions diverge, a process of reconciliation must take place, where we determine which moral considerations are more important. There is no set formula for reconciliation; instead, the insight and judgment of the person facing the moral problem are crucially important.

With these considerations in mind, we turn to the three ethical approaches, which we shall interpret as models of common morality. Each of the theories attempts to organize the elements of common morality around an overriding theme or principle. As with most models, each of the models will suffer from incompleteness, but each provides valuable insight into fundamental moral ideas and into the basis of many moral controversies.

2.11 THE UTILITARIAN APPROACH

The fundamental principle of the utilitarian model of common morality is "We should maximize overall well-being." We refer to the population over which well-being is maximized as the *audience*. In order to implement the utilitarian approach, we must determine the scope of this audience. Ideally, perhaps the audience should include all humans, or at least all humans who might be affected by the action to be evaluated. Some utilitarians think even those animals clearly able to experience pain or pleasure should be included in the audience, if they would also be affected. But then it becomes enormously difficult to calculate which actions produce the most good for so large an audience. If we limit the audience so that it includes only our country, company, or community, then we face the criticism that others have been arbitrarily excluded. Therefore, in practice, those with utilitarian sympathies need to develop acceptable ways of limiting the audience.

Once we determine the audience, we must know which course of action will produce the most good in both the short and the long term. Unfortunately, this knowledge is sometimes not available at the time decisions must be made. We do not have enough factual knowledge, for example, to know for sure whether permitting or prohibiting advertising and competitive pricing for professional services in engineering will maximize the well-being of the public. The well-being of the public in this context is interpreted broadly as having the best professional services at the best price. Sometimes all we can do is try a certain course of action and see what happens. Unfortunately, this may be risky in some situations.

Another issue is that the utilitarian approach sometimes favors the greater aggregate good at the expense of a minority. From a utilitarian standpoint, it might be justifiable to allow the emission of pollutants from a plant that will severely harm a few, if the benefits from the plant (good jobs, etc.) outweigh the harms to the few. Thus, utilitarianism can lead to unjust distributions, suggesting that it has not adequately captured all of the elements of common morality. As in applying any model, one must be aware of the characteristic weaknesses of the model. Despite this weakness, utilitarian thinking is often enormously useful. Now we can look at three tests suggested by the utilitarian approach.

The Cost-Benefit Test

If a utilitarian approach requires that we maximize well-being, how should we go about determining the criteria we should use in seeking this maximization? One approach that

BOX 2.9 Applying the Cost-Benefit Test

1. Identify the available options that can provide a solution to the problem under consideration.
2. Assess the costs (measured in monetary terms) and the benefits (also measured in monetary terms) of each option. The costs and benefits must be assessed for the entire audience of the action, or all who are affected by the decision.
3. Make the decision that is likely to result in the greatest benefit relative to cost; that is, the course of action chosen must not be one for which the funds spent on implementing the action could be spent on another action that would better resolve the problem under consideration.

has appeal from the engineering perspective is *cost-benefit analysis* (CBA), which holds that the *course of action that produces the greatest benefit or utility relative to cost should be chosen*. In using this method, one must convert negative and positive utilities into monetary terms. A close relative of CBA is *risk-benefit analysis* (RBA), which attempts to balance the risk of benefit against the risk of harm. Because it is often more difficult to determine risks than costs, we shall consider only CBA, which involves three steps, detailed in Box 2.9.

As we should expect, there are serious problems with using CBA as a sole guide for moral thinking. One problem is that the cost-benefit approach assumes that economic measures of cost and benefit override all other considerations. Suppose a wilderness area is damaged by a plant's emissions. From the CBA standpoint, it might not be justifiable to eliminate the pollutant, but economic considerations alone may not be an adequate measure of the value of the wilderness.

In fact, CBA might seem to justify many practices in the past that we now believe were morally wrong. In the nineteenth century, many people opposed child labor laws, arguing that they would lead to economic inefficiencies. They pointed out, for example, that tunnels and shafts in coal mines were too small to accommodate adults and that using children was more economically efficient. Again, many arguments in favor of slavery were based on considerations of economic efficiency. When our society finally decided to eliminate child labor and slavery, it was not simply because they became economically inefficient, but because they came to be considered unjust, an objection that can be made more straightforwardly from an RP approach than from a utilitarian perspective.

Another problem with CBA is how to ascertain the cost of the loss of human life or even serious injury. Estimates are often made on the basis of such factors as how much a person is willing to pay for a safer vehicle or how much more a person would have made if they lived a normal lifespan, but both of these measures are dependent on how wealthy a person is and are considered unjust by many. Aside from the difficulty of determining the costs and benefits of known factors (such as immediate death or injury), it is also difficult to predict what factors will be relevant in the future. If the threat to human health posed by a substance is not known, then it is impossible to execute a definitive CBA. This problem becomes especially acute if we consider long-term costs and benefits, most of which are impossible to predict or measure.

In a slightly different way of stating the problem of injustice described earlier, we can say that CBA fails to take into account the distribution of costs and benefits. Suppose a plant dumps a pollutant into a river in which many poorer members of the community fish to supplement their diets. Suppose also that after all of the known costs and benefits are calculated, it is concluded that the costs of eliminating the pollutant outweigh all of the health costs to the poor. Still, if the costs are paid by the poor and the benefits are enjoyed by the rich, then the costs and benefits are not equally shared. Even if the poor are compensated for the damage to their health, many would say that an injustice has still been done. After all, the wealthy members of the community do not have to suffer the same threats to their health.

After recognizing its limitations, we can still see that CBA can make an important contribution to moral problem solving. We cannot imagine constructing a large engineering project, such as a hydroelectric dam, without performing an elaborate CBA. Its ability to evaluate many conflicting considerations in terms of a single measure—monetary value—makes it enormously useful in certain circumstances. As with all other tools for moral analysis, however, we must keep its limitations in mind.

The Test of Maximizing Good Consequences

Some utilitarian approaches do not require that values be measured in strictly quantitative terms. However, they do require that we try to determine what will, in some sense, maximize good consequences. Here, we can try to proceed on the assumption that *an action is right if it results in more utility than any alternative action that is available in this situation*. In other words, the question is, "Will this particular course of action result in more good than any alternative course of action that is available in this situation?" To answer this question, the procedure in Box 2.10 is useful.

Although the Universalization Principle requires that if two situations are similar, we must resolve them in a similar way, focusing on the consequences in particular situations is still often appropriate. For example, assuming the costs are roughly equal, a utilitarian would make the choice between two safety devices in an automotive design by determining which device is more likely to reduce the most injuries and fatalities. To take another example, the choice between two plans for road improvements would be decided on the basis of such considerations as which plan would save the most lives and which plan is most economically feasible. Or again, unless one believes that hydroelectric plants should not be built at all, because of environmental or other considerations, an engineer would ordinarily focus on the pros and cons of how and where a particular site should be built. In these cases, the focus is on a single case, not all similar cases.

By contrast, in some situations, the questions about the utilitarian pros and cons of a general practice are more relevant, *especially if there already exists a general practice governing the situation*. Here, the utilitarian considerations should focus on the general practice: whether it should be followed, whether it should be modified, whether it should be violated in this particular situation, or whether the practice should be abolished altogether. The Universalization Principle, that is, comes into much greater prominence. We now consider this version of the utilitarian approach.

BOX 2.10 Applying the Test of Maximizing Good Consequences

1. Identify the available options in this situation.
2. Determine the appropriate audience for the options, keeping in mind the problems in determining the audience.
3. Decide which available option is likely to bring about the greatest good for the appropriate audience, taking into account the harms as well as benefits.

The Rules and Practices Test

Consider the following case. James works for Precision Parts, which supplies high-quality components for large machines. Precision Parts has a substantial in-house manufacturing operation, but also contracts with other manufacturers to make some of the components it supplies to customers. James has called for bids from some of the firm's trusted manufacturers for Part X. After the bids have been submitted, Wendell, head of the in-house manufacturing operation, comes into James' office and says, "I know the bids are supposed to be secret, but why don't you tell me what the lowest bid was and I will try to come in under that bid. We are all in this together, and it would help Precision Parts to be able to make Part X in-house."

Looking at Wendell's request, James decides that it makes a lot of sense. The outside manufacturer that made the lowest bid is large and will not be hurt by the loss of this contract. Precision Parts is not able to keep its own employees busy because of decreased business, and its profits are down. It seems like everyone will be better off if James honors Wendell's request.

But then James broadens his perspective. He realizes that he is trying to justify helping his company violate a rule (respecting confidentiality) that is understood to apply to *all* involved in the bidding process, including his company. He realizes that the Universalization Principle requires him to ask some more general questions. What if Precision Parts made the violation of confidentiality their general practice? What would other companies do if they discovered that this is how Precision Parts operates? What if other companies make themselves exceptions to the practice in this way, too?

Now he may reflect, "Precision Parts is just one player in the practice of bidding; and I cannot convincingly argue that it is so special that it need not abide by the confidentiality rule even though others should." So, James asks a different question: "Suppose Precision Parts and other firms supported the practice, 'Whenever it is in a firm's interest, it may break the confidentiality of bids.' Would this practice, if generally adopted, benefit Precision Parts, or other firms, or the public?"

Now James is looking at things from a very different perspective. Instead of trying to determine the consequences of one action—his firm's secretly violating the confidentiality of bids in this one case—he is thinking about the consequences of the adoption of the practice of violating confidentiality by other firms as well. If this happened, it would be common knowledge that the confidentiality of bids would not be honored, and the integrity of the whole bidding process might unravel. Firms might even be reluctant to submit bids to firms with in-house manufacturing facilities, like Precision Parts, knowing that their bids probably would not be successful.

This fictional case illustrates an important point. It is one thing to ask about the utility of the consequences of a single action, and another thing entirely to ask about the utility of the consequences of a general practice, as this practice is enshrined in a rule or set of rules.[7] In the case under discussion, while breaking the confidentiality of bids in this situation might seem like a good idea, the general practice of doing so is a very bad idea indeed.

Determining the consequences of a general practice may be more difficult than determining the consequences of a single act, because the number of people affected by a general practice—the audience—is usually much larger. However, as the bidding case illustrates, this is not always so. Sometimes the consequences of a general practice are so obvious that little imagination is needed to know what the consequences of the policy would be. Think of traffic rules designed to enhance cooperative, safe driving. It is late at night and there seems to be no one around, and the light is red. You might think it is obvious that no one would be harmed and it would be more convenient to you to violate the law and go through the red light.

Then you think of the general practice involved. Clearly, general disobedience of traffic lights, stop signs, yield signs, and other conventions of the road would be disastrous for everyone, including you. So it seems reasonable to conclude that, in general, it is better for all of us that we guide our driving by conforming to these rules and conventions rather than trying in each circumstance to determine whether, for example, it is safe to go through a red light. That is, it is better to develop good driving habits that others can count on our having rather than trying to decide what to do in a less predictable manner, instance by instance.

Of course, rules and practices can, and sometimes should, change. At one time, there were no yield signs. Then some stop signs were replaced by yield signs, and yield signs were sometimes introduced where no traffic signs were present at all. Now many stoplight intersections are being replaced by roundabouts. Presumably, these changes were introduced to improve traffic safety and efficiency, desirable goals from a utilitarian perspective. But, it should be noted, these are examples of rule and practice replacements, not simply the elimination of rules and practices.

From a utilitarian perspective, in situations covered by well-understood, generally observed rules or practices that serve utilitarian ends, a case can be made for justifying your actions by appealing directly to these rules and practices. These generally observed rules and practices, in turn, are justified by their utility. In the vast majority of cases, you should probably just abide by the general rules and not even consider whether their violation in a particular case should be justified.

There are complications, however. If there are widespread departures from rules or practices, then it is less clear whether overall utility is still being promoted by continuing to conform to the rules or practices when others do not. To preserve the beauty of a grassy campus quad, a “Please Use Sidewalks” sign might be posted. As long as most comply with this request, the grassy area may retain its beauty. But if too many cut across the grass, a worn path will begin to form. Eventually, the point of complying with the sign may seem lost from a utilitarian standpoint—the valued end has been lost.

Another problem is that determining the precise nature of the rule to be followed is sometimes difficult and controversial. Suppose James, in considering whether to violate the confidentiality of bids, considers this rule: “An employee should always and without any exceptions act so as to maximize the firm’s profits.” This rule is too broad and would lead to disaster if implemented. Another rule might be, “If your name is James and you work for Precision Parts, you should violate the confidentiality of the bidding process in Situation X (the situation James faces in the case described above).” This rule is too specific and exhibits arbitrary pleading. What, we may ask, is so special about having the name James and working for Precision Parts? What about having the name Robert and working for Safety Parts? In short, limiting a moral rule about confidentiality to just James and Precision Parts will not work. Nevertheless, some “exceptions to the rule” do seem to be quite legitimate. If you are approaching a stop sign in an otherwise remote area when a large, out-of-control truck is right behind you, then you had better get out of the way.

Thinking about the utility of rules can be enormously useful in considering some decisions, especially decisions about legal and social policy issues having broad

BOX 2.11 Applying the Rules and Practices Test

1. Identify the established practice, if any, that applies to the appropriate audience in this situation. If the practice promotes utility better than any alternative practice, it should be followed.
2. If there is no applicable practice, select the one whose support in this situation is likely to have the best long-run consequences, all things considered.
3. Follow the justified practice in this situation, unless you think this might be a situation in which exception can justifiably be made on utilitarian grounds.

social consequences. Consider the question whether professions should be allowed to advertise. On the one hand, some believe that advertising provides information to the public that it would not otherwise have and promotes competition which keeps down prices for professional services. On the other hand, some believe that professional advertising can mislead the public and give an advantage to professionals and professional firms who are good at advertising, but not necessarily the most professionally competent. All of these arguments are utilitarian because they pose the question, "Which general practice followed by all professionals promotes the well-being of the public, all things considered?"

See Box 2.11 for useful steps to follow when engaging in utilitarian thinking about rules and practices.

Applying the utilitarian procedures described in this section requires addressing many questions, some of which may prove to be quite complex and may not yield answers about which we can be certain. Nevertheless, following these procedures can often be very useful in practical ethics, especially given the ease with which someone like James can otherwise overlook, or even deliberately ignore, factors that should be taken into account.

2.12 THE RESPECT FOR PERSONS APPROACH

The fundamental principle of the RP model of common morality is "Act so that you respect all humans as free and equal moral agents." This equal regard for moral agents can be understood as a basic requirement of justice. A moral agent must be distinguished from knives or airplanes, which can only fulfill goals or purposes that are imposed upon them from the outside. Inanimate objects cannot evaluate actions from a moral standpoint. A paradigm example of a moral agent is a normal adult human being who, in contrast to inanimate objects, can formulate goals or purposes of his or her own. Such a being is said to have *autonomy*.

From the RP standpoint, maximizing the welfare of the majority, as utilitarianism suggests, must take second place to the goal of respecting the moral agency of all individuals. People may not be killed, deceived, denied their freedom, or otherwise violated simply to bring about a greater total amount of utility. As with our treatment of utilitarian thinking, we consider three approaches to RP thinking.

The Golden Rule Test

RP theory places great importance on the Universalization Principle, and it may offer the most plausible explanation of why it is so important. Most of us would acknowledge that if we think we are acting in a morally acceptable fashion, we should allow others to do similar kinds of things in similar circumstances. This same insight can lead us to ask questions about fairness and equal treatment, such as "What if everyone did that?" and "Why should you make an exception to yourself?" The most obvious reason for this universalizability test is that we are all equally moral agents.

Reversibility is a special application of the Universalization Principle, because the idea of universalization implies that a judgment should not change simply because the roles are reversed. In thinking about treating others as I would have them treat me, I need to ask what I would think if I were in their position. If I am tempted to tell a lie in order to escape a particular difficulty, then I need to ask what I would think if the lie were told to me. Universalizing our thinking by applying the idea of reversibility can help us realize that we may be endorsing treating others in ways that we would object to if done to us. This is the basic idea behind the Golden Rule, variations of which appear in the religious and ethical writings of most cultures. Its most familiar formulation in our culture is "Do unto others as you would have them do unto you."

Suppose a manager orders a young engineer to remain silent about the discovery of an emission from the plant that might cause minor health problems for people who live near the plant. For this order to satisfy the Golden Rule, the manager must be willing to have her supervisor give a similar order to her if she were a young engineer. The manager must also be willing to place herself in the position of the people who live near the plant and would experience the health problems if the emission were not eliminated.

This example reveals a significant problem in using the Golden Rule to resolve a moral problem. Suppose the manager attempts to imaginatively put herself in the position of the young engineer. We can call the engineer the *recipient* of the action. Perhaps, the manager believes that a person should obey her superiors without question, especially if the superior is—as she is—a professional with many years of experience. Or she may believe that people are overly sensitive to minor health threats, especially when protecting people from them is very expensive, is detrimental to the economy, and may cost jobs. If she puts herself in the position of the recipient with these values and beliefs, she may conclude that her order is completely legitimate. On the other hand, the manager may think that people have a right to question their superiors, that industries are too prone to impose health risks on others when it is to their benefit, and that these risks are often imposed on the most economically vulnerable elements of the population, because they tend to live nearer to industrial facilities. In this case, the manager may conclude that her order is not justifiable by the Golden Rule. The results of using the Golden Rule as a test of morally permissible action may vary, then, depending on the values and beliefs of the actor.

One can try to avoid these problems by interpreting the Golden Rule as requiring not only that the actor place herself in the position of the recipient of the action, but also that the actor adopt the values of the recipient, and assume her particular circumstances. If the recipient is, in fact, troubled by the order and has the second set of values discussed above, the manager must not order the young engineer to remain silent.

Unfortunately, this tactic does not resolve all of the problems. Suppose I am an engineer who supervises other engineers and I find that I must dismiss one of my supervisees because he is lazy and unproductive. The engineer whom I want to dismiss, however, believes that "the world owes me a living" and does not want to be punished for his irresponsibility. Dismissing the supervisee fails this interpretation of the Golden Rule, even though most of us would probably believe that irresponsible employees should be dismissed, even if we are the irresponsible employee.

BOX 2.12 Applying the Golden Rule Test

1. Identify the action that is to be tested by applying the Golden Rule.
2. Ask whether you would be willing to have a similar action done when you are the recipient of the action, assuming that your values and those of others are similar.
3. If you are willing to be the recipient of your contemplated action, the action is morally permissible by the Golden Rule.

This is not the end of the problems in applying the Golden Rule. So far we have assumed that the class of recipients consists of only one person, the young engineer or the employee who does not want to be dismissed. But of course others are affected by the action. The decision whether to remain silent about a pollutant can affect those near the plant, and the decision whether to dismiss the irresponsible employee can affect many people, including other employees. If we enlarge the class of recipients to all those affected by the action, we have an almost impossible task on our hands. The recipients will almost certainly not all agree to the same decision, and then applying the Golden Rule yields no answer.

Although these problems need to be pointed out, they are often not as severe as we might suppose. In many situations, the effects of our action fall primarily on one person. Furthermore, when the effects fall on many people, we can often make reasonable assumptions about what others would want, and, in many situations where the wants and desires of people are probably similar everywhere (such as for health, safety, and equal treatment), we can have a fairly high degree of certainty about these assumptions. If we have reason to believe these assumptions cannot be made, we may have to use the insights of the Golden Rule in a more general way. What it really requires is that we consider matters from a more general perspective, one in which we strive to treat others in accordance with standards that we can share.[8] We must keep in mind that whatever standards are adopted, they must respect all affected parties. Viewing oneself as, potentially, both agent and recipient is required. This perspective mandates that we understand the perspectives of agents and recipients, and the Golden Rule serves the useful function of reminding us of this. See Box 2.12 for an account of how to apply it.

The Self-Defeating Test

The Golden Rule does not by itself provide all the criteria that must be met to satisfy the RP standard, but its requirements of universalizability and reversibility are vital steps in satisfying that standard. Now, we consider additional features of the Universalization Principle as they apply to the RP standard.

Still another way of applying the fundamental idea of the Universalization Principle is to ask whether I would be able to perform the action in question if everyone else performed the same action in the same or similar circumstances. If everyone else did what I am doing, would this undermine my ability to do the same thing?[9] If I must say "yes" to this question, then I cannot approve others doing the same kind of thing that I have done, and thus universalizing my action would be *self-defeating*. To proceed anyway, treating myself as an exception to the rule is to pursue my own good at the expense of others. Thus, it fails to treat them with appropriate respect. See Box 2.13.

A universalized action can be self-defeating in either of two ways. First, sometimes the action itself cannot be performed if it is universalized. Suppose John borrows money, promising to pay it back at a certain time but having no intention of doing so. For John's lying promise to work, the person to whom John makes the promise must believe that he will make good on his word. But if everyone borrowed money on the promise to return it and had no intention of keeping the promise, promises would not be taken seriously. No one would loan money on the basis of a promise. The very practice of promising would lose its point and cease to exist. Promising, as we understand it, would be impossible.

BOX 2.13 Applying the Self-Defeating Test

1. Identify the action you want to test by the Self-Defeating Test.
2. Ask whether the action would be self-defeating if everyone did it, either because (a) the action could not be performed if everyone did it, or (b) the purpose you have in performing the action would be undermined if everyone did it.
3. If the action fails either (a) or (b), it is impermissible. If not, it is permissible.

Consider an engineering example. Suppose engineer John decides to substitute an inferior and cheaper part in a product he is designing for one of his firm's large customers. He assumes that the customer will not check the product closely enough to detect the inferior part or will not have enough technical knowledge to know that the part is inferior. If everyone practiced this sort of deception and expected others to practice it as well, then customers would be far more inclined to have products carefully checked by experts before they were purchased. This would make it much less likely that John's deception would be successful.

It is important to realize that using the self-defeating test does not depend on whether anyone actually makes promises without intending to keep them, cheats on exams, or substitutes inferior and cheaper parts in a product. The question is, "What *if* everyone did this?" This is a hypothetical question—not a prediction that others actually will act this way as a result of what someone else does.

As with other approaches, the self-defeating test has limitations. Some unethical actions might avoid being self-defeating. Engineer Bill is by nature an aggressive person who genuinely loves a highly competitive, even brutal, business climate where everyone attempts to cheat and deceive as much as he can. He thinks of business as a game and values this aspect of business even more than making the highest possible profits. If everyone follows his example, then his ability to be ruthless in a ruthless business climate will not be undermined. His action is not self-defeating, even though most of us would consider his practice immoral.

Here is another example. Engineer Alex, who has no interest in preserving the environment, could design projects that are highly destructive to the environment without his action's being self-defeating. The fact that other engineers know what Alex is doing and even designed environmentally destructive projects themselves would not keep him from doing so or destroy the goal he had in designing such projects, namely to maximize his profit. However, as with the Golden Rule, the self-defeating test is a useful test in many practical circumstances. Now we can look at a third test for the RP approach.

The Rights Test

Some theorists in the RP tradition have concluded that one of the most useful ways of formulating the requirement to respect the moral agency of others is to say that we should honor the rights of people that are necessary for them to exercise their moral agency and to pursue their well-being. A right may be understood as both an entitlement to act and an entitlement to have another individual act in a certain way. Because of this dual aspect, rights are often thought of as existing in a correlative relationship with duties. Thus, if Kelly has a right to life, others have a duty not to kill Kelly. If Kelly has a right to bodily integrity, others have a duty not to cause bodily harm to Kelly.

As we have described them, rights serve as a protective barrier, shielding individuals from unjustified infringements of their moral agency by others. We can call these kinds of rights *negative rights*. Beyond this, rights are sometimes asserted more positively as requiring the provision of food, clothing, and education. Thus, if Kelly has a right to food, others have a correlative duty to provide her with at least minimal food for survival. We can call these *positive rights*. Because such positive rights are much more controversial in our culture and generally somewhat more difficult to satisfy, we focus on "negative rights," or those requiring only noninterference with another person, not active support of that person's interests.

Even though determining just what negative rights people have and what they require from others can be controversial, the general underlying principle is clear: an individual should not be deprived of anything that seriously impedes his or her moral agency. If someone takes your life, then you cannot exercise your moral agency at all, so this right is relatively uncontroversial, but some of the other proposed rights do not negate your moral agency, although they diminish your power to exercise it effectively. So their status as rights may be more subject to dispute.

One problem any account of rights must face is how to deal with conflicting rights. Suppose a plant manager wants to save money by eliminating a pollutant from his plant that is carcinogenic. The manager, acting on behalf of the firm, has a right not to be deprived of the freedom to use his property for economic benefit. But the pollutant threatens the right to life of the surrounding inhabitants. Note that the pollutant does not directly and in every case kill surrounding inhabitants, but it does increase the risk of the inhabitants getting cancer. So we can say that the pollutant *infringes* on the right to life of the inhabitants, but does not directly *violate* that right. In a rights violation, one's ability to exercise that right in a certain situation is essentially wholly denied, whereas in a rights infringement, one's ability to exercise a right is only diminished. This diminishment can occur in one of two ways. First, sometimes the infringement is a *potential* violation of that right, as in the case of a pollutant that increases the chance of death. Second, sometimes the infringement is a partial violation, as when some, but not all, of a person's property is taken.

The problem of conflicting rights requires that we prioritize rights, giving greater importance to some than to others. A useful way of prioritizing is offered by philosopher Alan Gewirth[10] in Box 2.14.

BOX 2.14 Gewirth's Hierarchy of Rights

- **Tier 1.** The most basic rights, the essential preconditions of action: for example, life, physical integrity, and mental health.
- **Tier 2**. Rights to maintain the level of purpose fulfillment one already has, such as the right not to be deceived or cheated, the right to informed consent to unusual risks, the right not to have possessions stolen, the right not to be defamed, and the right not to suffer broken promises.
- **Tier 3**. The rights necessary to increase one's level of purpose fulfillment: for example, the right to attempt to acquire property and wealth.

Using this hierarchy, it would be wrong for a plant manager to attempt to save money by emitting a pollutant that is highly carcinogenic, because the right to life is a first-tier right and the right to acquire and use property and wealth for one's benefit is a third-tier right. Sometimes, however, the hierarchy is more difficult to apply. How shall we balance a slight infringement of a first-tier right against a much more serious infringement or outright violation of a second-tier or third-tier right?

The hierarchy of rights provides no automatic answer to such questions. Nevertheless, it provides a framework for addressing them. We suggest a set of steps that could be taken, shown in Box 2.15.

BOX 2.15 Applying the Rights Test

1. Identify the action or rule to be to be evaluated and the available options.
2. Determine what options are available and what rights are at stake in each of the options.
3. Determine the place in the hierarchy of rights of the rights at stake and whether the rights are violated or infringed.
4. Identify the action or rule that will produce the least serious violations or infringements of the most significant rights.
5. Make a choice that seems likely to produce the least serious rights infringements or violations, all things considered.

2.13 THE VIRTUE ETHICS APPROACH

Virtue ethics, perhaps the oldest tradition of ethical thought, has become increasingly important among contemporary ethicists. The fundamental principle of virtue ethics is "Act in the way the good or virtuous person would act in the circumstances."

What Is a Virtue?

A virtue is usually described as a "dispositional trait," that is, a character trait that disposes or inclines a person to do the right thing. A virtue can be described as both deep and wide. It is deep in the sense that a virtue is a firmly entrenched habit that leads a person to consistently act in a certain way and to which he is strongly committed. It is wide in that it manifests itself in a variety of ways. A virtuous person exhibits virtue not only in actions but also in emotional reactions, in interests, and in general sensibilities. A truly honest person is not honest simply because she thinks it is the best way to stay out of trouble, but because she genuinely believes that being honest is the best way to live. She is disgusted by people who are dishonest and does not enjoy being in their company. She does not have to "make" herself be honest, because being honest has become a part of her character. Honesty is simply a part of who she is. She would not be happy or think she was living a good life if she were dishonest.

In order to better understand what a virtue is, virtue ethicists such as Aristotle have found it useful to think of virtues as occupying a middle position (or "mean") between vices. We can think of courage as a middle ground between the vice of cowardice on the one hand and the vice of foolhardiness on the other. We can think of the virtue of generosity as a middle ground between the vice of miserliness on the one hand and the vice of being a spendthrift on the other. We can think of the virtue of loyalty to an employer as a middle ground between the vice of complete disloyalty on the one hand and the vice of unquestioning obedience to the employer on the other.[11]

BOX 2.16 Core Virtues and Selected Character Strengths

1. Wisdom (creativity, open-mindedness, perspective)
2. Courage (bravery, persistence, vigor or energy)
3. Humanity (love, kindness)
4. Justice (citizenship, fairness, leadership)
5. Temperance (modesty, self-control)
6. Transcendence (appreciation of beauty and excellence, gratitude, spirituality)[13]

Just as Ross and Gert summarize common morality in terms of rules, virtue ethicists summarize common morality by a list of virtues. Various lists of virtues have been proposed, but there is a considerable overlap. The Greek philosopher Aristotle, the first and probably most important virtue ethicist, provided a very short list that includes courage, truthfulness, self-respect, wittiness, friendliness, modesty, and generosity or "magnificence."[12] This list probably summarized the moral ideals of upper-class Athenians in the fifth-century BC, but we need a more universal list. Contemporary psychologists Christopher Peterson and Martin Seligman have surveyed cultures throughout the world and come up with what they believe is a comprehensive list of core virtues and associated "character strengths" (listed in parentheses in Box 2.16). You may find it more plausible to consider the character strengths as simply additional virtues. Here is an account of the core virtues and a selection of the character strengths identified by Peterson and Seligman. Even the list in Box 2.16 may not enumerate all of the virtues (such as integrity and loyalty), but it is a good start.

In addition to these general virtues, some virtues that we can call *professional virtues* can assist professionals in carrying out the special mission of their profession. The virtue of compassion toward patients is an especially important professional virtue in medicine and loyalty to clients is an especially important virtue in law.[14] What about engineering? In Chapter 1, we saw that the primary function of engineering is to promote human "welfare," "well-being," and "quality of life." We suggest the following two virtues have a special relevance to the mission of engineering to promote well-being.

Professional Care

Engineers recognize the importance of this virtue, because they often refer to taking "due care" as important for members of their profession. Care is a disposition to both protect and promote the well-being of another—in the case of engineering, the well-being of the public. The paradigm of care is the relationship of parents to their children. The care relationship to children has two dimensions: protecting children from harm, and promoting their well-being. In manifesting the virtue of care for the public, these same dimensions are important. Engineers must insure that they not only do not harm the health, safety, and welfare of the public (prohibitive and preventive ethics), but also promote the well-being of the public through their professional work (aspirational ethics). As an optional further extension of aspirational ethics, engineers may devote themselves to improving the well-being of the poor and disadvantaged.

Respect for Nature

In recent years, engineers have come to recognize the relation of their work to the natural world. Technology both draws from and affects the environment. It is not surprising, then, that the virtue of respect for nature is becoming increasingly important for the engineering profession. According to *The American Heritage Dictionary*,respecting something is "to show esteem for; to honor," "to show consideration for; avoid violation of; treat with deference." This attitude toward nature can motivate engineers to engage in environmentally friendly or "green" engineering, not simply because it may be required by law, but because it is deeply rooted in the engineer's character. Recalling that a virtue must be not only deep but also wide, we can say that respecting nature means not only that one's intellect is involved but also that one's emotions and sensibilities must come into play. An engineer is concerned about sustainability and unnecessary exploitation of natural resources. She is offended by lack of respect for the natural world and takes pride in creating environmentally friendly technology. She may even be uncomfortable in associating with engineers who do not share this attitude.

Strengths of Virtue Ethics: The Rational and Intuitive Elements in Morality

For utilitarian and RP theorists, moral thinking is primarily a rational task, involving the application of moral concepts and rules to particular circumstances. Until recently, many psychologists studying moral thinking took the same view. Rational, logical thought is the way to arrive at correct moral judgments.[15] Evidence exists for this view. Classroom work can promote the rational side of moral development. Korean students who had moral education classes during childhood and adolescence showed significantly more brain activity associated with mental calculation.[16] Presumably, this calculation involved moral reflection, including the study of cases, and making appropriate moral judgments about them. Moral reflection on issues involving care and respect for nature might include the meaning of care and how to implement a caring attitude toward the public and the natural world.

More recently, psychologists have become aware of the dual nature of what we might broadly call "moral thinking." One aspect is indeed the "rational" system, which works relatively slowly and involves voluntary effort and conscious moral reasoning. The other element is the "intuitive" or "automatic" element in moral judgments and behavior. Located in a different part of the brain, the "intuitive" system, is quick and automatic or involuntary. It is especially associated with emotion, and it produces moral judgments that appear in consciousness with little apparent effort. Most moral judgments and actions that we make in daily life come from this source.[17] These two systems often work together to produce moral judgments, although one system may be dominant in a given situation.[18]

This picture of the dual sources of moral judgment and behavior coincides with what virtue ethicists have long held: being a morally good person requires cultivating not only one's reasoning skills but also an intuitive, automatic part, closely related to what we usually call a habit. We have already seen how the rational part can be cultivated. What about the intuitive, automatic part? We suggest two ways.

Moral Exemplars

One of the most effective ways to take advantage of the intuitive automatic element in morality is by exposure to paradigms of virtue—people who exhibit the virtues to an outstanding degree. In studying these exemplars, we learn that virtue is not so much taught as caught. In their classic study of moral exemplars, psychologists

Anne Colby and William Damon set up some criteria for identifying moral exemplars. They include a strong tendency to act on moral ideals, a willingness to risk self-interest to follow one's ideals, a tendency to inspire others to moral action, humility about one's own importance, and a consequent lack of concern about one's own ego.[19] Summarizing their study of actual cases, Colby and Damon identified some additional characteristics of exemplars: a high degree of moral certainty, close family ties in their formative years, a strong sense of meaning and mission in their lives, a positive attitude toward life and lifelong optimism, a sense of humor, an ability to forgive, and resilience that allowed them to recover from setbacks.[20] Most of us probably recognize these as admirable traits which we all wish we had.

Empirical evidence supports the importance of moral exemplars in forming character. College students showed significant signs of self-improvement when they watched exemplars in their major field. Interestingly, such improvement was not evident when less relevant exemplars were used.[21] This suggests the importance of exposing young engineers to outstanding members of their profession, engineers who are not only technically accomplished and successful but also outstanding from the standpoint of professionalism and moral commitment. This would include engineers who exhibit the two virtues of care for the health, safety and welfare of the public, and respect for nature.

Moral Habituation

Following Aristotle, virtue theorists have also recognized that developing habits of virtuous conduct is an important way to enhance moral virtue. Again, psychologists have confirmed this insight. Participating in morally praiseworthy action (perhaps designing technologies to assist the handicapped or engaging in some type of community service) is an effective and a meaningful type of moral education.[22] Students who are members of Engineers Without Borders have many opportunities for moral habituation.

Strengths of Virtue Ethics: Open-Ended Situations

Virtue ethics also has a special strength related to areas where a person has a considerable degree of discretion as to how a moral imperative is to be implemented. Engineering codes require engineers to hold paramount the safety of the public, but they provide minimal specification as to how this obligation should be implemented. Of course, one should not violate the prohibitions of such activities as having conflicts of interest or practicing without proper qualifications, but what about the more positive aspects of this imperative? Rules are inadequate here, and we must rely primarily on the character of the engineer, especially on the two professional virtues of care and respect for nature.

This need to rely on character rather than rules is especially relevant in that part of aspirational ethics that goes beyond what is morally required, such as attempts to improve the well-being of the poor or marginalized members of society. How or even whether an engineer engages in such projects depends on personal values and character, not on a set of rules.

Deficiencies of Virtue Ethics

Despite these advantages, virtue ethics has some deficiencies that render it inadequate as a complete account of ethical thinking. We have already said that prohibitive rules are more useful, where legal enforcement is appropriate. Also, appeal to virtues rather than rules, while advantageous where a considerable degree of discretion is appropriate, may not yield direction for action that is sufficiently precise. In general, appeal to virtues seems to yield less precise direction for action than appeal to rules. The procedure shown in Box 2.17, however, should give some direction for applying virtue ethics.

BOX 2.17 Applying Virtue Ethics

1. Determine the alternative courses of action that are possible in the situation.
2. Determine the virtues (or vices) that correspond to these courses of action.
3. Evaluate the actions in terms of the virtues (or vices) that motivate them. If a course of action is motivated by vices, a course of action motivated by virtues should be chosen instead. If two or more courses of action are motivated by different virtues, the course of action motivated by the most appropriate virtues for the situation should be chosen.
4. If no decision can be made as to which virtues are most appropriate, the actions associated with different virtues are equally permissible.[23]

Virtue Ethics: An Application

Because applying virtue ethics may cause special difficulties, we supply an example of how these guidelines apply to a moral issue.[24]

After completing his degree in chemical engineering in June, Gerald is scheduled to return to the family farm to help with its operation. In early May, his father became seriously ill, and Gerald is convinced that the only way to save the family farm is to take a job in engineering. Most of his fellow seniors have already taken jobs, and the interviewing season is over. The only employment opportunity Gerald finds is with Pro-Growth Pesticides. The family farm is an organic farm, however, and Gerald's father has always strongly opposed the use of pesticides. Gerald himself has become convinced that pesticides harm the environment generally and farm products in particular. He knows that he will be asked about his views on pesticides. What should he do? Let us look at the issue from the standpoint of virtue ethics.

1. Gerald must first determine the alternative actions that are possible in the situation. He thinks of three possibilities. He could (a) refuse to interview for the job, (b) interview but answer questions about pesticides honestly, or (c) interview and misrepresent his views on pesticides in order to get the job.
2. In determining the virtues and vices that correspond to these courses of action, Gerald might come up with the following analysis. (a) If he refuses to interview for the job, he will continue to be an honest person and also maintain his integrity. That is, he will continue to be a person who acts consistently with his principles. He may, however, not manifest proper loyalty to his family members, because he would fail to help them keep the farm. He would show loyalty to the family ideals, however. (b) If he interviews for the job but answers questions about his views on pesticides honestly, he will preserve his honesty, but may compromise his integrity by applying for (and possibly getting) a job that would be inconsistent with his principles. He will preserve his loyalty to his family, however, at least in the sense of helping to keep the farm. (c) If he interviews for the job and misrepresents his views on pesticides, he will manifest loyalty to his family, but fail to be honest or a person of integrity.

3. Now we must evaluate the alternatives open to Gerald in terms of whether they are grounded, either directly or indirectly, in the virtues appropriate to a morally worthy person. How should he evaluate these three options? He will fail to properly manifest at least one of the virtues he prizes no matter what he does. Options (a) and (b) will violate only one of the virtues, while (c) will violate two. Option (c), furthermore, seems to more directly manifest the vices of dishonesty and lack of integrity. While (c) seems to be the least desirable choice, the choice between (a) and (b) is more difficult. If he can find another job opportunity, clearly option (a) is the most desirable. If this possibility is not open to him, it may depend upon what kind of person Gerald most wants to be: a loyal person or a person with integrity. Gerald may well decide that he wants to manifest integrity by being consistent with his own values even more than he wants to be loyal to his family, so that he should refuse the interview. Gerald may be able to find a creative middle way, so that such a difficult choice will not have to be made.

2.14 USING MORAL THEORIES OR APPROACHES IN PRACTICAL ETHICS

These three approaches are to be used in the same way as line-drawing and creative-middle-way techniques: as aids to resolving practical moral issues whenever they are found to be relevant. Just as a carpenter chooses a saw or hammer when these tools are useful in building a house, so a practical ethicist chooses techniques useful to the purposes at hand.

Knowledge of moral theories can make a contribution to moral analysis in several ways. First, the theories can help us to understand the moral basis of alternative ways of thinking about moral issues. When we think about the advisability of building a hydroelectric facility on a river and consider such issues as the benefits of increased electrical power and also the costs and possible environmental damage, it is useful to know that this way of thinking is utilitarian and that is a widely used and morally legitimate method of moral analysis. When we consider whether the rights of individuals are being violated, we are doing a very different kind of moral analysis, but one that is equally legitimate. Furthermore, it is important to know ahead of time that these two approaches can lead to different moral conclusions, and that a process of reconciliation may be necessary. Finally, in some situations, an evaluation in terms of character may be more important. What character traits prompted an engineer or a moral exemplar to act as she did, and what can be done to encourage these traits in others? Why did one engineer exhibit such high professionalism in a situation of great stress, while another did not?

Second, these approaches can suggest more detailed and adequate ways of moral analysis than might otherwise be available. Ethical theories reminded us of the importance of considering all of the people affected by an action or a policy (the audience) and to consider the difference between looking at the utility of a particular action and the utility of a general practice. They bring up the relevance of asking whether rights are being violated and we would be willing to universalize an action. They prompt us to ask what character traits are important in prompting professionally responsible action and how those character traits might be developed. It is unlikely that we would ask many of these questions apart from the prompting of moral theory.

Third, we have seen that a knowledge of these approaches can alert us to the limitations of important ways of thinking about moral issues and to remind us that we should examine a moral problem from more than one perspective. As we have seen, a utilitarian analysis can neglect considerations of justice or respecting individuals. An RP analysis can fail to give adequate weight to overwhelming public goods in the face of minor infringements of individual rights. Both approaches neglect character traits that are important in motivating many types of professional activity. Virtue theory often does not provide clear answers to moral questions.

2.15 CHAPTER SUMMARY

Ethical methodologies and theories are a set of tools to be used in dealing with ethical issues. It is always useful to divide a moral problem into factual, conceptual, application, and moral components. Deciding whether and how line-drawing and creative-middle-way solutions, and utilitarian, RP, and virtue ethics approaches should be used must be left to the judgment of the person facing an ethical dilemma. Thinking of the three theory approaches as partial and incomplete models of common morality can aid in understanding how the three moral theories or approaches should be used in applied ethics.

Ross and Gert have attempted to summarize common morality in duties and rules, and Davis has offered several tests for the moral acceptability of actions that reflect ideas in common morality and the classic moral theories. It is also important to know that moral judgments can evaluate actions or practices as permissible, impermissible, obligatory, or supererogatory and that moral evaluations can be of particular actions, general practices, or very general moral criteria. Finally, in moral evaluation in common morality, the intention behind an action can be critically important.

NOTES

1. This account is based on Terrence Petty, "Use of Corpses in Auto-Crash Test Outrages Germans," *Time,* December 6, 1993, p. 70.
2. This case is suggested by the experience of a former engineering student at Texas A&M University.
3. W. D. Ross, *The Right and the Good* (Oxford: Oxford University Press, 1930), pp. 20–22.
4. Bernard Gert, *Common Morality: Deciding What to Do* (New York: Oxford University Press, 2004).
5. Ibid, p. 9.
6. Michael Davis, "The Usefulness of Moral Theory in Practical Ethics," *Teaching Ethics*, 10, no. 1, Fall 2009, pp. 73–74.
7. Let us say that a practice is a customary or habitual way of doing something and that a practice is defined by a rule or set of rules. Thus, the practice of professional confidentiality is defined by a rule such as, "Do not reveal to others information that was acquired in the client or patient relationship." Sometimes a practice may be defined by a set of rules. Since practices are defined by rules, we often use the terms interchangeably.
8. For a defense of this interpretation, see Marcus G. Singer, "Defense of the Golden Rule," in Marcus G. Singer, ed., *Morals and Values* (New York: Scribners, 1977).
9. This version of the Universalization Principle is suggested by Immanuel Kant. See *Foundations of the Metaphysics of Morals, with Critical Essays,* Robert Paul Wolff, ed.,

(Indianapolis, IN: Bobbs-Merrill, 1969). For another exposition of it, see C. E. Harris, *Applying Moral Theories*, 5th ed. 2007, pp. 155–158.

10. Alan Gewirth, *Reason and Morality* (Chicago: University of Chicago Press, 1978), especially pp. 199–127 and 338–354.
11. W. D. Ross, *Aristotle* (London, UK: Methuen, 1930), p. 203.
12. One of the reasons that Aristotle's list sounds strange to our ears is that some of his virtues (e.g., self-respect, wittiness, friendliness, and magnificence) are not considered strictly "moral" virtues by moderns.
13. Christopher Peterson and Martin E. P. Seligman, *Character Strengths and Virtues* (New York: Oxford University Press, 2004), pp. 29–30.
14. Suggestions for this approach can be found in Alasdair MacIntyre, *After Virtue* (Notre Dame, IN: University of Notre Dame Press, 1981), p. 178.
15. Psychologist Lawrence Kohlberg, perhaps the most important psychologist in this tradition, held that moral thinking follows a series of stages, beginning with a type of thinking that considers self-interest to be primary, continuing to stages that focus on thinking governed by the conventional moral views of one's society, and culminating in a type of moral thinking governed by considerations of general well-being (broadly utilitarian) and justice (broadly RP). For a summary of Kohlberg, see Detlef Garz, *Lawrence Kohlberg: An Introduction* (Opladen and Farmington Hills, MI: Barbara Burdich, 2009). See also John Gibbe, "Kohlberg's Stages of Moral Development: A Constructive Critique," *Harvard Educational Review,* 47, 1977, pp. 43–61; and James Rest, "The Hierarchical Nature of Moral Judgment: A Study of Patterns of Comprehension and Preference of Moral Stages," *Journal of Personality,* 41, no. 1, March 1973, pp. 86–109.
16. H. Hahn, "Analyzing Theoretical Frameworks of Moral Education Through Lakatos's Philosophy of Science," *Journal of Moral Education,* 43, no. 1, 32–53.
17. Lisa Tessman, "Virtue Ethics and Moral Failure: Lessons from Neuroscientific Moral Psychology," in *Virtues in Action*, ed. Michael W. Austin (New York: Palgrave Macmillan, 2013), 171. See also Jonathan Haidt, "The Emotional Dog and Its Rational Tail: A Social Intuitionist Approach to Moral Judgment," *Psychological Review*, 108, pp. 814–834; and J. Green et al., "An fMRI Investigation of Emotional Engagement in Moral Judgment, *Science*, 293, no. 5537, pp. 2105–2108.
18. To see how these two systems work, consider the following two hypothetical situations, which, despite their artificial nature, have often been used in psychological research. In the first situation (call it "Switch"), a runaway trolley is barreling down a steep incline and will run over five people if it is not stopped. You can divert the trolley to another track, but the trolley will run over one person if you do this. In the second situation (call it "Push"), the trolley is barreling down the same incline and will again run over five people if it completes its run. This time, you can stop the trolley by pushing a fat man onto the track from an overhead bridge. If you had to choose one option, which would you select? In a slightly more realistic situation (call it "Smother"), you and four other adults are hiding from some criminals who intend to kill all of you, as well as a small child who is with you. The child is crying and, unless smothered, will reveal your location, resulting in the deaths of the adults and the child. Would you smother the child to protect the adults, since the child would be killed either way? These examples have been presented to many experimental subjects, and here are the results. Most subjects have a strongly negative, emotional, and immediate response to "Push" and "Smother." In "Switch," the results are mixed, some choosing one option and some another. Furthermore, in "Switch," a part of the brain associated with rational calculation is involved, and the response time is slower, whereas a part of the brain associated with emotion is involved when subjects are considering "Push" and "Smother." Regardless of what moral judgments you make about these dilemmas, this research strongly suggests that the way you come to moral judgments is different in the examples where the

judgments are quick and in which they are slower and more labored. The quick judgments appear to be primarily emotional responses and the judgments made more slowly involve a rational, cognitive element. Furthermore, a full picture of what is involved in making moral judgments apparently includes both rational and emotional elements. See Tessman, *op. cit.,* pp. 175–177.

19. Anne Colby and William Damon, *Some Do Care* (New York: Free Press, 1992), p. 29.
20. *Ibid,* pp. 49–62, and 262–287.
21. P. Lockwood and Z. Kunda, "Superstars and Me: Predicting the Impact of Role Models on the Self," *Journal of Personality and Social Psychology*, 73, pp. 91–103.
22. T. Lickona, "Eleven Principles of Effective Character Education," *Journal of Moral Education*, 25, no. 1, pp. 93–100.
23. This scenario closely follows the one presented in C. E. Harris, Jr., *Applying Moral Theories, 5th ed*. (Belmont, CA: Thompson Wadsworth, 2007), pp. 208–209.
24. This case analysis is taken from Harris, *Applying Moral Theories* (Belmont, CA. Thompson Wadsworth, 2007), pp. 216–217. The case is adapted from Michael S. Pritchard, *Teaching Engineering Ethics: A Case Study Approach*, National Science Foundation, Grant No. DIR-8820837, pp. 244–262.

CHAPTER THREE

Responsibility in Engineering

Main Ideas in This Chapter

- **Responsibility has to do with accountability, both for what one does in the present and future and for what one has done in the past.**
- **The responsibilities of engineers require not only adhering to regulatory norms and standard practices of engineering but also satisfying the standard of reasonable care.**
- **Engineers can expect to be held accountable, if not legally liable, for intentionally, negligently, and recklessly caused harms.**
- **Responsible engineering practice requires good judgment, not simply following algorithms.**
- **A good test of engineering responsibility is the question: "What does an engineer do when no one is looking?" This makes evident the importance of *trust* in the work of engineers.**
- **Responsible engineering requires taking into account various challenges to appropriate action, such as blind spots, normalized deviance, bounded ethicality, uncritical acceptance of authority, and groupthink.**

ON JANUARY 16, 2003, AT 10:39 A.M. Eastern Standard Time, the *Columbia* lifted off at Kennedy Space Center, destined for a 16-day mission in space.[1] The seven-person *Columbia* crew was scheduled to conduct numerous scientific experiments and return to earth on February 1. Only 81.7 seconds after lift-off, a briefcase-size piece of the brownish-orange insulating foam that covered the large external tank broke off and hit the leading edge of the orbiter's left wing. Unknown to the *Columbia* crew or the ground support staff, the foam knocked a 10-inch hole in the leading edge of the wing.

Cameras recorded the foam impact, but the images provided insufficient detail to determine either the exact point of impact or its effect. Several engineers, including Rodney Rocha, requested that attempts be made to get clearer images. There were even requests that the *Columbia* crew be directed to examine the wing for possible damage. However, it had become a matter of faith at NASA that foam strikes, although a known problem, could not cause significant damage and were not a safety-of-flight issue, so management rejected this request. The astronauts were not told of the problem until shortly before reentry, when they were informed that the foam strike was inconsequential, but that they should know about it in case they were asked about the strike by the press on return from their mission.

Upon reentry into the Earth's atmosphere, a snaking plume of superheated air, probably exceeding 5,000 degrees Fahrenheit, entered the breach in the wing and began to consume the wing from the inside. The destruction of the spacecraft began when it was over the Pacific Ocean and grew worse when it entered U.S. airspace. Eventually, the bottom surface of the left wing began to cave upward into the interior of the wing, finally causing *Columbia* to go out of control and disintegrate, mostly over east Texas. The entire crew, along with the spacecraft, was lost.

3.1 INTRODUCTION

This tragic event, which has many striking similarities with the *Challenger* disaster 17 years earlier, illustrates many of the issues surrounding notions of responsibility in the engineering profession. Engineers obviously played a central role in making the *Columbia* flight possible and in safeguarding the spaceship and its travelers. From the outset of the launch, engineers had a special eye out for possible problems. Rodney Rocha and other engineers on NASA's Debris Assessment Team became concerned about flying debris. Noticing and assessing such details was their responsibility. If they did not handle this well, things could go very badly. Even if they did handle this well, things could go very badly. The stakes were high.

As Box 3.1 indicates, ideas of responsibility are many faceted. Responsibility may focus primarily on legal liabilities, job-defined roles, expectations of professional engineering societies, commonly accepted standards of engineering competency, or self-imposed moral standards. Furthermore, although legal and ethical concepts are distinct from each other, they are also interrelated. For example, the legal obligations of engineers help inform their moral obligations. Under its I. Fundamental Canons, NSPE Code of Ethics says that engineers shall "6. Conduct themselves honorably, responsibly, ethically, and *lawfully* so as to enhance the honor, reputation, and usefulness of the profession [emphasis added]."

As professionals, engineers are expected to commit themselves to high standards of conduct.[2] As noted in Chapter 1, the Preamble of NSPE's Code of Ethics emphasizes the importance of engineers being committed to honesty, integrity, fairness, and the protection of public safety, health, and welfare. This is based on the special roles engineers assume in their work and the crucial impact that this work has on our lives. We can refer to this as *role-responsibility.*

Our dependence on the responsible exercise of engineering expertise points

BOX 3.1 Responsibility as Accountability

Applied to:

- individual engineers;
- teams of engineers;
- divisions or units within organizations;
- organizations themselves.

Understood in terms of:

- legal accountability (which sometimes includes *strict* [no fault] liability);
- moral accountability (which does not include *strict* [no fault] liability).

BOX 3.2 Desirable Qualities in Engineers

- Basic engineering competence
- Professional integrity
- Honesty
- Willingness to make self-sacrifice
- Working well with others
- Imaginativeness
- Perseverance
- Communicating clearly with others
- Commitment to objectivity
- Openness to acknowledging and correcting mistakes
- Commitment to quality
- Ability to see "the big picture," as well as minute details
- Civic-mindedness

to the need to place our trust in the reliable performance of engineers, both as individual engineers and as members of teams of engineers and others who work together. In turn, when given opportunities to provide services to others, engineers need to conduct themselves in ways that do not generate distrust. This has important implications for a professional's approach to his or her responsibilities. In general, we can think of possible approaches to responsibility along a spectrum. At one end of the spectrum is the attitude of doing as little as one can get away with while still staying out of trouble, keeping one's job, and the like. Clearly, this minimalist attitude falls far short of the basic requirements of the NSPE code, most of which prohibit the violation of standards that require much more from engineers. At the other end of this spectrum are attitudes and dispositions that may take one "above and beyond the call of duty" (sometimes referred to as the *supererogatory*, or as "going the extra mile"). NSPE code also encourages (but does not require) such aspirations. For example, provision 2a, under section III (Professional Obligations) says: "Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community." Provision 2.c. says: "Engineers are encouraged to extend public knowledge and appreciation of engineering and its achievements." Finally, 2.d. says: "Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations."

What sorts of attitudes and dispositions might employers look for in engineers if they want to hire those who take seriously both what the NSPE code requires and encourages?[3] Box 3.2 lists some leading candidates, all of which are at least implicitly endorsed in engineering codes of ethics such as NSPE's.

3.2 ENGINEERING STANDARDS

Like other engineering codes of ethics, the NSPE code also requires that the work of engineers satisfies "applicable engineering standards." See Box 3.3.

Regulatory and procedural standards and the standard of care are intended to provide some assurance of quality, safety, and efficiency in engineering. It is important to realize, however, that they also leave considerable room for professional discretion in engineering design and practice. There are few algorithms for engineers to follow here. So, the need for engineering *judgment* must be emphasized.[5]

BOX 3.3 Applicable Engineering Standards

- Regulatory: specifying technical requirements (e.g., for safety)
- Procedural: e.g., procedures to be followed for determining measurable quality or level of safety
- Standard of Care: that level or quality of service ordinarily provided by other normally competent practitioners, contemporaneously providing similar services in the same locality and under the same circumstances[4]
- Judgment: needed because regulatory and procedural standards, and the standard of care still require the exercise of good judgment

Although the NSPE Code of Ethics is the product of the collective reflection of members of one particular professional society of engineers, it seems intended to address the ethical responsibilities of all practicing engineers. Given this, the standards endorsed by the code should be supportable by reasons other than the fact that NSPE members publically commit themselves to those standards. That is, the standards should be supportable by reasons that apply to all engineers, not just those who are members of NSPE. Are they?

In answering this question, it is important to note that the Preamble does not single out NSPE members, as distinct from other engineers, when prescribing how engineers ought to conduct themselves. Instead, it depicts the general role that engineering plays in society, along with more specific standards of conduct suitable for fulfilling that role responsibly. Presumably, this depiction is apt regardless of whether or not engineers are members of NSPE.

Engineers and nonengineers alike can readily agree that engineers do play the sort of vital societal role depicted by the Preamble, which emphasizes that engineers are required to use their specialized knowledge and skills in ways that benefit employers, clients, and the public and that they do not betray the trust placed in them. This is a matter of, we will say, *obligation-responsibility.* Assessments of how well engineers handle their obligation-responsibilities are typically in terms of praise and blame.

Unfortunately, we seem more inclined to blame shortcomings and failures than to praise everyday competent, if not exceptional, engineering practice. (We *expect* our cars to start, the elevators and trains to run, and the traffic lights to work.) In any case, we speak of engineers as being responsible for mistakes or accidents. This is a fundamentally negative and backward-looking concept of responsibility. Let us refer to it as *blame-responsibility.* However, it is important not to forget that assessments can be positive as well as negative.

We shall next discuss obligation-responsibility in relation to what is commonly called the *standard of care*, a standard of engineering responsibility accepted both in law and engineering practice. Then, we will turn to the more negative notion of blame-responsibility and its relation to the standard of care. We shall consider issues of responsibility in regard to failures in the design or functioning of engineered products. These issues are complicated by the organizational structures within which most engineers work. Whether organizations themselves (as distinct from individuals) can sensibly be held morally responsible for harms is a controversial question. However, they can be (and are) held liable in law, and this can have important implications for the moral responsibilities of their employees, including engineers.

3.3 THE STANDARD OF CARE

Engineers have a professional obligation to conform to the standard operating procedures and regulations that apply to their profession and to fulfill the basic obligation-responsibilities of their job as defined by the terms of their employment. Sometimes, however, it is not enough to follow standard operating procedures and regulations. Unexpected problems can arise that standard operating procedures and current regulations are not well equipped to handle. In light of this, engineers are expected to satisfy a more demanding norm, the *standard of care*. To explain this idea, we will first turn to codes of ethics.

Codes of ethics of professional engineering societies attempt to identify in a structured, comprehensive way standards its members believe should govern their conduct as engineers. However, because particular situations cannot be anticipated in all their relevant nuances, applying these standards requires professional judgment. For example, although sometimes it is obvious what would constitute a failure to protect public, health, and safety, often it is not. But not actively protecting public safety will fail to satisfy the public safety standard only if there is a responsibility to provide that level of safety. Still, since no engineering product can be expected to be "absolutely" safe (at least, not if it is to be a useful product), and since there are economic costs associated with safety improvements, there can be some uncertainty about what a reasonable standard of safety is for this or that product. Box 3.4 provides similarities of corporations to individual agents.

Rather than leave the determination of what counts as safe solely in the hands of individual engineers and their employers, safety standards are set by government agencies (such as the National Institute of Standards and Technology, the Occupational Safety and Health Administration, and the Environmental Protection Agency) or nongovernmental organizations (such as professional engineering societies and the International Organization for Standardization). Nevertheless, standards of safety, as well as standards of quality, may still leave room for considerable engineering discretion. Although some standards have a high degree of specificity (e.g., minimal requirements regarding the ability of a structure to withstand winds of a certain velocity that might strike that structure at, say, a 90 degree angle), some simply require that unspecified standard processes be developed, followed, and documented.[6]

Engineering codes of ethics typically make general statements about engineers being required to conform to accepted standards of engineering practice. What such standards come to in actual practice depends, of course, on the area of engineering practice in question, along with whatever formal regulatory standards may be in place. However, underlying all of this is a broader standard of care in engineering practice, a standard appealed to in law and about which experienced, respected engineers can be called upon to testify in the courts in particular cases.

Joshua B. Kardon presents a useful characterization of the standard of care.[7]

BOX 3.4 Similarities of Corporations to Individual Moral Agents

1. Corporations make decisions
2. Corporations like people have decision-making policies
3. Corporations have "interests" that are distinct from those of corporations executives and employee

He says that although some errors in engineering judgment and practice can be expected to occur as a matter of course, not all errors are acceptable. He explains:

> An engineer is not liable, or responsible, for damages for every error. Society has decided, through case law, that when you hire an engineer, you buy the engineer's normal errors. However, if the error is shown to have been worse than a certain level of error, the engineer is liable. That level, the line between non-negligent and negligent error is the "standard of care."

How is this line determined in particular cases? It is not up to engineers alone to determine this, but they do play a crucial role in assisting judges and juries in their deliberations. Kardon continues:

> A trier of fact, a judge or jury, has to determine what the standard of care is and whether an engineer has failed to achieve that level of performance. They do so by hearing expert testimony. People who are qualified as experts express opinions as to the standard of care and as to the defendant engineer's performance relative to that standard.

For this legal process to be practicable and reasonably fair to engineers, it is necessary that there be an operative notion of accepted practice in engineering that is well understood by competent engineers in the areas of engineering under question. As Kardon puts it:[8]

> A good working definition of the standard of care of a professional is: that level or quality of service ordinarily provided by other normally competent practitioners of good standing in that field, contemporaneously providing similar services in the same locality and under the same circumstances.

Given this, we should not expect to find a formal statement of what specifically satisfies the standard. Rather, an appeal is made to what is commonly and ordinarily done (or not done) by competent engineers. So, the legally recognized standard of care might best be seen as representing the highest *shared* standard among competent, responsible engineers in the relevant areas of practice.

3.4 BLAME RESPONSIBILITIY AND CAUSATION

Now let us turn to the more negative concept of responsibility, blame-responsibility. We can begin by considering the relationship of responsibility for harm to causation of harm. When the *Columbia* Accident Investigation Board looked at the *Columbia* tragedy, it focused on what it called the "causes" of the accident. It identified two principal causes: the "physical cause" and the "organizational causes." The physical cause was the damage to the leading edge of the left wing by the foam that broke loose from the external tank. The organizational causes were defects in the organization and culture of NASA that led to an inadequate concern for safety.[9] The board also made reference to individuals who were "responsible and accountable" for the accident. The board, however, did not consider its primary mission to be the identification of individuals who should be held responsible and perhaps punished.[10] Thus, it identified three types of explanations of the accident: the physical cause, organizational causes, and individuals responsible or accountable for the accident.

The concept of cause is related in an interesting way to that of responsibility. Generally speaking, the more we are inclined to speak of the physical cause of

BOX 3.5 Holding Organizations Responsible

1. For causing harms
2. For making reparations for wrong done
3. For making reforms

something, the less we are inclined to speak of responsibility—and the more we are inclined to speak of responsibility, the less inclined we are to focus on physical causes. When we refer only to the physical cause of the accident—namely, the damage produced by the breach in the leading edge of the orbiter's left wing—responsibility is not yet in the picture. Physical causes, as such, cannot be responsible agents. The place of responsibility with respect to organizations and individuals raises more complex issues. Let us turn first to organizations (Box 3.5).

The relationship of organizations to the concepts of causation and responsibility is controversial. The *Columbia* Accident Investigation Board preferred to speak of the organization and culture of NASA as a cause of the accident. With respect to the physical cause, the board said:[11]

> The physical cause of the loss of the *Columbia* and its crew was a breach in the Thermal Protection System on the leading edge of the left wing, caused by a piece of insulating foam which separated from the left bipod ramp section of the External Fuel Tank at 81.7 seconds after launch, and struck the wing in the vicinity of the lower half of Reinforced Carbon-Carbon panel number 8.

With respect to the organizational causes of the accident, the board said:[12]

> The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, and lack of an agreed national vision for human space flight. Cultural traits and organizational practices detrimental to safety were allowed to develop, including: reliance on past successes as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements); organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.

With respect to the relative importance of these two causes, the board concluded:[13]

> In the Board's view, NASA's organizational culture and structure had as much to do with this accident as the External Tank foam. Organizational culture refers to the values, norms, beliefs, and practices that govern how an institution functions. At the most basic level, organizational culture defines the assumptions that employees make as they carry out their work. It is a powerful force that can persist through reorganizations and reassignments of key personnel.

If organizations can be causes, can they also be morally responsible agents, much as humans can be? Some theorists believe it makes no sense to say that organizations (such as General Motors or NASA) can be morally responsible agents.[14] An organization is not, after all, a human person in the ordinary sense. Unlike human persons, corporations do not have a body, cannot be sent to jail, and have an indefinite life. On the other hand, corporations are described as "artificial persons" in the law. According to *Black's Law Dictionary*, "the law treats the corporation itself as a person which can sue and be sued. The corporation is distinct from the individuals who comprise it (shareholders)."[15] Corporations, like persons, can also come into being, pass away, and be fined.

Philosopher Peter French argues that corporations can, in a significant sense, be morally responsible agents.[16] Although French focuses on corporations, his arguments can also be applied to governmental organizations such as NASA. Corporations have three characteristics that can be said to make them very similar to moral agents. First, corporations, like people, have a decision-making mechanism. People can deliberate and then carry out their decisions. Similarly, corporations have boards of directors and executives who make decisions for the corporation, and these decisions are then carried out by subordinate members of the corporate hierarchy. Second, corporations, like people, have policies that guide their decision-making. People have moral rules and other considerations that guide their conduct. Similarly, corporations have corporate policies, including, in many cases, a corporate code of ethics. In addition to policies that guide conduct, corporations also have a "corporate culture" that tends to shape their behavior, much as personality and character shape the actions of individuals. Third, corporations, like people, can be said to have "interests" that are not necessarily the same as those of the executives, employees, and others who make up the corporation. Corporate interests include making a profit, maintaining a good public image, staying out of legal trouble, and so forth.

Consider an example of a corporate decision. Suppose an oil corporation is considering beginning a drilling operation in Africa. A mountain of paperwork will be forwarded to the chief executive officer (CEO), other top executives, and probably the board of directors. When a decision is made, according to the decision-making procedure established by the corporation, it can properly be called a "corporate decision." It was made for "corporate reasons," presumably in accordance with "corporate policy," to satisfy "corporate interests," and guided by "corporate ethics."

Regardless of whether organizations, as such, are seen as moral agents, organizations can be held responsible in at least three senses.[17] First, they can be criticized for causing harms, just as the *Columbia* Accident Investigation Board criticized NASA. Second, an organization that harms others can be asked to make reparations for wrong done. Finally, an organization that has harmed others is in need of reform, just as the board believed NASA needs reform.

One worry about treating organizations as morally responsible agents is the fear that individual responsibility might be displaced. However, there need be no incompatibility in holding both organizations and the individuals within them accountable for what they do. We will now turn to the responsibilities of individuals.

3.5 LEGAL LIAILITY

Although engineers and their employers might try to excuse apparent failure to provide safety and quality by pointing out that they have met existing regulatory standards, it is evident that the courts will not necessarily agree. As already noted in Section 3.3, the standard of care recognized in law is not adequately explained solely in terms of regulations. A better explanation of the standard of care is found in the legal case *Coombs v. Beede*:[18]

> The responsibility resting on an architect is essentially the same as that which rests upon the lawyer to his client, or upon the physician to his patient, or which rests upon anyone to another where such person pretends to possess some special skill and ability in some special employment, and offers his services to the public on account of his fitness to act in the line of business for which he may be employed. The undertaking of an architect implies that he possesses skill and ability, including taste, sufficient enough to enable him to perform the required services at least ordinarily and reasonably well; and that he will exercise and apply, in the given case, his skill and ability, his judgment and taste reasonably and without neglect.

As noted earlier, Joshua B. Korden points out that this does mean that all failure to provide satisfying services is wrongful injury. Even when reasonable care is exercised, this cannot guarantee that no injuries will ever occur, especially in areas of innovative technology. Given the desirability of encouraging innovative engineering design, it is unrealistic for the public to regard all failures and mishaps to be blameworthy; at the same time, it is incumbent on engineers to do their best to anticipate and avoid failures and mishaps as innovations are introduced and tested.

It should be noted that *Coombs v. Beede* does not say that professionals need only conform to the already established standards and practices of their field of expertise. Those standards and practices may be in a state of change, and they may not be able to keep pace with advancing knowledge of risks in particular areas. Furthermore, as many liability cases have shown, reasonable people often disagree about precisely what those standards and practices should be taken to be.

3.6 HARMS: LEGAL LIABILITY AND MORAL RESPONSIBILITY

Legal liability and moral responsibility for harms parallel each other in several ways, but they are importantly different as well. We begin with the similarities. For an individual to be held legally liable for causing harm is to be judged as either warranting punishment, or as being obligated to make restitution for that harm. Liability for harm ordinarily implies that the person caused the harm, but it also implies something about the conditions under which the harm was caused (Box 3.6). These conditions ordinarily include such "mental" elements as malicious intent, recklessness, or negligence. In examining these elements, we shall see that although the concept of causing harm is present, it is the notions of liability and responsibility that are the focus of attention.[19]

First, a person can *intentionally*, or knowingly and deliberately, cause harm. If an assailant stabs someone in the back to steal that person's money, the assailant is both legally liable and morally responsible for deliberately causing injury or death. The causal component in this case is the physical assault, and the mental component is the intention to do serious harm.

Second, someone can *recklessly* cause harm, not by aiming, or intending to cause harm but by being aware that harm is likely to result. If someone recklessly causes harm, the causal factor is present, so the reckless person is both legally liable and morally responsible for the harm. In reckless behavior, although there is not an intent to harm, there is an intent to engage in behavior that is known to place others at risk of harm. Furthermore, the person exhibits a reckless attitude, one which disregards the well-being of others, and perhaps even oneself. This attitude may result in serious injury, or even death, as in car accidents caused by reckless driving. Reckless drivers may not intend to cause an accident, but they do intend to drive fast, and they are not heeding their own safety or that of others. If their reckless action causes harm, then they are legally liable and morally responsible for the harms caused.

BOX 3.6 Legal and Moral Responsibility for Causing Harm

- Intentionally (or knowingly and deliberately) causing harm
- Recklessly causing harm—awareness of likelihood of causing harm, but not intending or aiming at harm
- Negligently causing harm—overlooking or not noticing risk of harm, failure of due care
- Strict liability for causing harm, even without fault: legal but not moral liability

A third kind of legal liability is associated with *negligently* causing harm. Unlike recklessness, where an element of deliberateness or intent is involved (such as a decision to drive fast) in negligent behavior, the person may simply overlook something, or not even be aware of the factors that could cause harm. The person is responsible because of a failure to exercise *due care*, which is the care that would be expected of a reasonable person in the circumstances. In law, a successful charge of negligence must meet three conditions:

1. A legal obligation to conform to certain standards of conduct is applicable.
2. The person charged with negligence fails to conform to the standards.
3. There is a reasonably close causal connection between the conduct and any resulting harm.

The first condition also applies to moral responsibility, except that we must substitute "moral obligation" for "legal obligation." Also, it is assumed that the standards of conduct in question are morally, and not just legally, binding. Professions such as engineering have recognized standards of professional practice, both technical and moral. Professional negligence, therefore, is the failure to perform duties that professionals have implicitly or explicitly assumed by virtue of being professionals. If engineers do not exercise standard care according to the recognized standards of their profession, and are therefore negligent, then they can be held responsible for any resulting harm.

One important difference between legal liability and moral responsibility is that, whereas the former typically requires actual harm, the latter does not. Whether or not harm is involved may be a matter of luck. However, the good fortune of not actually causing harm does not relieve one of moral responsibility, as one's sense of guilt, or of falling short morally, is still operative, as is the critical assessment of others.

There is one concept of legal liability that seems to have no parallel in moral responsibility. In some areas of the law, there is *strict liability* for harms caused; there is no attribution of fault or blame, but there is a legal responsibility to provide compensation, make repairs, or the like. Strict liability is directed at corporations rather than individual engineers within the organization. However, insofar as they have a duty to be faithful and loyal employees, and perhaps even as a matter of specifically assigned duties, engineers can have a moral responsibility to their employer to help minimize the likelihood that strict liability will be imposed on the organization. So even strict liability at the corporate level can have moral implications for individual engineers.

However, litigation that seeks redress from harm commonly appeals to the law of torts, which deals with harm to someone caused by another, usually as a result of fault or negligence on the part of the injuring party. The standard of proof in tort law is the *preponderance of evidence*, meaning that there is more and better evidence in favor of the plaintiff than the defendant. This is a weaker standard than in criminal law, which calls for proof *beyond reasonable doubt*. Appreciating this difference can be important for engineers who have a responsibility to try to minimize their company's liabilities falling under either sort of law.

Finally, even if certain engineers are not responsible in any of the earlier discussed ways for harms attributable to their organization, their managers may assign them responsibility for fixing the problems that were none of their making.

3.7 SHIFTING TO THE POSITIVE

Focusing attention on *failure* to satisfy the standard of care can easily result in overemphasizing the harms that can come from engineering practice. What about engineering *success* in satisfying this standard? As Coombs v. Beede stresses, professionals are expected to provide their services "at least ordinarily and reasonably well" and to exercise their "judgment and taste reasonably and without neglect." Success in this regard is no mean achievement. However, especially in the case of engineers, we are inclined to take this success for granted. We routinely and without question carry on our daily activities, assuming that our bridges are safe, that our elevators are reliable, and that our heating systems are efficient and safe—unless, or until, something goes wrong. We know how badly such things could go. In fact, it is stories of occasional mishaps rather than successes that receive the most media attention.

Although the standard of care plays a prominent role in law, it is important to realize that it encompasses a broader notion of moral responsibility. Dwelling on its role in law alone may suggest to some a more calculative, "legalistic" consideration of reasonable care. Regarding the standard of care as only a guide to protecting oneself (or one's employer or company) from legal liability hardly does justice to its moral underpinnings. Ideally, the standard of care reflects a concern to protect others from harm and wrongdoing. This captures a sense of at least minimal moral concern for others. However, the spectrum of responsibility we introduced earlier in this chapter can embrace much more.

We have already mentioned in Chapter 1 air bag pioneer Carl Clark, who continued after retirement to try to develop air bags for car bumpers and wearable air bags for the elderly to prevent broken hips when they fall. He did this without pay. This is what we call superogatory work on his part—work that goes "beyond the call of duty." A second example of such work is that of Michael Stoline, a statistician with strong interests in environmental issues. He volunteered to help analyze data to determine whether it was safe for residents in Love Canal, near Buffalo, New York, to return to their homes after being ordered to leave because of the likelihood that toxic wastes in the area posed a serious health risk. Although modestly compensated for his services, he realized that there were many more lucrative consulting opportunities. Asked why he accepted this task instead, he said: "Analyzing data just for the money doesn't mean anything to me. I want it to do some good."[20]

These two examples illustrate dedication that goes well beyond what can be ordinarily, and rightfully, expected of others, whether in their regular place of employment or elsewhere. Although we appreciate the fact that these individuals have taken on additional responsibilities, we do not think that they had a *duty* to assume them in the first place. Even though *they* might say to themselves, "This is what I ought to be doing," it is unlikely that we would feel it is appropriate for *us* to tell them that they ought to be doing what they are doing. Instead, we praise them for their good works and admire their enlarged sense of responsibility.

Such exemplary work can be undertaken by groups as well as individuals. In the late 1930s, a group of General Electric engineers worked together to develop the sealed beam headlamp, which promised to reduce sharply the number of fatalities caused by night driving.[21] To accomplish this, it was necessary to involve engineers in research, design, production, economic analysis, and governmental regulation. Although the need for headlight improvement was widely acknowledged, there was also widespread skepticism about its technical and economic feasibility. By 1937, the General Electric team proved the technical feasibility of the sealed beam headlamp. However, the remaining task was to persuade car builders and designers to cooperate with each other in support of the innovation, as well as to convince regulators of its merits.

There is little reason to suppose that the General Electric engineers were simply doing what they were told—namely to come up with a more adequate headlamp. Apparently, the virtual consensus was that this could not be done, so the engineers had to overcome considerable resistance. This was no ordinary task, as evidenced by the remarks of another engineer of that era:

> The reaching of the consensus embodied in the specifications of the Sealed Beam Headlamp is an achievement which commands the admiration of all who have any knowledge of the difficulties that were overcome. It is an achievement not only in illuminating engineering, but even more in safety engineering, in human engineering, in the art of cooperation.[22]

The difficulties faced by this group of engineers remind us that enthusiasm for such undertakings needs to be tempered with realism. Other demands and constraints may discourage undertaking such projects. Nevertheless, looking for opportunities to go beyond what is standardly required, as well as taking advantage of these opportunities when they arise, is a desirable trait in an engineer. It is easy not to notice that such exemplary work commonly occurs in engineering practice. Those involved may view themselves as simply doing what needs to be done. They may see important tasks that we fail to notice, and they quietly do them. Or we may grow accustomed to how they approach their work and simply take their dedication and accomplishments for granted. Furthermore, once they take on a responsibility and the work is underway, it often is appropriate to hold them accountable for completing the work. What we may overlook is that taking on the responsibility in the first place was their choice.

3.8 RESPONSIBILITY IN DESIGN

As we have noted, most engineering codes of ethics insist that, in designing products, engineers are expected to hold considerations of public safety paramount. However, there is likely more than one way to satisfy safety standards, especially when stated broadly. But if there is more than one way to satisfy safety standards, how are designers to proceed?

If we are talking about the overall safety of a product, there may be much latitude, a latitude that, of course, provides space for considerations other than safety (e.g., overall quality, usability, cost). For example, in the late 1960s, operating under the constraints of coming up with an appealing automobile that weighed under 2,000 pounds that would cost consumers no more than $2,000, Ford engineers decided to make more cargo space by putting the Pinto's gas tank in an unusual place.[23] This raised a safety question regarding rear end collisions. Ford claimed that the vehicle passed the current standards. However, some Ford engineers urged that a protective buffer should be inserted between the gas tank and protruding bolts. This, they contended, would enable the Pinto to pass a more demanding standard that it was known would soon be imposed on newer vehicles. They warned that, without the buffer, the Pinto would fail to satisfy the new standard, a standard that they believed would come much closer to meeting the standard of care enforced in tort law.

Ford decided not to put in the buffer. It might have been thought that satisfying the current safety standard ensured that courts and their juries would agree that reasonable care was exercised. However, this turned out to be a mistaken view. As noted earlier in the text, the courts can determine that existing technical standards are not adequate, and engineers themselves are sometimes called upon to testify to that effect.

Given the bad publicity Ford received regarding the Pinto and its history of subsequent litigation, Ford might regret not having heeded the advice of those engineers who argued for the protective buffer. This could have been included in the original design, or perhaps there were other feasible alternatives during the early design phases. However, even after the car was put on the market, a change could have been made. This would have involved an expensive recall, but this would not have been an unprecedented move in the automotive industry.

These possibilities illustrate a basic point about regulatory standards, accepted standards of engineering practice, and engineering design. Professional standards for engineers underdetermine design. In principle, if not in practice, there will be more than one way to satisfy the standards. This does not mean that professional standards have no effect on practice. As Stuart Shapiro points out:[24]

> Standards are one of the principal mechanisms for managing complexity of any sort, including technological complexity. Standardized terminology, physical properties, and procedures all play a role in constraining the size of the universe in which the practitioner must make decisions.

For a profession, the establishment of standards of practice is typically regarded as contributing to professionalism, thereby enhancing the profession in the eyes of those who receive its services. At the same time, standards of practice can contribute both to the quality and safety of products in industry. Still, standards of practice have to be applied in particular contexts that are not themselves specified in the standards. Shapiro notes:[25]

> There are many degrees of freedom available to the designer and builder of machines and processes. In this context, standards of practice provide a means of mapping the universal onto the local. All one has to do is think of the great variety of local circumstances for which bridges are designed and the equally great variety of designs that result…. Local contingencies must govern the design and construction of any particular bridge within the frame of relative universals embodied in the standards.

Shapiro's observation focuses on how standards of practice allow engineers freedom to adapt their designs to local, variable circumstances. This often brings surprises, not only in design but also in regard to the adequacy of formal standards of practice. As Louis L. Bucciarelli points out, standards of practice are based on the previous experience and testing of engineers. Design operates on the edge of "the new and the untried, the unexperienced, the ahistorical."[26] Thus, as engineers come up with innovative designs, we should expect formal standards of practice themselves sometimes to be challenged and found to be in need of change. All the more reason why courts of law are unwilling simply to equate the standard of care with current formal standards of practice.

3.9 THE RANGE OF STANDARDS OF PRACTICE

Some standards of practice are clearly only local in their scope. The New York City building code requirement that high-rise structures be tested for wind resistance at 90 degree angles applied only within a limited geographic region. Such specific code requirements are local in their origin and applicability. Of course, one would expect somewhat similar requirements to be in place in comparable locales in the United States as well as in other high-rise locales around the world. This suggests that local codes, particularly those that attempt to ensure quality and safety, reflect more general standards of safety and good engineering practice.

One test of whether we can meaningfully talk of more general standards is to ask whether the criteria for engineering competence are only local (e.g., New York City civil engineers, Chicago civil engineers), statewide, or national. Philosopher Vivian Weil has argued that there is good reason to believe that professional standards of engineering practice can cross national boundaries.[27] She offers the example of the early twentieth-century Russian engineer Peter Palchinsky. Critical of major engineering projects in Russia, Palchinsky was nevertheless regarded to be a highly competent engineer in his homeland. He also was a highly regarded consultant in Germany, France, England, the Netherlands, and Italy. Although he was regarded as politically dangerous by Russian leaders at the time, no one doubted his engineering abilities—either in Russia or elsewhere.[28]

Weil also reminds readers of two fundamental principles of engineering that Palchinsky applied wherever he practiced:[29]

> Recall that the first principle was: gather full and reliable information about the specific situation. The second was: view engineering plans and projects in context, taking into account impacts on workers, the needs of workers, systems of transportation and communication, resources needed, resource accessibility, economic feasibility, impacts on users and on other affected parties, such as people who live downwind.

Weil goes on to point out that underlying Palchinsky's two principles are principles of common morality, particularly respect for the well-being of workers—a principle that Palchinsky argued was repeatedly violated by Lenin's favored engineering projects.

We have noted that the codes of ethics of engineering societies typically endorse principles that seem intended to apply to engineers in general rather than only to members of those particular societies. Common morality was suggested as providing the ground for basic provisions of those codes (e.g., concern for the safety, health, and welfare of the public). Whether engineers who are not members of professional engineering societies actually do, either explicitly or implicitly, accept the principles articulated in a particular society's code of ethics is, of course, another matter. However, even if some do not, it could be argued that they *should*. Weil's point is that there is no reason, in principle, to believe that supportable international standards cannot be formulated and adopted. Furthermore, this need not be restricted to abstract statements of ethical principle. As technological developments and their resulting products show up across the globe, they can be expected to be accompanied by global concerns about quality, safety, efficiency, cost-effectiveness, and sustainability. This, in turn, can result in uniform standards in many areas regarding acceptable and unacceptable engineering design, practice, and products. In any case, in the context of an emerging global economy, constructive discussions of these concerns should not be expected to be only local.

3.10 IMPEDIMENTS TO RESPONSIBILITY

So far in this chapter, we have tried to explain different aspects of engineering responsibility, both legal and moral. However, it is one thing to have a basic understanding of engineering responsibility, but it is quite another to apply this understanding in actual engineering practice, especially when addressing questions of wrongdoing. Unfortunately, many impediments can stand in the way of handling one's responsibilities as well as one should. Box 3.7 lists some of the more significant ones we will be discussing.

The Problem of Many Hands

Individuals often attempt to evade personal responsibility for wrongdoing. Perhaps the most common way this is done, especially by individuals in large organizations, is by pointing out that many individuals had a hand in causing the harm. The argument here goes as follows: "So many people are responsible for what happened that it is irrational and unfair to pin the responsibility on any individual person, including me." Let us call this the *problem of fractured responsibility* or (preferably) the *problem of many hands*.[30] In response to this argument, philosopher Larry May has proposed the following principle to apply to the responsibility of individuals in a situation where many people are involved in causing harm, either through inaction or through action. First, consider harm through collective inaction. May suggests, "[I]f a harm has resulted from collective inaction, the degree of individual responsibility of each member of a putative group for the harm should vary based on the role each member could, counterfactually, have played in preventing the inaction."[31] Let us call this the *principle of responsibility for inaction in groups*. Our slightly modified version of

BOX 3.7 Common Impediments to Responsibility

- The problem of many hands (or fractured responsibility)
- Blind spots
  - self-deception
  - willful blindness
  - inattentional blindness
- Normalizing deviance
- Egoistic perspectives (self-interest first)
- Egocentric perspectives (assuming others see matters as we do)
- Microscopic vision (seeing fine details, but missing the bigger picture)
- Uncritical deference to authority
- Groupthink
  - illusion of invulnerability of group
  - shared stereotypes
  - rationalizations
  - illusion of morality
  - self-censorship
  - illusion of unanimity
  - direct pressure to agree
  - mind-guarding (keeping dissenters away from the group)

this principle reads as follows: In a situation in which a harm has been produced by collective inaction, the degree of responsibility of each member of the group depends on the extent to which the member could reasonably be expected to have tried to prevent the action. The qualification "the extent to which each member could reasonably be expected to have tried to prevent the action" is necessary because there are limits to reasonable expectation here. If a person could have prevented an undesirable action only by taking his own life, sacrificing his legs, or harming someone else, then we cannot reasonably expect him to do it.

A similar principle can apply to collective action that causes harm. Let us call it the *principle of responsibility for action in groups*: Here, the degree of responsibility of each member of the group depends on the extent to which the member caused the action by some action reasonably avoidable on his part. Again, the reason for the qualification is that if an action causing harm can only be avoided by extreme or heroic action on the individual's part (such as taking his own life, sacrificing his legs, or harming someone else), then we may find reason for not holding the person responsible, or at least holding him less responsible.

These two principles are not easy to apply in complex organizations, where much that goes on is not clearly explainable in terms that enable one to determine just what this or that individual did or did not do. Still, for the individuals in question, seriously imagining that they bear *no* responsibility for what happened may be quite questionable.

Blind Spots

Those who drive automobiles are familiar with *blind spots.* Applying this term to organizational and business arenas, Dennis Moberg draws an analogy between business blind spots and those we experience when driving.[32] Once regular attention is given to the deficit area, driving habits can be developed to help compensate for this perceptual deficit. In the case of driving, such adaptations are welcomed by all. However, in the business arena, blind spots often protect us from having to face unwelcome information.

Max H. Bazerman and Ann E. Tenbrunsel, authors of *Blind Spots*, contend that although nearly all of us want to think of ourselves as ethically decent, our blind spots result in a tendency to overestimate how ethical we actually are.[33] This blindness should not be confused with unethical intent. We are capable of this, too, of course. But Bazerman and Tenbrunsel are more interested in explaining how otherwise decent, well-intentioned people can, without consciously intending to do so, lend support to ethically unacceptable outcomes.

Self-deception is a key to much of this. Although we might well be sincerely opposed to wrongdoing and not want to be complicit in it, we may also be highly motivated, perhaps through fear or lack of courage, to turn the other way. Taking action against wrongdoing may risk unpopularity, censorship, or even retaliation (e.g., demotion or job loss). But we cannot take action against that which we do not notice. Not noticing may in many instances be what we might call *willful blindness.*[34] Ignorance of vital information is an obvious barrier to responsible action. If an engineer does not realize that a design poses a safety problem, for example, then he or she will not be in a position to do anything about it. Sometimes such a lack of awareness is willful avoidance—a turning away from information in order to avoid having to deal with the challenges it may pose. However, often it results from a lack of imagination, from not looking in the right places for necessary information, from a failure to persist, or from the pressure of deadlines. Although there are limits to what engineers can be expected to know, these examples suggest that ignorance is not always a good excuse.

Still, the pervasiveness, and limitations, of selective attention are effectively illustrated in the perceptual experiments of Ulric Neisser in the mid-1970s.[35] In one experiment, participants watched a short video in which a group of people passed a basketball to one another. The viewers were asked to count the number of passes that were completed. On their first viewing, very few noticed a woman carrying an open umbrella walking between those passing the ball. When the video was replayed, attention was easily focused on the woman, but at the expense of not being able to count the number of completed passes. This "selective looking," as Neisser called it, is now labeled *inattentional blindness.* Neisser's simple experiment effectively illustrates that typically what we see is a function of what we are looking for and that this selectivity blinds us to things "right before our eyes." So, we need to be ready to refocus in order to notice what is readily available to take into account if only we will do this.

Normalizing Deviance

In the case of the *Columbia* disaster, Rodney Rocha accused NASA managers of "acting like an ostrich with its head in the sand."[36] NASA managers seemed to him to have convinced themselves that past successes are an indication that a known defect would not cause problems, instead of deciding the issue on the basis of testing and sound engineering analysis. Often, instead of attempting to remedy the problem, they simply engaged in the practice of *normalizing deviance*, which enlarges the boundaries of acceptable risk without sound engineering basis.[37] Instead of attempting to eliminate foam strikes or doing extensive testing to determine whether the strikes posed a safety-of-flight issue, managers "increasingly accepted less-than- specification performance of various components and systems, on the grounds that such deviations had not interfered with the success of previous flights."[38] Enlarging on the issue, the *Columbia* Accident Investigation Board observed: "With each successful landing, it appears that NASA engineers and managers increasingly regarded the foam-shredding as inevitable, and as either unlikely to jeopardize safety or simply an acceptable risk."[39]

Finally, there was a subtle shift in the burden of proof with respect to the shuttle. Instead of requiring engineers to show that the shuttle was safe to fly or that the foam strike did not pose a safety-of-flight issue, "[T]he engineers found themselves in the unusual position of having to prove that the situation was unsafe—a reversal of the usual requirement to prove that a situation is safe." As the Board observed, "Imagine the difference if any Shuttle manager had simply asked, 'Prove to me that Columbia has not been harmed.'"[40]

An important lesson is that organizations need continually to determine whether important factors are being underestimated, or even overlooked, and whether this is the result of time pressures, viewing matters only in the short term, or some other shortcoming. In any case, once an organization has identified such problems, possible remedies need aggressively to be sought. Key questions here are as follows: First, what role might engineers play in *identifying* serious problems? Second, how might they best *communicate* these problems to managers who have responsibilities in these areas? Third, what promising ways of *resolving*, or at least minimizing, these problems can they suggest?

In the case of the *Columbia*, it seems that NASA managers were often ignorant of serious problems associated with the shuttle. One of the reasons for this is that as information made its way up the organizational hierarchy, more and more of the dissenting viewpoints were filtered out, resulting in an excessively sanitized version of the facts. According to the *Columbia* Accident Investigation Board, there was a kind of "cultural fence" between engineers and managers. This resulted in high-level managerial decisions that were based on insufficient knowledge of the facts.[41]

Egoistic and Egocentric Perspectives

A common feature of human experience is that we tend to interpret situations from very limited perspectives, or "mindsets," and it takes special efforts to acquire a more inclusive viewpoint.[42] Although these limited perspectives can sometimes be narrowly self-interested (or *egoistic*), they need not be. It is not just self-interest that interferes with our ability to understand things from larger perspectives. For example, we may have good intentions for others but fail to realize that their perspectives are different from ours in important ways. This is commonly called *egocentric* thinking, especially characteristic of very young children, but something that even adults never overcome completely. For example, some people may not want to hear bad news about their health. They may also assume that others are like them in this respect. So, if they withhold bad news from others, this is done with the best of intentions—even if others would prefer hearing the bad news. Similarly, an engineer may want to design a useful product but fail to realize how different the average consumer's understanding of how to use it is likely to be from those who design it. This is why test runs with typical consumers are desirable.

Microscopic Vision

Michael Davis warns of the danger of what he calls *microscopic vision*. Precise and accurate as it may be, microscopic vision greatly limits our field of vision. When we look into a microscope, we see things that we could not see before—but only in the narrow field of resolution on which the microscope focuses. We gain accurate, detailed knowledge—at a microscopic level. At the same time, we cease to see things at the more ordinary level. This is the price of seeing things microscopically. Only when we lift our eyes from the microscope will we see what is obvious at the everyday level. Every skill, says Davis, involves microscopic vision to some extent:

> A shoemaker, for example, can tell more about a shoe in a few seconds than I could tell if I had a week to examine it. He can see that the shoe is well or poorly made, that the materials are good or bad, and so on. I can't see any of that. But the shoemaker's insight has its price. While he is paying attention to people's shoes, he may be missing what the people in them are saying or doing.[43]

Just as shoemakers need to raise their eyes and listen to their customers, engineers sometimes need to raise their eyes from their world of scientific and technical expertise and look around them in order to understand the larger implications of what they are doing.

Large organizations, especially, tend to foster microscopic thinking. Each person has his or her own specialized job to do, and he or she is not responsible, from the organizational standpoint, for the work of others. This was evidently generally true of the NASA organizational structure. It may also have been a contributing factor to the *Columbia* accident.

Authority Versus Autonomy

Engineering codes of ethics emphasize the importance of engineers attempting to exercise independent, objective judgment in performing their functions. This is sometimes called professional *autonomy*. At the same time, the codes of ethics insist that engineers have a duty of fidelity to their employers and clients. Independent consulting engineers may have an easier time maintaining professional autonomy than the vast majority of engineers, who work in large, hierarchical organizations. Most engineers are not their own bosses, and they are expected to defer to authority in their organizations.

An important finding of the research of social psychologist Stanley Milgram is that a surprisingly high percentage of people are inclined to defer uncritically to authority.[44] In his famous obedience experiments during the 1960s, Milgram asked volunteers to administer electric shocks to "learners" whenever they made a mistake in repeating word pairs (e.g., nice/day and rich/food) that volunteers presented to them earlier. He told volunteers that this was an experiment designed to determine the effects of punishment on learning. No shocks were actually administered, however. Milgram was really testing to determine the extent to which volunteers would continue to follow the orders of the experimenter to administer what they believed were increasingly painful shocks. Surprisingly (even to Milgram), nearly two-thirds of the volunteers continued to follow orders all the way up to what they thought were 450-volt shocks—even when shouts and screams of agony were heard from the adjacent room of the "learner." The experiment was replicated many times to make sure that the original volunteers were a good representation of ordinary people rather than especially cruel or insensitive people.[45]

In the Milgram experiments, the volunteers were told that the "learners" would experience pain but no permanent harm or injury. Perhaps volunteers who were engineers would have had doubts about this as the apparent shock level moved toward the 450-volt level. This would mean only that the numbers need to be altered for engineers, not that they would be unwilling to administer what they thought were extremely painful shocks.

One of the interesting variables in the Milgram experiments was the respective locations of volunteers and "learners." The greatest compliance occurred when "learners" were not in the same room with the volunteers. Volunteers tended to accept the authority figure's reassurances that he would take all the responsibility for any unfortunate consequences. However, when volunteers and "learners" were in the same room and in full view of one another, volunteers found it much more difficult to divest themselves of responsibility.

Milgram's studies seem to have special implications for engineers. As previously noted, engineers tend to work in large organizations in which the division of labor often makes it difficult to trace responsibility to specific individuals. The combination of the hierarchical structure of large organizations and the division of work into specialized tasks contributes to the sort of "distancing" of an engineer's work from its consequences for the public. This tends to decrease the engineer's sense of personal accountability for those consequences. However, even though such distancing might make it easier psychologically to be indifferent to the ultimate consequences of one's work, this does not really relieve one from at least partial responsibility for those consequences.

One further interesting feature of Milgram's experiments is that volunteers were less likely to continue to administer what they took to be shocks when they were in the presence of other volunteers. Apparently, they reinforced each other's discomfort at continuing, and this made it easier to disobey the experiment. However, as discussed in the next section, group dynamics do not always support critical response. Often quite the opposite occurs, and only concerted effort can overcome the kind of uncritical conformity that so often characterizes cohesive groups.

Groupthink

A noteworthy feature of the organizational settings within which engineers work is that individuals tend to work and deliberate in groups. This means that an engineer will often participate in group decision making rather than function as an individual decision maker. Although this may contribute to better decisions ("two heads are better than one"), it also creates well-known but commonly overlooked tendencies to engage in what Irving Janis calls *groupthink*—situations in which groups come to agreement at the expense of critical thinking.[46] Janis documents instances of groupthink in a variety of settings, including a number of historical fiascos (e.g., the bombing of Pearl Harbor, the Bay of Pigs invasion, and the decision to cross the 38th parallel in the Korean War).[47] Concentrating on groups that are characterized by high cohesiveness, solidarity, and loyalty (all of which are prized in organizations), Janis identifies eight symptoms of groupthink:

- An *illusion of invulnerability* of the group to failure
- A strong "we-feeling" that views outsiders as adversaries or enemies and encourages *shared stereotypes* of others
- *Rationalizations* that tend to shift responsibility to others
- An *illusion of morality* that assumes the inherent morality of the group and thereby discourages careful examination of the moral implications of what the group is doing
- A tendency of individual members toward *self-censorship*, resulting from a desire not to "rock the boat"
- An *illusion of unanimity*, construing silence of a group member as consent
- An application of *direct pressure* on those who show signs of disagreement, often exercised by the group leader who intervenes in an effort to keep the group unified
- *Mindguarding*, or protecting the group from dissenting views by preventing their introduction (e.g., by outsiders who wish to present their views to the group)[48]

Traditionally, engineers have prided themselves on being good team players, which compounds the potential difficulties with groupthink. How can the problem of groupthink be minimized for engineers? Much depends on the attitudes of group leaders, whether they are managers or engineers (or both). Janis suggests that leaders need to be aware of the tendency of groups toward groupthink and take constructive steps to resist it. He notes that after the ill-advised Bay of Pigs invasion of Cuba, President John F. Kennedy began to assign each member of his advisory group the role of critic. He also invited outsiders to some of the meetings, and often absented himself from meetings to avoid influencing unduly its deliberations.

Many of NASA's *Columbia* engineers and managers may have been affected with the groupthink mentality. Commenting on management's decision not to seek clearer images of the leading edge of the left wing of the shuttle in order to determine whether the foam strike had caused damage, one employee said, "I'm not going to be Chicken Little about this."[49] The *Columbia* Accident Investigation Board described an organizational culture in which "people find it intimidating to contradict a leader's strategy or a group consensus," evidently finding this characteristic of the NASA organization.[50] The general absence of a culture of dissent that the board found at NASA could have encouraged the groupthink mentality.

To overcome the problems associated with the uncritical acceptance of authority, organizations need to establish a culture in which dissent is accepted and even encouraged. The *Columbia* Accident Investigation Board cites organizations in which dissent is encouraged, including the U.S. Navy Submarine Flooding Prevention and Recovery program and the Naval Nuclear Propulsion programs. In these programs, managers have the responsibility, not only of encouraging dissent, but also of coming up with dissenting opinions themselves if such opinions are not offered by their subordinates. According to the Board, "program managers [at NASA] created huge barriers against dissenting opinions by stating preconceived conclusions based on subjective knowledge and experience, rather than on solid data." Toleration and encouragement of dissent, then, was noticeably absent in the NASA organization. If dissent is absent, then critical thinking is absent.

Another widely discussed instance in which groupthink may have been operative involves the production of General Motors' Corvair automobile in the early 1960s. Safety differences were heatedly discussed among engineers and management. The car was released for public sale even though some engineers insisted the Corvair had stabilizing problems.[51] The first models (1960–1963) had a swing-axle suspension design which was prone to "tuck under" in certain circumstances. An anti-roll bar was needed to stabilize the vehicle.[52] Yet, it was decided to solve the problem by requiring higher tire pressure at a level that was outside the tire manufacturer's recommended tolerances. Additionally, according to Ralph Nader, a strong critic of the car, the tire pressure changes were not clearly stated to Chevrolet salespeople and Corvair owners.[53] There was a failure to recognize the seriousness of the engineering problems with the car. Nader claimed that rather than making the necessary stabilizing change, the General Motors team added styling features to the dashboard. These shiny dashboard features caused a visual impediment in the form of windshield glare, allegedly triggering crashes because of flashes obstructing the driver's vision. These styling changes cost $700. It was estimated that the safety changes needed would have only cost about 23 cents.[54] John DeLorean was an engineer and vice president with General Motors at the time. He believed that individually the executives were "moral men." However, thinking as a group, he concluded that they made immoral decisions.[55]

3.11 CHAPTER SUMMARY

Engineers are responsible for exercising a standard of care in their work. They need to be concerned with complying with the law, adhering to norms and practices commonly accepted by competent engineers who exercise reasonable care in their work in relevantly similar areas, and avoiding wrongful behavior. But this may not be good enough. The standard of care view insists that existing regulatory standards may be inadequate, for these standards may fail to address problems that have yet to be taken adequately into account. This suggests that particularly in areas of technological innovation, engineers need to exercise imaginative, critical thinking in trying to anticipate and address new risks before they become serious problems.

We might wish for some sort of algorithm for determining what our responsibilities are in particular circumstances. But this is an idle wish. Even the most detailed codes of ethics of professional engineering societies can provide only general guidance. The determination of responsibilities and how they should be pursued in particular circumstances depend on discernment and judgment on the part of engineers. The manner in which one approaches one's work-related responsibilities may exceed what can reasonably be required, but be important, nonetheless. Some "good works" fall entirely beyond one's standard job description. However, once undertaken, they carry obligations with them.

Blame-responsibility can be applied to individuals and perhaps to organizations. If we believe organizations can be morally responsible agents, it is because we believe the analogies between undisputed moral agents (people) and organizations are stronger than the disanalogies. In any case, organizations can be criticized for the harms they cause, be asked to make reparations for harm done, and be assessed as needing to be reformed.

Understanding concepts of responsibility needs to be accompanied by efforts at actually satisfying the requirements of one's responsibilities. These efforts need to address the challenges posed by blind spots, the normalization of deviancy, deference to authority, groupthink, and other impediments to responsibility.

NOTES

1. This account is based on three sources: *Columbia Accident Investigation Board*, vol. 1 (Washington, DC: National Aeronautics and Space Administration, 2003); "Dogged Engineer's Effort to Assess Shuttle Damage," *The New York Times*, September 26, 2003, p. A1; William Langewiesche, "Columbia's Last Flight," *Atlantic Monthly*, November 2003, pp. 58–87.
2. The next several paragraphs and some later segments of this chapter are based on Michael S. Pritchard, "Professional Standards for Engineers," in *Handbook Philosophy of Technology and Engineering Sciences*, ed. A. Meijers, Part V, "Normativity and Values in Technology," Ibo van de Poel, ed. (Elsevier Science, 2010).
3. The list that follows is based on interviews of engineers and managers conducted by James Jaksa and Michael S. Pritchard and reported in Michael S. Pritchard, "Responsible Engineering: The Importance of Character and Imagination," *Science and Engineering Ethics*, 7, no. 3, 2001, pp. 394–395.
4. See, for example, the Association for Computing Machinery: ACM Code of Ethics and Professional Conduct, 2.2 Acquire and maintain professional competence.
5. This is a major theme of Stuart Shapiro's, "Degrees of Freedom: The Interaction of Standards of Practice and Engineering Judgment," *Science, Technology, & Human Values*, 22, no. 3, Summer 1997.
6. Shapiro, "Degrees of Freedom," p. 290.
7. Joshua B. Kardon, "The Structural Engineer's Standard of Care," presented at the OEC International Conference on Ethics in Engineering and Computer Science, March 1999. This article is available at http://www.onlineethics.org.
8. Ibid. Kardon bases this characterization on *Paxton v. County of Alameda* (1953) 119c.C.A. 2d 393, 398, 259P 2d 934.
9. *Columbia Accident Investigation Board*, p. 6.
10. Nevertheless, the investigation eventually resulted in the displacement of no less than a dozen key people at NASA, as well as a public vindication of Rocha for doing the right thing.
11. Ibid., p. 9.
12. Ibid.
13. Ibid., p. 177.
14. For discussions of this issue see, for example, Peter French, *Collective and Corporate Responsibility* (New York: Columbia University Press, 1984); Kenneth E. Goodpaster and John B. Matthews, Jr., "Can a Corporation Have a Conscience?" *Harvard Business Review*, 60, January–February 1982, pp. 132–141; and Manuel Velasquez, "Why Corporations Are Not Morally Responsible for Anything They Do," *Business and Professional Ethics Journal*, 2, no. 3, Spring 1983, pp. 1–18.
15. *Black's Law Dictionary*, 6th ed. (St. Paul, MN: West 1990), p. 340.
16. See Peter French, "Corporate Moral Agency" and "What Is Hamlet to McDonnell-Douglas or McDonnell-Douglas to Hamlet: DC-10," in *Ethical Issues in Professional Life*, ed. Joan C. Callahan (New York: Oxford University Press, 1988), pp. 265–269,

274–281. The following discussion has been suggested by French's ideas, but it diverges from them in several ways.

17. These three senses all fall on the blame-responsibility side. A less explored possibility is that corporations can be morally responsible agents in positive ways.
18. *Coombs v. Beede*, 89 Me. 187, 188, 36 A. 104 (1896). This is cited and discussed in Margaret N. Strand and Kevin Golden, "Consulting Scientist and Engineer Liability: A Survey of Relevant Law," *Science and Engineering Ethics*, 3, no. 4, October 1997, pp. 362–363.
19. We are indebted to Martin Curd and Larry May for outlining parallels between legal and moral notions of responsibility for harms and their possible applications to engineering. See Martin Curd and Larry May, *Professional Responsibility for Harmful Actions*, Module Series in Applied Ethics, Center for the Study of Ethics in the Professions, Illinois Institute of Technology (Dubuque, IA: Kendall/Hunt, 1984).
20. Personal communication with statistician Michael Stoline at Western Michigan University.
21. This account is based on G. P. E. Meese, "The Sealed Beam Case," *Business & Professional Ethics*, 1, no. 3, Spring 1982, pp. 1–20.
22. H. H. Magsdick, "Some Engineering Aspects of Headlighting," *Illuminating Engineering*, June 1940, p. 533, cited in Meese, p. 17.
23. Information on Ford Pinto here is based on a case study prepared by Manuel Velasquez, "The Ford Motor Car," *Business Ethics: Concepts and Cases*, 3rd ed. (Englewood Cliffs, NJ: Prentice-Hall, 1992), pp. 110–113.
24. Shapiro, "Degrees of Freedom," p. 290.
25. Ibid., p. 293.
26. Louis L. Bucciarelli, *Designing Engineers* (Cambridge, MA: MIT Press, 1994), p. 135.
27. Vivian Weil, "Professional Standards: Can They Shape Practice in an International Context?" *Science and Engineering Ethics*, 4, no. 3, 1998, pp. 303–314.
28. For more on the life and career of Peter Palchinsky, see Loren Graham's, *The Ghost of an Executed Engineer: Technology and the Fall of the Soviet Union* (Cambridge, MA: Harvard University Press, 1993).
29. Ibid., p. 306. Similar principles are endorsed by disaster relief specialist Frederick Cuny and his Dallas, Texas, engineering relief agency. Renowned for his relief efforts around the world, Cuny's principles of effective and responsible disaster relief are articulated in his *Disasters and Development* (New York: Oxford University Press, 1983).
30. The phrase "the problem of many hands" is suggested by Helen Nissenbaum in "Computing and Accountability" in Deborah G. Johnson and Helen Nissenbaum, eds., *Computers, Ethics, and Social Values* (Upper Saddle River, NJ: Prentice-Hall, 1995), p. 529.
31. Larry May, *Sharing Responsibility* (Chicago: University of Chicago Press, 1992), 106. For a more nuanced discussion of these notions, as well as notions of responsibility in engineering, see Michael Davis, "Ain't No One Here but Us Social Forces," *Science and Engineering Ethics*, 18, no. 1, March 2012, pp. 13–34.
32. Dennis Moberg, "Ethics Blind Spots in Organizations: How Systematic Errors in Person Perception Undermine Moral Agency," *Organizational Studies*, 27, no. 3, 2006, p. 414.
33. Max H. Bazerman and Ann E. Tenbrunsel, *Blind Spots: Why We Fail to Do What's Right and What to Do About It* (Princeton: Princeton University Press, 2011), p. 29.
34. For an excellent discussion of various forms this can take, see Margaret Heffernan, *Willful Blindness* (Princeton, NJ: Walker and Company, 2011).
35. For more on Ulric Neisser's, Google him on Wikipedia.See also his groundbreaking *Cognitive Psychology* (Englewood Cliffs: Prentice-Hall, 1967). He and N. Harsch are also noted for their, "Phantom Flashbulbs: False Recollections of Hearing the News About Challenger," in *Affect and Accuracy in Recall: Studies of 'Flashbulb' Memories*, eds., E. Winograd and U. Neisser, (New York: Cambridge University Press, 1992), pp. 9–31.

36. “Dogged Engineer’s Effort to Assess Shuttle Damage,” p. A1.
37. The notion of “normalizing defiance” is featured in Diane Vaughn’s, *The Challenger Launch Decision* (Chicago: University of Chicago Press, 1996), esp. pp. 409–422. We discuss this in more detail in our chapter on risk.
38. *Columbia Accident Investigation Board*, p. 24.
39. Ibid., p. 122
40. Ibid., p. 198
41. Ibid., p. 168, 170, 198.
42. The challenges these and other limited perspectives, or “mindsets,” pose to sound, ethical decision making are discussed in detail in Patricia H. Werhane et al., *Obstacles to Ethical Decision-Making* (Cambridge, UK: Cambridge University Press, 2013).
43. This expression was introduced into engineering ethics literature by Michael Davis. See his “Explaining Wrongdoing,” *Journal of Social Philosophy*, now retain 1 & 2, Spring–Fall 1989, pp. 74–90. Davis applies this notion to the *Challenger* disaster, especially when Robert Lund was asked to take off his engineer’s hat and put on his manager’s hat.
44. Stanley Milgram, *Obedience to Authority* (New York: Harper & Row, 1974).
45. It might be thought that after a series of unpopular wars and a variety of social protest movements, Milgram’s results could not be replicated today—we are less likely to defer, uncritically to authority. However, a recent replication of much of the Milgram experiment suggests that this is not so. See Jerry Bulger, “Replicating Milgram: Would People Obey Today?” *American Psychologist*, 64, no. 1, 2009, pp. 1–11.
46. Irving Janis, *Groupthink*, 2nd ed. (Boston: Houghton Mifflin, 1982).
47. The most recent edition of the McGraw-Hill video *Groupthink* features the *Challenger* disaster as illustrating Janis’s symptoms of groupthink.
48. Ibid., pp. 174–175.
49. “Dogged Engineer’s Effort to Assess Shuttle Damage,” p. A1.
50. *Columbia Accident Investigation Board*, p. 203.
51. J. Patrick Wright, *On a Clear Day You Can See General Motors* (Detroit, MI: Wright Enterprises, 1979), p. 237.
52. Ibid.
53. Ralph Nader, *Unsafe at Any Speed* (New York: Grossman Publishers, 1965), p. 14.
54. Ibid.
55. Wright, *On a Clear Day*, p. 237.

CHAPTER FOUR

Engineers in Organizations

Main Ideas in This Chapter

- **Communication and culture are vital components within the organization, and employees need to understand them well.**
- **Employees should take advantage of organizational resources in order to enhance their own integrity and independence.**
- **Organizational and management practices may be unchanged for years, which can result in blind spots, or obstacles to ethical decision-making. Understanding the obstacles and remedies for these obstacles can improve the organization's communication and ethical decision-making.**
- **Many organizations hire an ethics and compliance officer to study inappropriate policies and procedures and to assist employees in appropriate communication and daily ethical choices at work.**
- **Engineers and managers have different perspectives, both legitimate, and it is useful to distinguish between decisions that should be made by managers, or from a management perspective, and decisions that should be made by engineers, or from an engineering perspective.**
- **Differences of opinion can be expected within the organization between engineers themselves and between engineers and management. Careful verbal and written communication can be utilized to work through disagreements.**
- **Whistleblowing sometimes becomes a necessary option for an employee when other avenues of communication fail. An employee should explore numerous ways of solving an organizational problem before whistleblowing. However, new federal regulations are in place to assist employees who believe they have exhausted all other means of solving the workplace problem.**

VALUING THE CUSTOMER ENABLED Ray C. Anderson to change his very profitable business into an even more profitable one—and one that serves as model of values that go far beyond monetary gains. Anderson's firm, Interface Carpets Global, is in the business of manufacturing modular carpet tiles. Anderson was the founder and 38 years chief executive officer (CEO) of Interface Carpets. (Anderson died in 2011 still holding those titles.) He had an engineering background as an honors graduate from Georgia Institute of Technology's School of Industrial and Systems Engineering and founded Interface Carpets in 1973. Twenty years later, Anderson's personal and professional attitude toward the customer was changed when engineer Jim Hartzfield, from the research division, relayed a question from a sales associate: "Some customers want to know what Interface is doing for the environment. How should we answer?"[1]

Initially, Anderson said, he wasn't as worried about the harms to the environment as he was concerned about his client. He commented, "I wasn't about to ignore any customer's concerns or to turn my back on any piece of business. If we didn't answer the question Jim had relayed, I knew we stood to lose other sales."[2] So, Anderson insisted, Interface needed to focus on its customers' needs. Anderson began by reading Paul Hawken's *The Ecology of Commerce*. The book transformed Anderson's customer-driven goals into a series of environmentally friendly business practices. "Mission Zero," was a promise initiated by Anderson and Interface to eliminate any negative impact the company might have on the environment by the year 2020. In 2009, Anderson estimated Interface was half-way to its goal of redesign of processes and products, the pioneering of new technologies, and efforts to reduce or eliminate waste and harmful emissions while increasing the use of renewable materials and sources of energy.[3]

4.1 INTRODUCTION

Most engineers are corporate employees rather than self-employed. This means that their role-responsibilities are a function of relationships they have with, not only other engineers but also their managers and, ultimately, with the aims and goals of the organizations within which they work. So, most engineers are not their own bosses, and they are expected to defer to recognized authority in their organizations.

When an organization radically changes its aspirations, as in the case of Ray Anderson's Interface Carpets, engineers in its employ need to be able to adapt to these changes or seek employment elsewhere. At Interface, engineer Jim Hartzfield played a key role in triggering CEO Anderson's reconsideration of Interface's goals. Insofar, as an organization has aspirations like those at Interface, this may be regarded as ideal for environmentally concerned engineers who work there. However, it must be realized that there is often a lack of match between the ideal and the real. We now turn to some problematic areas.

4.2 ENGINEERS AND MANAGERS

Management theorist Joseph Raelin, says, "There is a natural conflict between management and professionals because of their differences in educational background, socialization, values, vocational interests, work habits, and outlook."[4] Raelin notes that engineers often experience a conflict between loyalty to their employer and loyalty to their profession.[5] Most engineers want to be loyal employees who are concerned about the financial well-being of their firms and who carry out instructions from their superiors without protest. This is in line with most engineering codes of ethics prior to the 1970s, which insisted that being "faithful agents" of their companies is the engineer's first obligation. However, as noted in Chapter 1, in the early 1970s, leading professional engineering societies introduced a new first principle for their codes: the notion that engineers have a more fundamental obligation, namely that they must hold paramount the health, safety, and welfare of the public.

Complicating matters further, most managers are not engineers and do not have engineering expertise, so communication is often difficult. Engineers sometimes complain that they have to use oversimplified language in explaining technical matters to managers and that their managers do not really understand the engineering issues.

BOX 4.1 Engineers and Management

- Engineers have a paramount obligation to protect the health, safety, and welfare of the public.
- Some engineers may aspire to become managers. This does not change their paramount obligation as engineers.

Finally, many engineers who are not managers aspire to management roles in the future, where the financial rewards and prestige are perceived to be greater. Thus, many engineers who do not yet occupy the dual roles of engineer and manager probably expect to do so at some time in their careers. Those who do occupy both roles can experience conflict as a result. For example, Robert Lund, vice president for engineering at Morton Thiokol at the time of the *Challenger* disaster in 1986, was both an engineer and a manager. Before the disaster, Lund was even directed by his superior to take a managerial rather than an engineering perspective.

This account of the differences between the perspectives of engineers and managers suggests the possibility of frequent conflicts. Although Robert Jackall's well-known study of corporate management focuses only infrequently on the relationship between managers and professionals, its occasional references to the relationship of managers to engineers and other professionals make it clear that Jackall believes his general description of the manager–employee relationship applies to the relationship of managers to professionals, including engineers. In his study of managers in several large U.S. corporations, Jackall found that large organizations place a premium on "functional rationality," which is a "pragmatic habit of mind that seeks specific goals." Jackall found that the managers and firms he studied had several characteristics that challenge full respect for the moral commitments of conscientious professionals.[6]

First, he claimed, the organizational ethos does not allow genuine moral commitments to play a significant part in the decisions of corporate managers, especially highly placed ones. They may have whatever private moral beliefs they choose, as long as these beliefs do not interfere with expected behavior in the workplace. They must learn to separate individual conscience from corporate action. Managers prefer to think in terms of trade-offs between moral principles, on the one hand, and expediency, on the other hand. What we might think of as genuine moral considerations play little part in managerial decisions, according to Jackall. Faulty products or environmental harms are bad only insofar as they might ultimately harm the company's public image.

Second, loyalty to one's peers and superiors is the primary virtue for managers. Successful managers are team players, persons who can accept a challenge and get the job done in a way that reflects favorably upon themselves and others.[7]

Third, lines of responsibility are deliberately blurred to protect oneself, one's peers, and one's superiors. Details are pushed down and credit is pushed up. Actions are separated from consequences insofar as this is possible so that responsibility can be avoided. In making difficult and controversial decisions, successful managers will always get as many people involved as possible so they can point a finger at others if

BOX 4.2 Primary Trade-offs

- Some managers prefer to think in terms of trade-offs between moral principles, on the one hand, and expediency, on the other hand.
- Most managers have concerns for the well-being of the organization. Organizational well-being is measured primarily in financial terms, but it also includes a good public image and relatively conflict free operation.
- Organizational culture is generally set at the top levels of management.

things go wrong. They should also avoid putting things in writing to avoid being held responsible. Protecting and covering for one's boss, one's peers, and oneself supersedes all other considerations.

Jackall's study implies that managers have a strong and probably overriding concern for the well-being of the organization. Well-being is measured primarily in financial terms, and it also includes a good public image and relatively conflict free operation.

The managerial decision-making process involves making trade-offs among relevant considerations, of which ethical considerations are only one type (Box 4.2). Furthermore, if we are to believe Jackall, managers tend not to take ethical considerations seriously unless they can be translated into factors affecting the well-being (e.g., the public image) of the firm.

4.3 BEING MORALLY RESPONSIBLE IN AN ORGANIZATION

The Importance of Organizational Culture

The example of Ray Anderson demonstrates engineering having a positive, direct effect on the top leader. Both CEO Anderson and his engineers seem to be concerned about values in ways that conflict with the perspectives of typical managers, as depicted by Raelin and Jackall. Anderson's global company remains committed to its 2020 goal of eliminating any negative impact it may have on the environment, with the engineers participating in the goal in areas such as factory design, materials for carpets and pads, glues, and even natural carpet dyes.[8]

However, the progressive organizational setting of Interface Carpets is not standard for engineers. In order to be morally responsible in an organization without suffering the fate of the employees in Jackall's study, engineers must first have some understanding of the organization in which they are employed. This knowledge helps them to understand (1) how they and their managers tend to frame issues under the influence of the organization and (2) how one can act in the organization effectively, safely, and, one hopes, in a morally responsible way.

The qualities of the organization we have in mind here fall into the category of "organizational culture." It is generally agreed that organizational culture is set at the top of an organization—by high-level managers, by the president or CEO of the organization, by directors, and sometimes by owners. If the organization values success and productivity over integrity and ethical principles, these values will powerfully influence the decisions of members of the organization. The values become, in the words of Christopher Meyers, "a mindset, a filter through which participants view their world."[9] If this filter is strongly rooted in an organizational culture of which one is a part, it has an even more powerful influence on behavior.

Some use the term "organizational scripts" or "schemas" to refer to the way an organization conditions its members to view the world in a certain way, seeing some things and not seeing others. Dennis Gioia was a manager at Ford in the early 1970s. He made the recommendation not to recall the Pinto, even though the car had been involved in the tragic deaths of passengers after relatively minor accidents. He describes his experience at Ford as follows:

> My own schematized … knowledge influenced me to perceive recall issues in terms of the prevailing decision environment and to unconsciously overlook key features of the Pinto case, mainly because they did not fit an existing script. Although the outcomes of the case carry retrospectively obvious ethical overtones, the schemas driving my perceptions and actions precluded considerations of the issues in ethical terms because the scripts did not include ethical dimensions.[10]

We have to be careful not to allow an appreciation of the influence of organizational culture to completely override a belief in individual moral responsibility. Nevertheless, employees, including professional employees, do make decisions in the context of the organization in which they are employed, and one needs to understand the forces that bear upon his or her decision-making.

Some Recommendations

Bearing in mind the sorts of problems discussed earlier in the text, we offer the following recommendations, for both employees and their organizations:

First, engineers and other employees should be encouraged to report bad news. Sometimes there are formal procedures for lodging complaints and warnings about impending trouble. If possible, there should be formal procedures for lodging complaints. One of the best known procedures is the Differing Professional Views and Differing Professional Opinions of the Nuclear Regulatory Commission.[11] In addition, many large corporations have "ombudsmen" and "ethics officers," who can promote ethical behavior as well as serve as a conduit for complaints. Critics have suggested, however, that in-house ethics officers are too much the creatures of the organizations in which they work; instead, they contend, outside ethics consultants should be hired to handle complaints and internal disagreements. The argument is that in-house ethics officers have been nurtured in the organizational culture and are dependent on the organizations for their salaries, so they are not able to adopt a genuinely objective perspective.[12]

Second, companies and their employees should adopt a position of *critical* loyalty rather than uncritical or blind loyalty. Uncritical loyalty to the employer is placing the interests of the employer, as the employer defines those interests, above every other consideration. Stanley Milgram's obedience studies illustrate how susceptible many of us are to complying uncritically with the requests and orders of those perceived to be in positions of authority. By contrast, critical loyalty is giving due regard to the interests of those in positions of authority, but only insofar as this is possible within the constraints of the employee's personal and professional ethics. We can think of the concept of critical loyalty for engineers as a creative middle way that seeks not only to honor the legitimate demands of the organization but also to honor the engineer's obligation to protect the public. In response to the charge that this is encouraging disloyalty, it should be pointed out that oftentimes dissenters are acting in behalf of the company, whose leaders may not appreciate the dangers ahead unless they are effectively brought to their attention by those with lesser authority. Whistleblowing outside the organization may be very unpopular within the organization, but the whistleblower may still regard this as an action of last resort that is undertaken for the long-term benefit of the organization as for the public good.

Third, when making criticisms and suggestions, employees should focus on issues rather than personalities. This helps avoid excessive emotionalism and personality clashes.

Fourth, written records should be kept of suggestions and especially of complaints. This is important if court proceedings are eventually involved. It also serves to "keep the record straight" about what was said and when it was said.

Fifth, complaints should be kept as confidential as possible for the protection of both the individuals involved and the firm.

Sixth, provisions should be made for neutral participants from outside the organization when the dispute requires it. Sometimes, employees within the organization are too emotionally involved in the dispute or have too many personal ties to make a dispassionate evaluation of the issues.

Seventh, explicit provision for protection from retaliation should be made, with mechanisms for complaint if an employee believes he or she has experienced retaliation. Next to the fear of immediate dismissal, probably the greatest fear of an employee who is in disagreement with a superior, is that he or she will suffer discrimination in promotion and job assignment, even long after the controversy is resolved. Protection from this fear is one of the most important of employee rights, although it is one of the most difficult to provide.

Eighth, the process for handling organizational disobedience should proceed as quickly as possible. Delaying resolution of such issues can be a method of punishing dissent. Sufficient delay often allows management to perform the actions against which the protest was made. Prolonging the suspense and cloud of suspicion that accompanies an investigative process also serves to punish a protesting employee, even if his or her actions were completely justifiable.

As we have said, these are recommendations. Organizations that take them seriously provide a more supportive environment for engineers than those that do not.

The extent to which any given organization does so, of course, remains to be seen.

4.4 PROPER ENGINEERING AND MANAGEMENT DECISIONS

Functions of Engineers and Managers

How should we understand the boundary between decisions that should be made by engineers and those that should be made by managers? An answer to this question must begin with a delineation of the proper functions of engineers and managers in an organization and of the contrasting points of view associated with these differing functions.

The primary function of engineers within an organization is to use their technical knowledge and training to create structures, products, and processes that are of value to the organization and its customers. But engineers are also professionals, and they must endeavor to uphold the standards that their profession has decided should guide the use of their technical knowledge. Thus, engineers have a dual loyalty—to the organization and to their profession. Their professional loyalties go beyond their immediate employer.[13] See Box 4.3.

As we indicated in Chapter 3, the engineer's obligations include meeting the standards usually associated with good design and accepted engineering practice. The criteria embedded in these standards include such considerations as efficiency and economy of design, the degree of invulnerability to improper manufacturing and operation, and the extent to which state-of-the-art technology is used.[14] We summarize these considerations by saying that engineers have a special concern for quality.

BOX 4.3 The Dual Loyalty of Engineers

Engineers are professionals, and they must endeavor to uphold the standards that their profession has decided should guide the use of their technical knowledge. Thus, engineers have a dual loyalty—to the organization and to their profession.

Engineers also ascribe preeminent importance to safety. Moreover, they are inclined to be cautious in this regard, preferring to err on the conservative side in safety considerations. In the *Challenger* case, for example, the Morton Thiokol engineers did not have firm data on the behavior of the O-rings at low temperatures, even though their extrapolations indicated that there might be severe problems. So their initial recommendation was against the launch.

The function and consequent perspective of managers is different. Their function is to direct the activities of the organization, including many of the activities of engineers. Rather than being oriented toward standards that transcend their organization, they are more likely to be governed by the standards that prevail within the organization and, in some cases, perhaps by their own personal moral beliefs. Managers view themselves as custodians of the organization and are primarily concerned with its current and future well-being. This well-being is measured for the most part in economic terms, but it also includes such considerations as public image and employee morale.

Rather than thinking in terms of professional practices and standards, managers tend to enumerate all of the relevant considerations ("get everything on the table," as they sometimes say) and then balance them against one another to come to a conclusion. Managers feel strong pressure to keep costs down and may believe engineers sometimes go too far in pursuing safety, often to the detriment of such considerations as cost and marketability. By contrast, engineers tend to assign a serial ordering to the various considerations relevant to design so that minimal standards of safety and quality must be met before any other considerations are relevant.[15] Although they may also be willing to balance safety and quality against other factors to some extent, engineers are more likely to believe that they have a special obligation to uphold safety and quality standards in negotiations with managers. They will usually insist that a product or process must never violate accepted engineering standards and that changes be made incrementally. These considerations suggest a distinction between what we call a proper engineering decision (PED), a decision that should be made by engineers or from an engineering perspective, and what we call a proper management decision (PMD), a decision that should be made by managers or from the management perspective. While not claiming to give a full definition of either PED or PMD in the sense of necessary and sufficient conditions, we can formulate some of the features that should ordinarily characterize these two types of decision procedures. We refer to the following descriptions as "characterizations" of proper engineering and management decisions (Box 4.4).

BOX 4.4 Proper Engineering and Proper Management Decisions

- **Proper Engineering Decision (PED)**: It is a decision that should be made by engineers or at least governed by professional engineering standards because it either involves technical matters that require engineering expertise or falls within the ethical standards embodied in engineering codes, especially those that require engineers to protect the health and safety of the public.
- **Proper Management Decision (PMD)**: It is a decision that should be made by managers or at least governed by management considerations because it involves factors relating to the well-being of the organization, such as cost, scheduling, and marketing, and employee morale or welfare; and the decision does not force engineers (or other professionals) to make unacceptable compromises with their own technical or ethical standards.

We make three preliminary remarks about these characterizations of engineering and management decisions. First, the characterizations of the PED and PMD show that the distinction between management and engineering decisions is made in terms of the standards and practices that should predominate in the decision-making process. Furthermore, the PMD makes it clear that management standards should not override engineering standards when the two are in substantial conflict, especially with regard to safety and perhaps even quality. However, what is considered a "substantial conflict" may often be controversial. If engineers want much more than acceptable safety or quality, then it is not clear that the judgment of engineers should prevail. Second, the PMD specifies that a legitimate management decision not only must not force engineers to violate their professional practices and standards but also must not force other professionals to do so either. Even though the primary contrast here is the difference between engineering and management decisions, the specification of a legitimate management decision must also include this wider prohibition against the violation of other professional standards. A complete characterization of a legitimate management decision should also include prohibitions against violating the rights of nonprofessional employees, but this would make the characterization even more complicated and is not relevant for our purposes.

Third, engineers should be expected to give advice, even in decisions properly made by managers. Management decisions can often benefit from the advice of engineers (Box 4.5). Even if there are no fundamental problems with safety, engineers may have important contributions with respect to such issues as improvements in design, alternative designs, and ways to make a product more attractive. Furthermore, engineers may be in the best position to anticipate the sorts of problems products could pose down the road—problems regarding how well the product functions and in regard to making repairs or improvements when necessary.

BOX 4.5 Engineers Advising Managers

- As best they can, engineers need to forewarn managers of the problems that may lie ahead and advise them of available alternatives.
- This requires the exercise of engineering imagination and the employment of good communication skills with those who may not have their engineering expertise.

Paradigmatic and Nonparadigmatic Examples

Several terms in our characterizations of PED and PMD are purposely left undefined. The characterization of the PED does not define "technical matters," and it certainly does not define "health" and "safety." PMD does not fully specify the kinds of considerations that are typical management considerations, citing only "factors relating to the wellbeing of the company, such as cost, scheduling, marketing, and employee morale or welfare." The characterization of the PMD requires that management decisions not force engineers to make "unacceptable compromises with their own professional standards," but it does not define "unacceptable." We do not believe that it is useful to attempt to give any general definition of these terms. The application of these terms will be relatively uncontroversial in some examples, and no attempts at definition can furnish a definitive clarification in all of the controversial cases.

It will be useful to employ the line-drawing technique in handling moral issues that arise in this area. We refer to the relatively uncontroversial examples of PEDs and PMDs as paradigmatic.[16] The characterizations of PED and PMD provided earlier are intended to describe such paradigms. These two paradigms can be thought of as marking the two ends in a spectrum of cases.

We can easily imagine a paradigmatic PED. Suppose engineer Johnson is participating in the design of a chemical plant that her firm will build for itself. She must choose between valve A and valve B. Valve B is sold by a friend of Jane's manager, but it fails to meet minimum specifications for the job. It has, in fact, been responsible for several disasters involving loss of life, and Johnson is surprised that it is still in the market. Valve A, by contrast, is a state-of-the-art product. Among other things, it has a quicker shutoff mechanism and is also much less prone to malfunctions in emergencies. Although it is 5 percent more expensive, the expense is one that Johnson's firm can well afford. Valve A, therefore, is the clear and unequivocal choice in terms of both quality and safety. **Table 4.1** illustrates this.

Here, the decision should be made by Jane or other engineers, or at least in accordance with engineering considerations. This is because (1) the decision involves issues related to accepted technical standards and (2) the decision relates in important ways to the safety of the public and therefore to the ethical standards of engineers. The choice between valves A and B is a paradigmatic PED.

We can modify the example to make it a paradigmatic PMD. Suppose valves A and B are equal in quality and safety, but valve B can be supplied much faster than valve A, is 15 percent cheaper, and is manufactured by a firm that is a potential customer for some of the products of Jane's firm. Valve A, however, is made by a

TABLE 4.1 A Paradigmatic PED

Feature	PMD	Test	PED
Technical expertise	Not needed	______________ X	Needed
Safety	Not important	______________ X	Important
Cost	Important	______________ X	Not important
Scheduling	Important	______________ X	Not important
Marketing	Important	______________ X	Not important

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TABLE 4.2 A Paradigmatic PMD

Feature	PMD	Test	PED
Technical expertise	Not needed	X ________________	Needed
Safety	Not important	X ________________	Important
Cost	Important	X ________________	Not important
Scheduling	Important	X ________________	Not important
Marketing	Important	X ________________	Not important

firm that is potentially an even bigger customer for some of the products of Johnson's firm, although cultivating a relationship with this firm will require a long-term commitment and be more expensive. If there are no other relevant considerations, the decision as to whether to purchase valve A or valve B should be made by managers, or at least made in accordance with management considerations. Comparing the decision by the two criteria in the PMD, we can say that (1) management considerations (e.g., speed of delivery, cost, and the decision as to which customers should be cultivated) are important, and (2) no violation of engineering considerations would result from either decision. **Table 4.2** illustrates this case.

Many cases will lie between the two extremes of paradigmatic PEDs and paradigmatic PMDs. Some cases may lie so near the center of the imaginary spectrum of cases that they might be classified as either PED or PMD. Consider another version of the same case in which valve A has a slightly better record of long-term reliability (and is therefore somewhat safer), but valve B is 10 percent cheaper and can be both delivered and marketed more quickly. In this case, rational and responsible people might well differ on whether the final decision on which valve to buy should be made by engineers or managers. Considerations of reliability and safety are engineering considerations, but considerations of cost, scheduling, and marketing are typical management considerations. **Table 4.3** illustrates this situation. Would ordering valve B be an "unacceptable" compromise of engineering standards of safety and quality? Are the cost, scheduling, and marketing problems significant enough to overbalance the engineering considerations? Here, rational people of good will might differ in their judgments. In considering a case such as this, it is important to remember that, as in all line-drawing cases, the importance or moral "weight" of the

TABLE 4.3 PED/PMD: A Nonparadigmatic Case

Feature	PMD	Test	PED
Technical expertise	Not needed	______________X______	Needed
Safety	Not important	___________X_________	Important
Cost	Important	____X________________	Not important
Scheduling	Important	__________X__________	Not important
Marketing	Important	__________X__________	Not important

feature must be considered. One cannot simply count the number of features that fall on the PMD or PED side or where the "X" should be placed on the line.

Many issues regarding pollution also illustrate the problematic situations that can arise in the interface between proper engineering and PMDs. Suppose process A is so much more costly than process B that the use of process A might threaten the survival of the company. Suppose, furthermore, that process B is more polluting, but it is not clear whether the pollution poses any substantial threat to human health. Here again, rational people of good will might differ on whether management or engineering considerations should prevail.

4.5 RESPONSIBLE DISSENT

Sometimes engineers encounter serious difficulties in attempting to be both loyal employees and responsible professionals. In some instances, they may wonder whether "whistleblowing" on their part is called for. What guidelines should a responsible engineer make use of in deciding whether (and how) to undertake such a course of action?

A Case to Consider: *Richard M. Nixon v. Ernest Fitzgerald*

In 1969, President Richard M. Nixon asked for the termination of Ernest Fitzgerald, an engineer and manager for the U.S. Air Force. In 1965, Fitzgerald was Deputy for Management Systems at the Pentagon. Early in his work, he began warning superiors about cost overruns on defense contracts. Other employees were blindly following orders from their officers to conceal the cost overruns, but not Fitzgerald. In 1968 and 1969, he insisted on testifying before Congress about $2.3 billion in concealed cost overruns in the Lockheed C-5A transport plane. Because of his testimony before Congress, he was fired by order of President Nixon for allegedly revealing classified information.[17] Fitzgerald was fired by Secretary of Defense Melvin Laird. In an appeal, he was reinstated.[18] Fitzgerald was involved in several legal cases that defined government employees' rights, including the U.S. Supreme Court case *Nixon v. Fitzgerald*. He was influential in the passage the Civil Reform Act of 1978, which was the forerunner to the Whistleblower Protection Act of 1989.[19]

As the example of Ernest Fitzgerald illustrates, in some situations, engineers find the actions of the employer to be so objectionable that they believe mere nonparticipation in the objectionable activity is insufficient. Rather, some form of outward protest, or "whistleblowing," is required. After making some general comments about whistleblowing, we will consider two important theories of whistleblowing.

What Is Whistleblowing?

The origin and exact meaning of the metaphor of "whistleblowing" are uncertain. According to Michael Davis, there are three possible sources of the metaphor: a train sounding a whistle to warn people to get off the track, a referee blowing a whistle to indicate a foul, or a police officer blowing a whistle to stop wrongdoing.[20] One problem with all of these metaphors, Davis points out, is that they depict whistleblowers as outsiders, whereas typically a whistleblower is more like a team player who calls a foul play on his own team. This suggests two characteristics of whistleblowing: (1) One reveals information that the organization does not want to be shared with the public or some authority; and (2) one does this outside of approved channels in the organization.[21]

A whistleblower is usually defined as a person who is an insider, one who is a part of the organization. For this reason, the question of loyalty arises.

4.6 WHISTLEBLOWING AND LOYALTY

When considering whistleblowing, the question of company loyalty needs to be considered because a whistleblower is an individual who is part of the company. The individual will release information outside of company channels. Generally, the whistleblower will reveal information that the organization doesn't want public.

Whistleblowing: A Harm-Preventing Justification

Richard DeGeorge has provided a set of criteria that he contends must be satisfied before whistleblowing can be morally justified.[22] DeGeorge believes that whistleblowing is morally *permissible* provided that

1. the harm that "will be done by the product to the public is serious and considerable";
2. the employees report their concern to their immediate superiors; and
3. getting no satisfaction from their immediate superiors, they exhaust the channels available within the organization.

DeGeorge believes that whistleblowing is morally *obligatory* provided that

1. the employee has "documented evidence that would convince a responsible, impartial observer that his view of the situation is correct and the company policy is wrong"; and
2. the employee has "strong evidence that making the information public will in fact prevent the threatened serious harm."

Within the DeGeorge model, we note the potential harm to the public. This is what initiates the consideration that whistleblowing might be justified. The public will benefit if these harms are eliminated. There is also potential harm to the organization, and the prospective whistleblower must attempt to minimize this harm by first trying to use available channels within the organization. There is also potential harm to the whistleblower, and the risk of harm must only be undertaken when there is some assurance that others would be convinced of the wrong and the harm might be prevented. There is no reason, DeGeorge seems to believe, to risk one's career if there is little chance the whistleblowing will have the desired effect. Taken as general tests for justified or required whistleblowing have much to be said for them. However, there are times when DeGeorge's criteria are too demanding.[23]

1. The first criterion seems too strong. DeGeorge seems to assume that the employee must know that harm will result and that the harm must be great. Sometimes an employee is not in a position to gather evidence that is totally convincing. Perhaps just believing on the basis of the best evidence available that harm will result may be sufficient.
2. It should not always be necessary for employees to report their criticisms to their superiors. Often, one's immediate superiors are the cause of the problem and cannot be trusted to give unbiased evaluation of the situation.

3. It should not always be necessary to exhaust the organizational chain of command. There is not always time to do this before a disaster will occur. Also, sometimes employees have no effective way to make their protests known to higher management except by going public.
4. It is not always possible to get documented evidence of a problem. Often, organizations deprive employees of access to the vital information needed to make a conclusive argument for their position. They deprive protesting employees of access to computers and other sources of information necessary to make their case.
5. The obligation to make the protest may not always mean there will be strong evidence that a protest will prevent the harm. Just giving those exposed to a harm the chance to give free and informed consent to the potential harm is often a sufficient justification of the protest.

Whistleblowing: A Complicity-Avoiding View

Michael Davis proposes a very different theory of the justification of whistleblowing: "We might understand whistleblowing better if we understand the whistleblower's obligation to derive from the need to avoid complicity in wrongdoing rather than from the ability to prevent harm."[24] Davis formulates his "complicity theory" in the following way.

You are morally required to reveal what you know to the public (or to a suitable agent or representative of it) when

(C1) what you will reveal derives from your work for an organization;
(C2) you are a voluntary member of that organization;
(C3) you believe that the organization, though legitimate, is engaged in a serious wrong;
(C4) you believe that your work for that organization will contribute (more or less directly) to the wrong if (but not only if) you do not publicly reveal what you know;
(C5) you are justified in beliefs C3 and C4; and
(C6) beliefs C3 and C4 are true.[25]

According to complicity theory, the primary moral motivation for blowing the whistle is to avoid participating in a wrongful action, not to prevent a harm to the public.

Davis' approach to the moral justification of whistleblowing has several distinct advantages. First, since preventing harm to the public is not necessarily a motivation for whistleblowing, one does not have to know that harm would result if he does not blow the whistle. Second, since preventing harm to the organization is not necessarily a motivation for blowing the whistle, one does not have to first work through organizational channels. Nevertheless, there are some concerns with Davis' theory as well.[26]

BOX 4.6 Complicity Theory and Whistleblowing

1. Within complicity theory, the whistleblower does not want to be complicit in wrongdoing in the organization.
2. Preventing harm to the company isn't essential for blowing the whistle.
3. Preventing harm to the public is desirable, but not a necessary part of the justification for whistleblowing.

First, Davis requires that a person be a voluntary member of an organization. But suppose Williams, an army draftee, discovers a situation that poses a serious threat to his fellow soldiers. Williams has a moral obligation to blow the whistle, and the fact that he was drafted seems to have little relevance.

Second, Davis seems to have underestimated the importance of what many people would consider to be a clear—and perhaps the most important—justification of whistleblowing, namely that it is undertaken to prevent harm to the organization or (more often) to the public. Although avoiding complicity in wrongdoing is a legitimate and important justification for blowing the whistle, at the very least, it need not be the only one. In fact, combining this with the desire to prevent harm to the organization or the public would seem to offer a much more compelling case for whistleblowing than Davis's focus on avoiding complicity alone. "Complicity in what?" one may ask. Complicity in allowing harm to the organization or to the public would be the powerful answer.

We will close this chapter with an analysis of two classic cases of whistleblowing, taking into consideration what has been said so far about responsible dissent and also discussing complications that can arise even when the dissenters seem to have acted responsibly.

4.7 THE CASE OF PAUL LORENZ

Paul Lorenz was a mechanical engineer employed by Martin Marietta. He was laid off on July 25, 1975 for allegedly refusing to engage in acts of deception and misrepresentation concerning the quality of materials used by Martin Marietta in designing equipment for the National Aeronautics and Space Administration (NASA). The equipment was for the external tank of the space shuttle program. Before he was laid off, Lorenz was informed that he should "start playing ball with management." After being laid off, he filed a tort claim against Martin Marietta for wrongful discharge on the grounds that he was fired for refusing to perform an illegal act. Federal law does prohibit knowingly and willingly making a false representation to a federal agency. However, lower courts rejected Lorenz's claim of wrongful dismissal on the grounds that Colorado recognized no claim of wrongful discharge against employers.

In 1992, the Colorado Supreme court concluded that "Lorenz did present sufficient evidence at trial to establish a prima facie case for wrongful discharge under the public-policy exception to the at-will employment doctrine." The Court directed a new trial in accordance with its findings, but this never took place, probably because of an out-of-court settlement between Mr. Lorenz and his former employer.[27]

Analysis of Lorenz Case

This is an important case in the development of the law regarding the rights of professional employees in the workplace. The crucial idea in the case was the so-called "public-policy exception" to the traditional common law doctrine of "employment at will." Common law is the tradition of case law or "judge-made law" that originated in England and is fundamental in U.S. law. It is based on a tradition in which a judicial decision establishes a precedent, which is then used by succeeding jurists as the basis for their decisions in similar cases. Common law is distinguished from statutory law, or laws made by legislative bodies.

Traditionally, U.S. law has been governed by the common law doctrine of "employment at will," which holds that in the absence of a contract, an employer may discharge an employee at any time and for virtually any reason. Court decisions, such as this one, have held that the traditional doctrine must be modified if there is an important interest at stake. Precisely how far the public policy exception extends is still being formulated by the courts, but it includes such things as a refusal to break the law (such as in the Lorenz case), performing an important public obligation (e.g., jury duty), exercising a clear legal right (e.g., exercising free speech or applying for unemployment compensation), and protecting the public from a clear threat to health and safety. In general, the public policy exception has not been invoked to protect an employee when there is a mere difference in judgment with the employer.[28] The courts have also given more weight to the codes of administrative and judicial bodies, such as state regulatory boards, than to the codes promulgated by professional societies.[29]

In addition to the judicial modification of at-will employment, dissenting employees have also received some statutory protection, primarily through whistleblower laws. The first such state law was passed in Michigan in 1981. If the employee is unfairly disciplined for reporting an alleged violation of federal, state, or local law to public authorities, the employee can be awarded back pay, reinstatement to the job, costs of litigation, and attorney's fees. The employer can also be fined up to $500.[30] New Jersey's Conscientious Employee Protection Act forbids termination for conduct undertaken for the sake of compliance with "a clear mandate of public policy concerning the public health, safety, or welfare."[31] Many cases in the area of what might very generally be called "employee rights" involve nonprofessional employees, but our special interest is professional employees, especially engineers. Many of the cases, like the Lorenz case, involve a conflict between professional employees and managers. In fact, most of the classic cases in engineering ethics involve conflicts between engineers and managers.

4.8 ROGER BOISJOLY AND THE *CHALLENGER* DISASTER

Two events in the professional life of engineer Roger Boisjoly, both related to the 1986 *Challenger* disaster, illustrate several themes in this chapter. One of these events is the teleconference between Morton Thiokol and NASA the night before the launch of the *Challenger*. This dramatic event illustrates the conflict between engineers and management in decision-making. The second experience is Boisjoly's testimony before the Presidential Commission on the Space Shuttle *Challenger* Accident. Boisjoly's testimony raises the issue of whistleblowing and the extent of the legitimacy of loyalty of an engineer to the organization in which he or she is employed.

Proper Management and Engineering Decisions

Robert Lund, vice president of engineering at Morton Thiokol, was both an engineer and a manager. In the teleconference on the evening before the fateful launch, he, in concert with other engineers, had recommended against launch. The recommendation was based on a judgment that the primary and secondary O-rings might not seal properly at the low temperatures at which the vehicle would be launched. NASA officials expressed dismay at the no-launch recommendation, and Thiokol executives requested an interruption in the teleconference to reassess their decision. During the 30-minute interruption, Jerald Mason, senior vice president of Morton Thiokol, turned to Lund and told him to take off his engineering hat and put on his management hat. Afterward, Lund reversed his no-launch recommendation.

BOX 4.7 Engineering Hat

In the *Challenger* disaster, Robert Lund was told to take off his engineering hat and put on his management hat. This brought about the last-minute reversal of a long-standing policy, requiring the burden of proof to rest with anyone recommending a no-launch rather than a launch decision. This was a serious threat to the integrity of the engineering obligation to protect human life.

In admonishing Lund to take off his engineering hat and put on his management hat, Mason was saying that the launch decision should be a management decision (Box 4.7). Testifying before the Rogers Commission, which investigated the *Challenger* accident, Mason gave two reasons for this belief. First, the engineers were not unanimous: "[W]ell, at this point it was clear to me we were not going to get a unanimous decision."[32] If engineers disagreed, then there was presumably not a clear violation of the technical or ethical standards of engineers; thus, it could be argued that neither requirement of the PMD was being violated.

There are reasons to doubt the factual accuracy of Mason's claim, however. In his account of the events surrounding the *Challenger* given at the Massachusetts Institute of Technology (MIT) in 1987, Roger Boisjoly reported that Mason asked the Morton Thiokol engineers if he was "the only one who wanted to fly."[33] This would suggest that Mason did not have evidence at this point that other engineers supported the launch. Whatever validity Mason could give to his argument that some engineers supported the launch (and therefore that the opposition of the engineers to the launch was not unanimous) was apparently based on conversations with individual engineers after the teleconference. Nevertheless, Mason may be correct in maintaining that there was some difference of opinion among those most qualified to render judgment, even if this information was not confirmed until after the event. If engineers disagreed about the technical issues, then the engineering considerations were perhaps not as compelling as they would have been if the engineers had been unanimous.

Mason's second reason was that no numbers could be assigned to the time required for the O-rings to seal at various temperatures:

Dr. Keel: Since Mr. Lund was your vice president of engineering and since he presented the charts and the recommendations not to launch outside of your experience base—that is, below a temperature of 53 degrees for the O-rings—in the previous 8:45 Eastern Standard Time teleconference, what did you have in mind when you asked him to take off his engineering hat and put on his management hat?

Mr. Mason: I had in mind the fact that we had identified that we could not quantify the movement of that, the time for movement of the primary [O-ring]. We didn't have the data to do that, and therefore it was going to take a judgment rather than a precise engineering calculation, in order to conclude what we needed to conclude.[34]

This might also be a reason for holding that the decision to launch did not violate criterion 2 of the PMD and did not clearly satisfy criterion 1 of the PED. However, the fact that no calculations could be made to determine the time it would take the O-rings to seal at various temperatures does not necessarily justify the conclusion that a management decision should be made. Surely the fact that failure of the O-rings to seal could destroy the *Challenger* implies that the engineering considerations were of paramount importance even if they could not be adequately qualified. The engineer's concern for safety is still relevant.

Nevertheless, Mason's comment may make a valid observation. Given that engineers generally prefer to make judgments on the basis of quantitative calculations, they may well have been uncomfortable with the fact that there were no precise numbers for the degree of degradation of the O-rings at lower temperatures. As a result, the engineering judgment did not have the same degree of decisiveness that it would have had otherwise. All that Roger Boisjoly could argue was that the degree of degradation seemed to be correlated with temperature, and even the data he used to back up this claim were limited.

Mason's arguments, taken together, might be seen as an attempt to meet criterion 2 of the PMD. If the decision to recommend launch is not a clear violation of engineering practice, then an engineer would not violate his technical practices by recommending launch. Thus, Mason's argument could be seen as a claim that the decision whether to launch was at the very least not a paradigm instance of a PED. A paradigm PED would be one in which (among other things) the experts clearly agree and there are quantitative measures that unambiguously point to one option rather than another. Thus, the recommendation to launch was at the very least not a paradigm case of a violation of technical engineering practices.

Mason might also have argued that criterion 1 of the PMD was satisfied. A renewed contract with NASA was not assured, and failure to recommend launch might have been the decisive factor that persuaded NASA officials not to renew the contract with Morton Thiokol. Thus, the well-being of the company might have been substantially harmed by a no-launch recommendation.

Despite these arguments, we believe that the launch decision was properly an engineering decision, even though it perhaps was not a paradigm case of such a decision.

First, criterion 1 of the PMD was not as compelling a consideration as Mason may have supposed. There was no evidence that a no-launch decision would threaten the survival of Morton Thiokol, or even that it would in any fundamental way jeopardize Thiokol's well-being. In any case, engineering considerations should have had priority.

Second, criterion 2 of the PED was relevant because the decision to launch violated the engineer's propensity to modify or change criteria only in small increments. The temperature on the launch day was more than 20 degrees below that of any previous launch day. This was an enormous change, which should have given an engineer good reason to object to the launch.

Third, criterion 1 of the PED was relevant. Even though the quantitative data were limited and clearly did not give conclusive evidence that there would be a disaster, the data did seem to point in that direction so that the engineering need for quantitative measures was satisfied to some extent. Engineers, furthermore, are alert to the fact that composites, such as the ones the O-rings are made of, are temperature sensitive and that one could reasonably expect substantially lower temperatures to produce substantially greater blow-by problems.

Fourth, criterion 2 of the PED was also relevant because life was at stake. Engineers are obligated by their codes of ethics to be unusually cautious when the health and safety of the public are involved. This should be particularly important when those at risk do not give informed consent to special dangers. This was the case with the astronauts, who did not have any knowledge of the problems with the O-rings. The importance of the safety issue was further highlighted because of the violation of the practice of requiring the burden of proof to be borne by anyone advocating a launch decision rather than a no-launch decision. In testimony before the Rogers Commission, Robert Lund recounts this all-important shift in the burden of proof:

Chairman Rogers: How do you explain the fact that you seemed to change your mind when you changed your hat?

Mr. Lund: I guess we have got to go back a little further in the conversations than that. We have dealt with Marshall for a long time and have always been in the position of defending our position to make sure that we were ready to fly, and I guess I didn't realize until after that meeting and after several days that we had absolutely changed our position from what we had before. But that evening I guess I had never had those kinds of things come from the people at Marshall that we had to prove to them that we weren't ready.... And so we got ourselves in the thought process that we were trying to find some way to prove to them it wouldn't work, and we were unable to do that. We couldn't prove absolutely that the motor wouldn't work.

Chairman Rogers: In other words, you honestly believed that you had a duty to prove that it would not work?

Mr. Lund: Well that is kind of the mode we got ourselves into that evening. It seems like we have always been in the opposite mode. I should have detected that, but I did not, but the roles kind of switched.[35]

This last-minute reversal of a long-standing policy, requiring the burden of proof to rest with anyone recommending a no-launch rather than a launch decision, was a serious threat to the integrity of the engineering obligation to protect human life.

Although hindsight no doubt benefits our judgment, it does seem that the decision whether to recommend launch was properly an engineering decision rather than a management decision, even though it may not have been a paradigm case of a PED. There is insufficient reason to believe that the case diverged so much from the paradigm engineering decision that management considerations should have been allowed to override the engineering constraints. Engineers, not managers, should have had the final say on whether to launch. Or, if the person making the recommendation wore both an engineering hat and a management hat—as Robert Lund did—he should have kept his engineering hat on when he made the decision. The distinction between paradigmatic engineering and management decisions and the attendant methodology developed here help to confirm this conclusion.

Whistleblowing and Organizational Loyalty

Boisjoly's attempt in the teleconference to stop the launch was probably not an instance of whistleblowing. It certainly was not an instance of external whistleblowing because Boisjoly made no attempt to alert the public or officials outside Thiokol and NASA. His actions on the night before the launch were probably not even internal whistleblowing because (1) they did not involve revealing information that was not known (rather, they made arguments about the information already available) and (2) he did not go out of approved channels. His testimony before the Rogers Commission, however, might be considered a case of whistleblowing because it did fulfill these two criteria. His testimony revealed information that the general public did not know, and it used channels outside the organization, namely the Rogers Commission. Was his testimony a case of justified whistleblowing?

First, let us look at DeGeorge's criteria. Since his criteria focus on preventing harm, our first response might be to say that Boisjoly's testimony before the Rogers Commission could not be an instance of whistleblowing because the tragedy had already occurred. One writer has argued, however, that Boisjoly thought his testimony might contribute to the safety of future flights. He cites as his evidence a speech Boisjoly made at MIT, during which he reminded the audience that, as professional engineers, they had a duty "to defend the truth and expose any questionable practice that may lead to an unsafe product."[36] Whether or not Boisjoly actually believed his testimony might prevent future disasters, we can ask whether his testimony is in fact justified as a possible way to prevent future disasters. Certainly the harm of future disasters is serious and considerable (criterion 1). We can probably agree that, given his past experience, Boisjoly had reason to believe that reporting his concerns to his superiors would not be sufficient to bring about needed changes (criteria 2 and 3). If this is correct, his testimony, considered as a case of whistleblowing, would be permissible, even if not obligatory. Given the facts of the *Challenger* disaster, his testimony would probably convince a responsible, impartial observer that something should be done to remedy the O-ring problems (criterion 4). Whether he had strong evidence for believing that making this information public would prevent such harms in the future (criterion 5) is probably much more doubtful.

We can probably conclude, therefore, that from the standpoint of DeGeorge's criteria, Boisjoly's whistleblowing was justified but not required. In any case, it is clear that the major issue has to do with the legitimacy of our beliefs about the consequences of certain courses of action.

Now let us consider Boisjoly's testimony from the standpoint of Davis' criteria for justified whistleblowing. Unlike DeGeorge's criteria, where concern for preventing future harms must be the primary consideration, here we must be concerned with Boisjoly's need to preserve his own moral integrity. Was he complicit enough in the wrongdoing so that whistleblowing was necessary to preserve his own moral integrity? To review the criteria, his whistleblowing was certainly related to his work in the organization. Furthermore, he was a voluntary member of that organization. Also, he almost certainly believed that Morton Thiokol, though a legitimate organization, had made a serious mistake—one that should not be repeated. The central issue is raised by the fourth criterion, namely whether he believed that continued silence would make him complicit in possible future wrongdoing resulting from no significant changes being made at Morton Thiokol and NASA.

In order to better focus on the question of what it means to say that one contributes to wrongdoing, A. David Kline asks us to consider the following two examples.[37] In the first example, Researcher 1 is directed by his tobacco company to provide a statistical analysis that shows that smoking is not addictive. He knows that his analysis is subject to serious criticism, but his company nevertheless uses his work to mislead the public. In the second example, Researcher 2 is directed by his tobacco company to study the issue of smoking and addiction. He concludes that there is strong evidence that smoking is addictive, but his firm ignores his work and makes public claims that smoking is not addictive. According to Kline, Researcher 1 is complicit in the deception of the public, and Researcher 2 is not complicit. However, Boisjoly's situation, according to Kline, is closer to that of Researcher 2 than that of

Researcher 1. Since the claim that Boisjoly was complicit in wrongdoing is false, Kline believes that Davis cannot justify Boisjoly's blowing the whistle by his criteria. Boisjoly need not blow the whistle in order to preserve his own moral integrity.

However, let us modify Davis' criteria so that the question becomes whether remaining silent would make Boisjoly complicit in future wrongdoing by Thiokol. Here, there are two questions: whether blowing the whistle would prevent future wrongdoing and whether silence would make Boisjoly complicit in any future wrongdoing. If the answer to both of these questions is in the affirmative, Boisjoly's professional integrity would seem to be at stake.

We shall leave it to the reader to more fully explore these questions, but only point out that both theories of whistleblowing make useful contributions to discussion of the moral dimensions of Boisjoly's testimony. It is important to ask whether blowing the whistle will prevent wrongdoing and to ask whether and to what extent our own moral integrity is compromised by silence. In practical deliberation, both questions are important. A final issue raised by Boisjoly's testimony is whether he violated the obligation of loyalty to his firm. If that obligation calls for uncritical loyalty, he certainly fell short. But if the obligation of loyalty permits, if not requires, critical loyalty, Boisjoly could argue that he met this obligation.

In any case, it should be noted that the path of dissent taken by Boisjoly was not an easy one. It seldom is for whistleblowers. But, although he suffered rebuke from colleagues and many members of his community, Boisjoly seems not to have regretted his decision to speak up. He sought to do what he thought was right, even at the expense of great personal suffering.

4.9 CHAPTER SUMMARY

Outstanding organizational leaders such as Interface Carpets' Ray Anderson have set high standards for organizational behavior and communication. Anderson expected ethical employees who value the customer and the communities where they operate. With thorough communication, small work teams, and other strategies, the culture within an organization can be agreeable.

Conflicts between employees, including engineers, and managers often occur in the workplace. Sociologist Robert Jackall gives a negative account of the moral integrity of managers, implying that it may be difficult for an employee to preserve his integrity in the workplace. Other writers, however, have contradicted this account, implying that employees can usually be morally responsible without sacrificing their careers. In order to preserve their careers and their integrity, employees should educate themselves in the "culture" of their organization. They should also adopt some common-sense techniques for minimizing the threats to their careers when making a legitimate protest.

Given that engineers and managers have different perspectives, problems can be avoided if organizations make a distinction between decisions that should be made by managers and decisions that should be made by engineers. In general, engineers should make the decision when technical matters or issues of professional ethics are involved. Managers should make the decision when considerations related to the well-being of the organization are involved and the technical and ethical standards of engineers are not compromised. Many decisions do not neatly fall into either category, and the line-drawing method can be useful in deciding who should make a decision.

There are some occasions in which engineers face the question of whether they should blow the whistle on their organization. Richard DeGeorge's theory of justified whistleblowing focuses on the weighing of the relevant harms and benefits. Michael Davis' theory of justified whistleblowing focuses on the question whether whistleblowing is required in order to relieve one of complicity in wrongdoing. In any case, important as they are, questions about the justification of whistleblowing are controversial and seldom yield clear-cut answers.

NOTES

1. Ray C. Anderson and Robin White, *Confessions of a Radical Industrialist: Profits, People, Purpose—Doing Business by Respecting the Earth* (New York: St. Martin's Griffin, 2009), p. 17.
2. Ibid.
3. Ibid. Although Ray Anderson passed away in 2011, his legacy continues, both at Interface ad through programs sponsored by the Ray Anderson Foundation. The foundation sponsors an annual event, RayDay, which brings together hundreds who are devoted to reduce waste and support a sustainable environment. (For more information, search online for "Ray Anderson Foundation".)
4. Joseph A. Raelin, *The Clash of Cultures: Managers and Professionals* (Boston: Harvard Business School Press, 1985), p. xiv.
5. Ibid., p. 12.
6. Robert Jackall, *Moral Mazes: The World of Corporate Managers* (New York: Oxford University Press, 1988), p. 5.
7. Ibid., p. 69.
8. Anderson and White, *Confessions*, p. 28.
9. Christopher Meyers, "Institutional Culture and Individual Behavior: Creating the Ethical Environment," *Science and Engineering Ethics*, 10, 2004, p. 271.
10. Quoted in Patricia Werhane, *Moral Imagination and Management Decision Making* (New York: Oxford University Press, 1999), p. 56. (Cited in Raelin, *The Clash of Cultures*, p. 271.)
11. Stephen H. Unger, *Controlling Technology: Ethics and the Responsible Engineer*, 2nd ed. (New York: Wiley, 1994), pp. 122–123.
12. Meyers, op. cit., p. 257.
13. Raelin also points out the importance of professional loyalties that transcend the organization, contrasting the "local" orientation of managers with the "cosmopolitan" orientation of most professionals. While describing engineers as more locally oriented than most professionals, he does not deny that engineers have loyalties to professional norms that transcend loyalties to their own organization. See Raelin, *The Clash of Cultures*, pp. 115–118, for a description of the local–cosmopolitan distinction.
14. State-of-the-art technology may not always be appropriate. If an engineer is designing a plow for use in a less industrialized country, then simplicity, ease of repair, and availability of repair parts may be more important than the use of the most advanced technology.
15. We are indebted to Michael Davis for this and several other insights in this section. Davis uses John Rawls's term lexical ordering to describe the assigning of priorities. Rawls, however, seems to equate serial ordering with lexical ordering. He defines a lexical order as "an order which requires us to satisfy the first principle in the ordering before we can move on to the second, the second before we consider the third, and so on. A principle does not come into play until those previous to it are either fully met or do not apply. A serial ordering avoids, then, having to balance principles at all; those earlier in the ordering have an absolute weight, so to speak, with respect to the later ones, and hold

without exception." See John Rawls, *A Theory of Justice* (Cambridge, MA: Harvard University Press, 1971), p. 43; see also Michael Davis, "Explaining Wrongdoing," *Journal of Social Philosophy*, 20, Spring–Fall 1988, pp. 74–90.

16. For purposes of this analysis, we are assuming that all decisions are either PEDs or PMDs—that is, they should be made by either managers or engineers rather than by anyone else.
17. Alison Ross Wimsatt, "The Struggles of Being Ernest: A. Ernest Fitzgerald, Management Systems Deputy in the Office of the Asst. Sec of the Air Force," *Industrial Management*, July 2005, p. 28.
18. Ibid.
19. Ibid.
20. Michael Davis, "Whistleblowing," in *The Oxford Handbook of Practical Ethics*, ed. Hugh LaFollette (New York: Oxford University Press, 2003), p. 540.
21. An important distinction can be drawn between internal and external whistleblowing. In internal whistleblowing, the alarm about wrongdoing stays within the organization, although the whistleblower may bypass his immediate superiors, especially if they are involved in the wrongdoing. In external whistleblowing, the whistleblower goes outside the organization, alerting a regulatory organization or the press. Our discussion will focus on external whistleblowing. Another important distinction is between open and anonymous whistleblowing. In open whistleblowing, the whistleblower reveals his or her identity, whereas in anonymous whistleblowing, the whistleblower attempts to keep his or her identity secret.
22. Richard T. DeGeorge, *Business Ethics* (New York: Macmillan, 1982), p. 161. This account is taken directly from Richard T. DeGeorge, "Ethical Responsibilities of Engineers in Large Organizations," *Business and Professional Ethics Journal*, 1, no. 1, Fall 1981, pp. 1–14.
23. Several of these criticisms are suggested by Gene G. James, "Whistle-Blowing: Its Moral Justification," reprinted in *Ethical Issues in Engineering*, ed. Deborah G. Johnson (Englewood Cliffs, NJ: Prentice Hall, 1991), pp. 263–278.
24. Michael Davis, "Whistleblowing," p. 549.
25. Ibid, pp. 549–50.
26. Several of these criticisms are taken from A. David Kline, "On Complicity Theory," *Science and Engineering Ethics*, 12, 2006, pp. 257–264.
27. Justice Quinn, "The Opinion of the Court in *Lorenz v. Martin Marietta Corp., Inc.*" 802 P.2d 1146 (Colo. App. 1990).
28. See "Protecting Employees at Will against Wrongful Discharge: The Public Policy Exception," *Harvard Law Review*, 96, no. 8, June 1983, pp. 1931–1951.
29. Genna H. Rosten, "Wrongful Discharge Based on Public Policy Derived from Professional Ethics Codes," *52 American Law Reports*, 5, p. 405.
30. *Wall Street Journal*, April 13, 1981.
31. NJ Stat Ann at 34:19-1 to 19-8.
32. *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, vol. IV, Feb. 26, 1986 to May 2, 1986, p. 764.
33. Roger Boisjoly, "The *Challenger* Disaster: Moral Responsibility and the Working Engineer," in *Ethical Issues in Engineering*, ed. Deborah Johnson (Englewood Cliffs, NJ: Prentice Hall, 1991), p. 6.
34. *Presidential Commission on the Space Shuttle Challenger Accident*, pp. 772–773.
35. Ibid., p. 811.
36. Roger Boisjoly, "The Challenger Disaster: Moral Responsibility and the Working Engineer," op. cit., p. 14. Quoted in A David Kline, "On Complicity Theory," *Science and Engineering Ethics*, 12, 2006, p. 259.
37. Kline, op. cit., p. 262.

CHAPTER FIVE

Trust and Reliability

Main Ideas in This Chapter

- **This chapter focuses on issues regarding the importance of trustworthiness in engineers: honesty, confidentiality, intellectual property, expert witnessing, public communication, and conflicts of interest.**
- **Forms of dishonesty include lying, deliberate deception, withholding information, and failure to seek out the truth.**
- **Dishonesty in engineering research and testing includes plagiarism and the falsification and fabrication of data.**
- **Engineers are expected to respect professional confidentiality in their work.**
- **Integrity in expert testimony requires not only truthfulness but also adequate background and preparation in the areas requiring expertise.**
- **Conflicts of interest are especially problematic because they threaten to compromise professional judgment.**

IN SEPTEMBER 2016, ENGINEER JAMES ROBERT LAING, leader of diesel competence for Volkswagen (VW) from 2008 through June 2016, pled guilty to a U.S. District Court grand jury's indictment of conspiracy to defraud the U.S. government, to commit wire fraud, and to violate the Clean Air Act.[1]

In his plea, Laing admitted that he was involved in VW's efforts to cover up the development and use of a "defeat device" to enable more than 500,000 of its vehicles from 2009 to 2015 to appear to pass U.S. emissions tests. In laboratory testing of the vehicles by the government, the emissions control system operated as it should. But the "defeat device" was disabled for driving in ordinary conditions. Regulators eventually discovered that in those ordinary conditions the cars emitted up to 40 times more smog-causing nitrogen oxide than the legal limits allow.

5.1 INTRODUCTION

Noting that society has become increasingly professionalized, ethicist William F. May has observed that it has also become more dependent on the services of professionals whose knowledge and expertise are not widely shared or understood.[2] What this means is that, in our ignorance of that specialized knowledge and expertise, and of its employment in particular instances, we must hope that our reliance on the trustworthiness of professionals is warranted. These professionals include engineers, both as individuals and as members of teams of professionals. This chapter focuses on areas of moral concern that are especially relevant to the trustworthiness of engineers: honesty, confidentiality, intellectual property, expert witnessing, informing the public, and conflicts of interest.

As May puts it, there is "knowledge explosion" that comes with increasing expertise, but it is largely confined to the experts. So, it is accompanied by an "ignorance explosion" for those who do not share it; and none of us has expertise enough to be exempt from this. So, May concludes: "[Professionals] had better be virtuous. Few may be in a position to discredit [them]…. [I]f knowledge is power, then ignorance is powerlessness." He adds: "One test of character and virtue is what a person does when no one is watching. A society that rests on expertise needs more people who can pass that test."[3] As will no doubt eventually be confirmed, engineer Laing is just one of several engineers at VW who were complicit in its diesel emissions scandal. Insofar as they were, they would seem to have failed May's test for experts.

5.2 HONESTY

Whatever else passing May's test requires of engineers, it would seem that honesty in their professional work is fundamental. For honesty to play the basic role May is seeking, it must be a *virtue*. In Chapter 2 (Section 2.13), we characterized a virtue as a dispositional trait that inclines one to do the right thing. Although there may be special occasions in which an engineer is justified in lying in his or her professional role, this is rare. In any case, what would justify this is not the fact that no one is watching. Fortunately, those who have acquired the virtue of honesty can be trusted to abide by it even when no one is watching. It is, as we say in Chapter 2, a part of one's character.

The value placed on honesty in engineering practice is reflected in the many provisions about honesty and truthfulness that can easily be found in the codes of ethics of engineering societies. For example, the third canon of the code of ethics of the Institute of Electrical and Electronics Engineers (IEEE) encourages all members "to be honest and realistic in stating claims or estimates based on available data." Canon 7 requires engineers "to seek, accept, and offer honest criticism of technical work." The American Society of Mechanical Engineers (ASME) code of ethics is equally straightforward. Fundamental Principle II states that engineers must practice the profession by "being honest and impartial." The seventh Fundamental Canon states, "Engineers shall issue public statements only in an objective and truthful manner." A subsection enjoins engineers not to "participate in the dissemination of untrue, unfair, or exaggerated statements regarding engineering."

The National Society for Professional Engineers (NSPE) code urges engineers "to participate in none but honest enterprise." The preamble states that "the services provided by engineers require honesty, impartiality, fairness, and equity." The third Fundamental Canon (1.3) requires engineers to "avoid deceptive acts in the solicitation of professional employment." In the Rules of Practice, there are several references to honesty. In item II.1.d, the code states the following: "Engineers shall not permit the use of their name or firm name nor associate in business ventures with any person or firm which they have reason to believe is engaging in fraudulent or dishonest business or professional practices." Items II.2.a–II.2.c and II.3.a–II.3.c in the Rules of Practice give more detailed direction for the practice of the profession.

Item II.3 states that "engineers shall issue public statements only in an objective and truthful manner." Item II.5 states that "engineers shall avoid deceptive ads in the solicitation of professional employment." Items II.5.a and II.5.b give more detailed explanations regarding how to implement this statement. In Section III, "Professional Obligations," the code refers to the obligation for engineers to be honest and truthful and not to misrepresent facts—and does so in six different locations (III.1.a, III.1.d, III.2.c, III.3.a, III.7, and III.8). Part (a) of the third Rule of Practice states, "Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony."

BOX 5.1 Ways of Deceiving

- Lying
- Deliberate deception, but without lying
- Withholding expected information
- Failure to seek out the truth

Despite all the attention given to honesty and truthfulness in these codes of ethics, the subtlety and nuances of these and closely related notions are left to the reader to determine. Further, there is no discussion of why dishonesty in engineering practice is regarded to be generally unacceptable. We will now explore these matters. See Box 5.1.

5.3 FORMS OF DISHONESTY

Lying

When we think of dishonesty, we usually think of lying. However, coming up with a satisfactory definition of lying is difficult. One reason for the difficulty is that not every falsehood is a lie. If an engineer mistakenly conveys incorrect test results on soil samples, he or she is not lying even if what is reported is not true. To lie, a person must intentionally or at least knowingly try to convey what one believes to be false or misleading information. But even here complications arise. A person may give information that he or she believes to be false, even though it is actually true. In this case, we may be perplexed as to whether we should characterize this as lying. The intention is to lie but unknown to the would-be liar what is said is actually true.

To make matters more complicated, a person may give others false information by means other than making false statements. Gestures and nods, as well as indirect statements, can give a false impression in a conversation, even though the person has not told an outright lie. Despite these complications, most people believe that lies—or at least paradigm cases of lies—have three elements: First, a lie ordinarily involves something that is believed by the liar to be false or seriously misleading. Second, a lie is ordinarily stated in words. Third, a lie is made with the intention to deceive.

Deliberate Deception

If, in order to impress an employer or a potential customer, Andrew discusses technical matters in a manner that implies knowledge that he does not have, then he is certainly engaging in deliberate deception, even if he is not lying. In addition to misrepresenting one's own expertise, one can misrepresent the value of certain products or designs by praising their advantages inordinately.

Withholding Information

Omitting or withholding information can be another type of deceptive behavior. If Jane deliberately fails to discuss some of the negative aspects of a project she is promoting to her superior, she engages in serious deception even though she is not lying. Failing to report that you own stock in a company whose product you are recommending is a form of dishonesty. Perhaps we can say in more general terms that one is practicing a form of dishonesty by omission (1) if one fails to convey information that the audience would reasonably expect would not be omitted and (2) if the intent of the omission is to deceive.

Failure to Seek Out the Truth

The honest engineer is one who is committed to finding the truth, not simply avoiding dishonesty. Suppose engineer Mary suspects that some of the data she has received from the test lab are inaccurate. In using the results as they are, she is neither lying nor concealing the truth. But she may be irresponsible in using the results without inquiring further into their accuracy. Honesty in this positive sense is part of what is required of responsible engineers.

It would not be correct to assume that lying is always more serious than deliberate deception, withholding information, failing to adequately promote the dissemination of information, or failing to seek out the truth. Sometimes the consequences of lying may not be as serious as the consequences of some of these other actions. The order of these first four types of misusing the truth reflects primarily the degree to which one is actively distorting the truth rather than the seriousness of the consequences of the actions.

5.4 WHY IS DISHONESTY WRONG?

The term "honest" has such a positive connotation and the term "dishonest" such a negative one that we may forget that telling the full truth may sometimes be wrong and concealing the truth may sometimes be the right thing to do. A society in which people are totally candid with each other would be difficult to tolerate. The requirement of total candor would mean that people would be brutally frank about their opinions of each other and unable to exercise the sort of tact and reticence that we associate with polite and civilized society. In regard to professionals, the requirement never to conceal truth would mean that engineers, physicians, lawyers, and other professionals could not protect confidentiality or proprietary information. Doctors could never misrepresent the truth to their patients, even when there is strong evidence that this is what the patients prefer and that the truth could be devastating.

Despite possible exceptions, however, dishonesty and the various other ways of misusing the truth are generally wrong. A helpful way to see this is to consider dishonesty from the standpoints of virtue, respect for persons, and utilitarian thinking; each can provide valuable suggestions for thinking about moral issues related to honesty.

Honesty as a Virtue

In 1968, Norm Lewis was a 51-year-old doctoral candidate in history at the University of Washington.[4] While taking his final exam in the program, he excused himself to go to the restroom, where he looked at his notes. For the next 32 years, Lewis told no one of this, not even his spouse. At age 83, he decided to confess and he wrote to the president of the university, admitting that he had cheated and that he had regretted it ever since.

Commenting on the case, Jeanne Wilson, president of the Center for Academic Integrity, remarked, "I think there is an important lesson here for students about the costs of cheating. He has felt guilty all these years, and has felt burdened by this secret, believing that he never really earned the degree he was awarded." Wilson took the position that the University of Washington should not take action against Lewis, given his confession, his age, and the fact that, after all, he did complete his coursework and a dissertation.

Wilson did not hold the view that, since he was not caught, Lewis did nothing wrong. It was wrong for him to cheat. The question she asked was what, if anything, should be done about it more than three decades later. On this matter she addressed Lewis' field of study and his age, saying, "I think an institution might feel compelled to revoke the degree if we were talking about a medical or law degree or license, or some other professional field such as engineering or education, and the individual were younger and still employed on the basis of that degree or license."

Is Wilson saying that maintaining academic trustworthiness in some areas is more important than in others? Our individual and societal well-being very much depends on the competence and trustworthiness of those who employ their expertise in medicine, law, education, and engineering. Historical work (religious historical work in Lewis' case), Wilson seems to be saying, is less critical in this regard. However, without getting entangled in controversy about such matters, it should be pointed out that there may be little reason to think that cheating in one area can be clearly isolated from cheating in others. How credible is it to say, "I'll cheat in history or sociology, but not in engineering—which is where my future lies." Presumably, the engineering student who cheats in history is thereby trying to advance his or her career—by progressing toward a degree. How different is this from cheating in order to advance one's engineering career? Those who, through habit, have acquired the virtue of honesty are disposed against cheating in general, not simply in areas that are perceived to be directly relevant to one's career preparation. As we said in Chapter 2, virtues are both wide and deep. Being committed to honesty in all of one's academic pursuits illustrates its breadth. Norm Lewis being haunted by his act of dishonesty for more than 30 years testifies to its depth.

Dishonesty and Respect for Persons

Let us review first some of the major components of the respect for persons perspective. As discussed in Chapter 2, from this perspective, actions that violate the moral agency of individuals are usually wrong. Moral agents are human beings capable of formulating and pursuing goals and purposes of their own—they are autonomous. The word "autonomy" comes from two Greek terms: "auto," meaning "self," and "nomos," meaning "rule" or "law."

Thus, to respect the moral agency of patients, physicians have three responsibilities. First, they must ensure that their patients can make decisions about their medical treatment with informed consent. They must see to it that their patients understand the consequences of their decisions and can rationally make decisions that have some relationship to their life plans. Second, they have some responsibility to ensure that patients make decisions without undue coercive influences such as stress, illness, and family pressures. Finally, physicians must ensure that patients are sufficiently informed about options for treatment and their expected consequences.

Engineers, too, have some degree of responsibility to ensure that employers, clients, and the general public can make autonomous decisions, but their responsibilities are more limited than those of physicians. Their responsibilities probably extend only to the third of these three conditions of autonomy, ensuring that employers, clients, and the general public make decisions regarding technology with understanding, particularly understanding of their consequences. We have seen, for example, that the IEEE code requires members to "disclose promptly factors that might endanger the public or the environment," and ASCE members must "inform their clients or employers of the possible consequences" when the safety, health, and welfare of the public are endangered. In engineering, this applies to such issues as product safety and the provision of professional advice and information. If customers do not know that a car has an unusual safety problem, then they cannot make an informed decision regarding whether to purchase it. If customers are paying for professional engineering advice and are given misinformation, then they again cannot make free and informed decisions.

The astronauts on the *Challenger* flight in 1986 were informed on the morning of the flight about the ice buildup on the launching pad and were given the option of postponing the launch. They chose not to exercise that option. However, no one presented them with the information about O-ring behavior at low temperatures. Therefore, they did not give their fully informed consent to launch despite the O-ring risk because they were unaware of the risk. The fault, however, did not primarily lie with the engineers, but with the managers who supported the launch and did not inform the astronauts of the danger.

Many situations are more complex. To be informed, decision makers must not only have the relevant information but also understand it. Furthermore, nobody has all of the relevant information or has complete understanding of it, so being informed in both of these senses is a matter of degree. Therefore, the extent of the engineer's obligation regarding informed consent will sometimes be controversial and whether or not the obligation has been fulfilled will also sometimes be controversial. We return to these considerations later, but what we have said here is enough to show that even withholding information or failing to adequately disseminate it can be serious violations of professional responsibilities.

Utilitarian Considerations

Now let us turn to the utilitarian perspective on honesty and dishonesty. The utilitarian perspective requires that our actions promote human happiness and well-being and avoid the opposite. The profession of engineering contributes to these utilitarian goals by providing designs for the creation of buildings, bridges, electronic devices, automobiles, and many other things on which our society depends. It also provides information about technology that is important in decision-making at the individual, corporate, and public policy levels.

Dishonesty in engineering research can undermine these functions. If engineers report data falsely or omit crucial data, then other researchers cannot reliably depend on their results. This can undermine the relations of trust on which a scientific community is founded. Just as a designer who is untruthful about the strength of materials specified for a building fails to protect the building from harm, a researcher who falsifies the data reported in a professional journal threatens harm to the infrastructure of engineering.

Dishonesty can also undermine informed decision-making. Managers in both business and government, as well as legislators, depend on the knowledge and judgments provided by engineers to make decisions. If these are unreliable, then the ability of those who depend on engineers to make good decisions regarding technology is undermined. To the extent that this happens, engineers have failed in their obligation to promote the public welfare.

Trust and Truthfulness

From the perspectives of virtue, respect for persons, and utilitarian thinking, then, outright dishonesty as well as other forms of abusing the truth with regard to technical information and judgment are usually wrong. These actions threaten to compromise one's commitment to truthfulness, thereby weakening one's virtue of honesty. They undermine the moral agency of individuals by preventing them from making decisions with free and informed consent, thus failing fully to respect them as persons. They also interfere with engineers promoting the public welfare—the ultimate end of utilitarian thought.

So, resisting the various forms of dishonesty is clearly a central feature of ethics for engineers. Of course, commitment to honesty and truthfulness is not all that is needed for engineers to merit our trust. They also need to be competent and committed to serving us well. However, as philosopher Sissela Bok forcefully points out, honesty and truthfulness are essential:[5]

> I can have different kinds of trust: that you will treat me fairly, that you will have my interests at heart, that you will do me no harm. But if I do not trust your word, can I have genuine trust in the first three? If there is no confidence in the truthfulness of others, is there any way to assess their fairness, their intentions to help or to harm? How, then, can they be trusted? *Whatever* matters to human beings, trust is the atmosphere in which it thrives.

It is important to realize that good intentions alone are not sufficient to generate trust. Consider this Alaskan case, reported some years ago.[6] Charles Landers, former Anchorage assemblyman and unlicensed engineer for Constructing Engineers, was found guilty of forging partner Henry Wilson's signature and using his professional seal on at least 40 documents. The falsification of the documents was done without Wilson's knowledge, who was away from his office when they were signed. Constructing Engineers business was to design and test septic systems. The signed and sealed documents certified to the Anchorage city health department that local septic systems met city wastewater disposal regulations. Circuit Judge Michael Wolverton banned Landers for one year from practicing as an engineer's, architect's, or land surveyor's assistant. The judge also sentenced him to 20 days in jail, 160 hours of community service, $4,000 in fines, and 1 year of probation. Finally, Landers was ordered to inform property owners about the problems with the documents, explain how he would rectify the problem, and pay for a professional engineer to review, sign, and seal the documents.

Assistant Attorney General Dan Cooper had requested the maximum penalty: a four-year suspended sentence and $40,000 in fines. Cooper argued that "the 40 repeated incidents make his offense the most serious within the misuse of an engineer's seal." This may have been the first time a case like this was litigated in Alaska. The attorney general's office took on the case after seeking advice from several professional engineers in the Anchorage area.

According to Cooper, Landers said he signed and sealed the documents because "his clients needed something done right away." (The documents were needed before proceeding with property transactions.) Lander's attorney, Bill Oberly, argued that his client should be sentenced as a least offender since public health and safety were not really jeopardized—subsequent review of the documents by a professional engineer found no violations of standards (other than forgery and the misuse of the seal). The documents were resubmitted without needing changes.

However, Judge Wolverton contended that Lander's actions constituted a serious breach of public trust. The public, he said, relies on the word of those, like professional engineers, who are entrusted with special responsibilities: "Our system would break down completely if the word of individuals could not be relied upon."

The judge also cited a letter from Richard Armstrong, then chairman of the Architects, Engineers, and Land Surveyors Board of Registration for Alaska's Department of Commerce and Economic Development. Armstrong said,

> Some of the reasons for requiring professional engineers to seal their work are to protect the public from unqualified practitioners; to assure some minimum level of competency in the profession; to make practicing architects, engineers, and land surveyors responsible for their work; and to promote a level of ethics in the profession. The discovery of this case will cast a shadow of doubt on other engineering designed by properly licensed individuals.

5.5 DISHONESTY ON CAMPUS

Problems for engineering students regarding honesty in engineering can arise even before completing their undergraduate work. Here is a real-life example.[7] John is a co-op student with a summer job with Oil Exploration, Inc., a company that does exploratory contract work for large oil firms. The company drills, tests, and writes advisory reports to clients based on the test results. As an upper-level undergraduate student in petroleum engineering, John is placed in charge of a field team of roustabouts and technicians who test drill at various sites specified by the customer. John has the responsibility of transforming rough field data into succinct reports for the customer. Paul, an old high school friend of John's, is the foreperson of John's team. In fact, Paul was instrumental in getting this high-paying summer job for John.

While reviewing the field data for the last drilling report, John notices that a crucial step was omitted, one that would be impossible to correct without returning to the site and repeating the entire test at great expense to the company. The omitted step involves the foreperson's adding a certain test chemical to the lubricant being pumped into the test drill site. The test is important because it provides the data for deciding whether the drill site is worth developing for natural gas protection. Unfortunately, Paul forgot to add the test chemical at the last drill site.

John worries that Paul is likely to lose his job if his mistake comes to light. Paul cannot afford to lose his job at a time when the oil business is slow and his wife is expecting a child. John learns from past company data files that the chemical additive indicates the presence of natural gas in approximately 1 percent of the tests.

Should John withhold from his superiors the information that the test for natural gas was not performed? Given his friendship with Paul and what he knows about Paul's family life, no doubt John feels strong pressure to say nothing. Still, viewed as an ethical problem, there is much more that John needs to take into account. First and foremost, he must realize that, as an employee of Oil Exploration, Inc., he has special responsibilities to his employer that are not grounded in his friendship with Paul or anyone else. Included in these responsibilities is helping Oil Exploration meet its obligations to its clients. Oil Exploration is expected to present its clients with reliable information. In turn, its clients need to make important decisions on the basis of the information they receive. Both Paul and John have important roles to play in enabling others to succeed in meeting their responsibilities. John is worried that Paul is likely to lose his job if his company finds out about the oversight. Is this worry well-grounded? If John would not fire Paul for his oversight, why does he assume that Oil Expectations management would? Is it because John himself wonders if Paul's oversight, if discovered by management, really would warrant dismissal? In any case, whose call should this be? Would John support the firing of Paul were it not for their friendship? Should John allow friendship to influence his decision? Although attempting to answer these questions may not make it easier for John to decide what to do (quite the contrary), asking them is morally important. What John needs to bear in mind is that he and Paul are working in a professional setting and this means that each has special responsibilities that are wedded to that setting and that are not grounded in their relationship as friends.

Here is another actual situation. Three students were working on a senior capstone engineering design project. The project was to design, build, and test an inexpensive meter that would be mounted on the dashboard of automobiles and would measure the distance a car could travel on a gallon of gasoline. Even though personal computers, microchip calculators, and "smart instruments" were not available at the time, the students came up with a clever approach that had a good chance of success. They devised a scheme to instantaneously measure voltage equivalents of both gasoline flow to the engine and speedometer readings on the odometer while keeping a cumulative record of the quotient of the two. In other words, miles per hour divided by gallons per hour would give the figure for the miles the automobile is traveling per gallon of gasoline. The students even devised a way to filter and smooth out instantaneous fluctuations in either signal to ensure time-averaged data. Finally, they devised a benchtop experiment to prove the feasibility of their concept. The only thing missing was a flow meter that would measure the flow of gasoline to the engine in gallons per hour and produce a proportional voltage signal. Today, customers can order this feature as an option on some automobiles, but at the time the design was remarkably innovative. The professor directing the project (the late Michael Rabins, one of the original authors of this text) was so impressed that he found a source of funds to buy the flow meter. He also encouraged the three students to draft an article describing their design for a technical journal.

Several weeks later, the professor was surprised to receive a congratulatory letter from the editor of a prominent journal, announcing that the journal was accepting for publication the "excellent article" that the professor had "coauthored" with his three senior design students. The professor knew that the flow meter had not yet even arrived, nor had he seen any draft version of the paper. He asked the three students for an explanation. They said that they had followed the professor's advice and prepared an article about their design. They had put the professor's name on the paper as senior author because, after all, it was his idea to write the paper and he was the faculty advisor. They did not want to bother the professor with the early draft. Furthermore, they really could not wait for the flow-measuring instrument to arrive because they were all graduating in a few weeks and planned to begin new jobs. Finally, because they were sure the data would give the predicted results, they simulated some time-varying voltages on a power supply unit to replicate what they thought the flow-measuring voltages would be. They had every intention, they said, of checking the flow voltage and the overall system behavior after the flow meter arrived and, if necessary, making minor modifications in the paper.

As a matter of fact, the students incorrectly assumed that the flow and voltages would be related linearly. They also made false assumptions about the response of the professor to their actions. The result was that the paper was withdrawn from the journal and the students sent letters of apology to the journal. Copies of the letters were placed in their files, the students received an F in the senior design course, and their graduation was delayed six months. Despite this, one of them requested that the professor write a letter of recommendation for a summer job he was seeking, a request that the professor refused.

A student's experience in engineering school is a training period for his or her professional career. If dishonesty is as detrimental to engineering professionalism as we have suggested, then part of this training should focus on the importance of professional honesty. However, it might be thought that, in general, cheating as a student, especially if one succeeds in getting away with it, is a relatively minor matter. The three students above were unlucky. Their intention, they might plead, was simply to get credit for work that they were confident would turn out well. But they felt they could not wait for the actual results before submitting them for publication. At least, they might have thought, they credited the professor by listing him as lead author. Of course, they probably realized that listing an established researcher as lead author might enhance the chances of the paper being accepted—not to mention their chances of getting their nonacademic careers off to a good start.

So, was the students' mistake simply one of *miscalculation*—miscalculation of the odds of ultimate failure in the research itself, of the professor not finding out about their scheme, or of the professor not minding that he was listed as lead author? What if they thought that the academic world is simply a means to a better world for them, a world in which the questionable past (cheating) is easily forgotten as one's career advances?

As we shall see in the next section, there are exact counterparts in the scientific and engineering communities to the types of dishonesty exhibited by students, whether in science, engineering, or the humanities. Furthermore, it is simply not true that the sorts of pressures that invite cheating as a student are absent in the workplace. Smoothing data points on the graph of a freshman physics laboratory report to get an A on the report, selecting the research data that support the desired conclusion, entirely inventing the data, and plagiarism of the words and ideas of others all can advance one's academic aims, as can their obvious parallels in nonacademic settings.

5.6 DISHONESTY IN RESEARCH AND TESTING

Dishonesty in science and engineering takes several forms. Falsification of data, fabrication of data, plagiarism, and inappropriate attributions of authorship are among the most common, as shown in Box 5.2.

Falsification and Fabrication of Data

Falsification of data involves distorting data by smoothing out irregularities or presenting only those data that fit one's favored theory and discarding the rest. Whether such falsification has occurred is sometimes a matter of great controversy. Physicist Robert A. Millikan's famous oil drop experiment in the early part of the twentieth century is a case in point.[8] This experiment was credited with showing the uniformity of the charge of electrons and Millikan received a Nobel Prize for his work. Complicating matters is a subsequent discovery that, despite claiming in his published report of the data that his findings were based on all the trials he conducted, his laboratory notebooks indicate that he did not include data on 49 of the 189 trials he conducted. Defenders of Millikan point out that sometimes it is appropriate to leave out certain data, for example, when it is determined that the equipment used is not functioning as it should. Critics reply that if Millikan had such problems, he should have included this explanation of the exclusion of some of the data in his report. Further experimentation did confirm his conclusion about the uniformity of the charge of electrons. But some still dispute whether Millikan's own experiment should be credited with showing this.

Fabrication of data involves inventing data and even reporting results of experiments that were never conducted. The fabrication of data by psychologist Stephen Breuning illustrates the possibly far reaching harm that can result from this.[9] In December 1983, Dr. Robert Sprague of the University of Illinois wrote an 8-page letter, with 44 pages of appendices, to the National Institute of Mental Health documenting the fraudulent work submitted to him by Breuning. Breuning claimed he

BOX 5.2 Types of Dishonesty in Research and Testing

- Falsification of data: distortion in representing data (e.g., omission of relevant data)
- Fabrication of data: making up data (e.g., for tests that were not actually done)
- Failure to respect intellectual property of others (e.g., violating trade secrets, patents, trademarks, and copyrights)
- Plagiarism: falsely appropriating the work of others as one's own
- Inappropriate attribution of authorship (e.g., listing someone as an author who didn't warrant credit for this)

was reporting on research he had conducted in a Coldwater, Michigan, mental facility on the effects psychotropic medication has on children in need of help. However, Breuning simply made up the data.

Even though Breunings admitted to fabricating his data only three months after Sprague sent his letter to NIMH, the case was not finally resolved until July 1989. During that 5½-year interval, Sprague himself was the first target of investigation, he had his own funded research severely curtailed, he was subjected to threats of lawsuits, and he had to testify before a U.S. House of Representatives committee. Most painful of all, Sprague's wife died in 1986, after a lengthy bout with diabetes. In fact, Sprague said, his wife's serious illness was one of the major factors prompting his "whistle-blowing" to NIMH. Realizing how dependent his diabetic wife was on reliable research and medication, Sprague was particularly sensitive to the dependency that children, and vulnerable populations in general, have on the trustworthiness of not only their caregivers but also on those who use them in experimental drug research.

Writing some years after the closing of the Breuning case, Sprague concluded his reflections on his own experiences by bringing to his readers' attention other possible victims of Breuning's research misconduct—namely, other psychologists and researchers who had collaborated with Breuning without being aware that he had fabricated data.

Psychologist Alan Poling, who at one time had Breuning as a student, has written about the consequences of Breuning's misconduct for his collaborators in research.[10] Strikingly, Poling points out that between 1979 and 1981, Breuning was a contributor to 34 percent of all published research on the psychopharmacological areas in which he was allegedly working. Of course, it does not follow that all of Breuning's publications are based on fabricated data, but determining which are and which are not is a time-consuming, demanding task. So, those who cited Breuning's publications in their own work may have wondered about the reliability of those publications that were not yet validated and they may have suffered from accusations of "guilt by association." As Poling points out, this is especially unfair in those instances in which Breuning's collaborations with others involved no fraud at all. In short, Breuning's fabrications presented serious ethical issues from both utilitarian and respect for persons perspectives. For Breuning himself, shortcomings from a virtue perspective are evident.

5.7 INTELLECTUAL PROPERTY

"Intellectual property" refers to creations of the intellect that can be protected in several ways, including as trade secrets, patents, trademarks, and copyrights.

Trade secrets are formulas, patterns, devices, or compilations of information that are used in business to gain an advantage over competitors who do not possess the trade secrets. The formula for Coca-Cola is an example of a trade secret. Trade secrets must not be in the public domain and the secrecy must be protected by the firm because trade secrets are not protected by patents.

Patents are documents issued by the government that allow the owner of the patent to exclude others from making use of the patented information for 20 years from the date of filing. To obtain a patent, the invention must be new, useful, and nonobvious. As an example, the puncture-proof tire is patented.

Trademarks are words, phrases, designs, sounds, or symbols associated with goods or services. "Coca-Cola" is a registered trademark.

Copyrights are rights to creative products such as books, pictures, graphics, sculptures, music, movies, and computer programs. Copyrights protect the expression of the ideas but not the ideas themselves. The script of *Star Wars*, for example, is copyrighted.

Many companies require their employees to sign a patent assignment whereby all patents and inventions of the employee become the property of the company, often in exchange for a token fee of $1. Sometimes, employees find themselves caught between two employers with respect to such issues. Consider the case of Bill, a senior engineering production manager of a tire manufacturing company, Roadrubber, Inc. Bill has been so successful in decreasing production costs for his company by developing innovative manufacturing techniques that he has captured the attention of the competition. One competing firm, Slippery Tire, Inc., offers Bill a senior management position at a greatly increased salary. Bill warns Slippery Tire that he has signed a standard agreement with Roadrubber not to use or divulge any of the ideas he developed or learned at Roadrubber for two years following any change of employment.

Slippery Tire's managers assure Bill that they understand and will not try to get him to reveal any secrets and also that they want him as an employee because of his demonstrated managerial skills. After a few months on the job at Slippery Tire, someone who was not a part of the earlier negotiations with Bill asks him to reveal some of the secret processes that he developed while at Roadrubber. When Bill refuses, he is told, "Come on, Bill, you know this is the reason you were hired at the inflated salary. If you don't tell us what we want to know, you're out of here." This is a clear case of an attempt to steal information. If the managers who attracted Bill to Slippery Tire were engineers, then they also violated the NSPE code.

"Professional Obligations," item III.1.d of the NSPE code, says, "Engineers shall not attempt to attract an engineer from another employer by false or misleading pretenses." Some cases are not as clear. Sometimes an employee develops ideas at Company A and later finds that those same ideas can be useful—although perhaps in an entirely different application—to her new employer, Company B.

Suppose Betty's new employer is not a competing tire company but one that manufactures rubber boats. A few months after being hired by Rubberboat, Betty comes up with a new process for Rubberboat. It is only later that she realizes that she probably thought of the idea because of her earlier work with Roadrubber. The processes are different in many ways and Rubberboat is not a competitor of Roadrubber, but she still wonders whether it is right to offer her idea to Rubberboat.

Let's examine what the NSPE code of ethics has to say about such situations. As already noted, under Rules of Practice, item II.1.c states, "Engineers shall not reveal facts, data, or information obtained in a professional capacity without the prior consent of the client or employer except as authorized or required by law or this Code." Item III.4 states,

> Engineers shall not disclose confidential information concerning the business affairs or technical processes of any present or former client or employer without his consent. (a) Engineers in the employ of others shall not without the consent of all interested parties enter promotional efforts or negotiations for work or make arrangements for other

> employment as a principal or to practice in connection with a specific project for which the engineer has gained particular and specialized knowledge. (b) Engineers shall not, without the consent of all interested parties, participate in or represent an adversary interest in connection with a specific project or proceedings in which the engineer has gained particular specialized knowledge on behalf of a former client or employer.

Similarly, the Model Rules of Professional Conduct for the National Council of Examiners for Engineering and Surveying (NCEES) require engineers to "not reveal facts, data, or information obtained in a professional capacity without the prior consent of the client or employer as authorized by law" (I.1.d).

These code statements strongly suggest that even in the second case Betty should tell the management at Rubberboat that it must enter into licensing negotiations with Roadrubber. In other words, she must be honest in fulfilling all of her still existing obligations to Roadrubber.

Other cases can be even less clear, however. Suppose the ideas Betty developed while at Roadrubber were never used by Roadrubber. She realized they would be of no use and never even mentioned them to management at Roadrubber. Thus, they might not be considered a part of any agreement between her and Roadrubber. Still, the ideas were developed using Roadrubber's computers and laboratory facilities. Or suppose Betty's ideas occurred to her at home while she was still an employee of Roadrubber, although the ideas probably would never have occurred to her if she had not been working on somewhat related problems at Roadrubber.

We can best deal with these problems by employing the line-drawing method. As we have seen, the method involves pointing out similarities and dissimilarities between the cases whose moral status is clear and the cases whose moral status is less clear. Additional features may come to light in analyzing a particular case. There can also be other intermediate cases between the ones presented here. The particular case of interest must be compared with the spectrum of cases to determine where the line between permissible and impermissible action should be drawn.

So far, our discussion of intellectual property has focused on the protection of business interests. In addition to this, however, there are related moral and legal issues regarding the credit due to authors for the original expression of ideas in books and articles whether or not they serve business purposes.

For example, *plagiarism* is the use of the intellectual property of others without proper permission or credit. It takes many different forms. Plagiarism is really a type of theft. Drawing the line between legitimate and illegitimate use of the intellectual property of others is often difficult and the method of line drawing is useful in helping us discriminate between the two. Some cases are undeniable examples of plagiarism, such as when the extended passages involving the exact words or the data of another are used without proper permission or attribution. On the other side of the spectrum, the quotation of short statements by others with proper attribution is clearly permissible. Between these two extremes are many cases in which drawing the line is more difficult.

Appropriately attributing the *authorship of papers* can often raise particularly vexing issues with regard to honesty in scientific and technological work. Sometimes, as many as 40 to 50 researchers are listed as the authors of a paper. One can think of several justifications for this practice. First, often a large number of scientists participate in some forms of research and they all make genuine contributions. For example, large numbers of people are sometimes involved in medical research. Second, the distinction between whether someone is the author of a paper or merely deserves to be cited may indeed be tenuous in some circumstances.

Complicating matters is the common, if understandable, desire to be credited with as many publications as possible. This can be true of both academic and nonacademic scientists and engineers. In addition, many graduate and postdoctoral students need to be credited with publications in order to advance their careers. Sometimes more senior researchers are tempted to list graduate students as authors in order to make the student's research record appear as impressive as possible, even though their contribution to the publication was minimal.

From an ethical standpoint, there are at least two potential problems with multiple authorship. First, it is fraudulent to claim significant credit for research when, in fact, a contribution is relatively insignificant. If claims to authorship are indeed fraudulent, then those who are evaluating the work of a scientist or engineer are being provided with false or unreliable information upon which to make their evaluations. As a lie, this is a failure of respect for persons. From a utilitarian perspective, if this misinformation is relied upon, there can be unfortunate consequences, such as the students performing poorly on the job. Second, fraudulent claims to authorship give one an unfair advantage in the competition for jobs, promotions, and recognition in the scientific community. From the perspective of respect for persons, unfairness of this sort falls far short of the mark. From a virtue perspective, supporting unwarranted claims to authorship is a form of dishonesty and should be avoided for this reason alone.

5.8 CONFIDENTIALITY

One can misuse the truth, not only by dishonesty through lying or otherwise distorting or withholding the truth, but also by disclosing it inappropriately as in an employee's disclosure of trade secrets (discussed briefly in Section 5.7). Engineers in private practice might sometimes be tempted to disclose confidential information without the consent of the client. Information may be confidential if it is either given to the engineer by the client or discovered by the engineer in the process of work done for the client.

Given that most engineers are employees, a more common problem involving the improper use of information is the violation of proprietary information of a former employer. Using designs and other proprietary information of a former employer can be dishonest and may even result in litigation. Even using ideas one developed while working for a former employer can be questionable, particularly if those ideas involve trade secrets, patents, or licensing arrangements.

Most engineers are employees of large corporations, but some, especially civil engineers, subcontract for design firms that have clients. For these engineers, there is an obligation to protect the confidentiality of the client–professional relationship, just as with lawyers and physicians. Confidentiality would ordinarily cover both sensitive information given by the client and information gained by the professional in work paid for by the client.

An engineer can mishandle client–professional confidentiality in two ways. First, she may break confidentiality when it is not warranted. Second, she may refuse to break confidentiality when the higher obligation to the public requires it. The following is an example of the first type of mishandling.[11] Jane, a civil engineer, is contracted to do a preliminary study for a new shopping mall for Greenville, California. The town already has a mall that is 20 years old. The owner of the existing mall is trying to decide whether to renovate or close the old mall. He has done a lot of business with Jane and asks her detailed questions about the new mall. Jane answers the questions.

The following is another example in the first category. Suppose Engineer A inspects a residence for a homeowner for a fee. He finds the residence in generally good condition, although it is in need of several minor repairs. Engineer A sends a copy of his one-page report to the homeowner, showing that a carbon copy was sent to the real-estate firm handling the sale of the residence.

This case was considered by the NSPE Board of Ethical Review, which ruled that "Engineer A acted unethically in submitting a copy of the home inspection to the real-estate firm representing the owners." It cites section II.1.c of the NSPE code, which states, "Engineers shall not reveal facts, data, or information obtained in a professional capacity without the prior consent of the client or employer except as authorized by law or this Code."[12] The clients paid for the information and therefore could lay claim to its exclusive possession. The residence was fundamentally sound and there was no reason to believe that the welfare of the public was at stake. The case would have been more difficult if there had been a fundamental structural flaw. Even here, however, we can argue that there was no fundamental threat to life. Prospective buyers are always free to pay for an inspection themselves.

The following hypothetical case raises more serious moral questions regarding whether confidentially should be overridden. Suppose engineer James inspects a building for a client before the client puts the building up for sale. James discovers fundamental structural defects that could pose a threat to public safety. James informs the client of these defects in the building and recommends its evacuation and repair before it is put up for sale. The client replies:

> James, I am not going to evacuate the building and I am certainly not going to spend a lot of money on the building before I put it up for sale. Furthermore, if you reveal the information to the authorities or to any potential buyer, I am going to take whatever legal action I can against you. Not only that, but I have a lot of friends. If I pass the word around, you will lose a lot of business. The information is mine. I paid for it and you have no right to reveal it to anyone else without my permission.

James' obligation to his client is clearly at odds with his obligation to the public. Although he may have an obligation to potential buyers, his more immediate and pressing one is to protect the safety of the current occupants of the building. Note that the section of the NSPE code quoted previously requires engineers to keep the confidentiality of their clients in all cases, except where exceptions are authorized "by law or this Code." This is probably a case in which part of the code (specifically, the part emphasizing the higher obligation to the safety of the public) should override the requirement of confidentiality.

Even here, however, James should probably try to find a creative middle way that allows him to honor his obligations to his client, the occupants of the building, and potential buyers. He might attempt to persuade the client that his intention to refuse to correct the structural defects is morally wrong and probably not even in his long-term self-interest. He might argue that the client may find himself entangled in lawsuits and that surely he would find it difficult to live with himself if a catastrophe occurred.

Unfortunately, such an approach might not work. James' client might refuse to change his mind. Then James must rank his competing obligations. Most engineering codes, including the NSPE code, are clear that the engineer's first obligation is to the safety of the public, so James must make public the information about the structural defects of the building, at least according to the NSPE code as we interpret it.

Still, not all cases involving confidentiality will be as clear-cut as the one James faces. In fact, his situation might serve as one extreme on a spectrum of cases. The other extreme might be a case in which an engineer breaks confidentiality to promote his own financial interests. Between these two extremes are many other possible situations in which the decision might be difficult. Again, in such cases, it is appropriate to use the line-drawing method.

5.9 EXPERT WITNESSING

Engineers are sometimes hired as expert witnesses in cases that involve accidents, defective products, structural defects, and patent infringements, as well as in other areas where competent technical knowledge is required. Calling upon an expert witness is one of the most important moves a lawyer can make in such cases and engineers are usually well compensated for their testimony. However, being an expert witness is time-consuming and often stressful.

Expert witnesses face certain ethical pitfalls. The most obvious is perjury on the witness stand. A more likely temptation is to withhold information that would be unfavorable to the client's case. In addition to being ethically questionable, such withholding can be an embarrassment to the engineer because cross-examination often exposes it. To avoid problems of this sort, an expert should follow several rules, outlined in Box 5.3.

BOX 5.3 Suggested Rules for Expert Witnesses

- One should not take a case if there is not enough time for a thorough investigation. Rushed preparation can be disastrous for the reputation of both expert and client.
- One should not accept a case if this cannot be done with good conscience. This means being able to testify honestly and not feel the need to withhold information to make an adequate case for one's client.
- The engineer should consult extensively with the lawyer so that the lawyer is as familiar as possible with the technical details of the case and can prepare the expert witness for cross-examination.
- The witness should maintain an objective and unbiased demeanor on the witness stand. This includes sticking to the questions asked and keeping an even temper, especially under cross-examination.
- The witness should always be open to new information, even during the course of the trial.

BOX 5.4 A Suggested Position for the Expert Witness

"I will have only one opinion, not a 'real' opinion and a story I will tell for you on the witness stand. My opinion will be as unbiased and objective as I can possibly make it. I will form my opinion after looking at the case and you should pay me to investigate the facts of the case. I will tell the truth and the whole truth as I see it on the witness stand and I will tell you what I will say beforehand. If you can use my testimony, I will serve as an expert witness for you. If not, you can dismiss me."

The following example does not involve an expert witness, but it does show how important new information gained during a trial can be. During a trial of an accident case in Kansas, the defendant discovered in his basement an old document that conclusively showed that his company was culpable in the accident. He introduced this new evidence in court proceedings, even though it cost his company millions of dollars and resulted in the largest accident court judgment in the history of Kansas.[13]

One position a potential expert witness can take with respect to a client is to say something similar to the suggestion in Box 5.4.

The suggested position in Box 5.4 may not solve all the problems. If an expert witness is dismissed by a lawyer because he has damaging evidence, then is it ethically permissible to simply walk away, without revealing the evidence, even when public safety is involved? Should the witness testify for the other side if asked?

5.10 INFORMING THE PUBLIC

Some types of professional irresponsibility in handling technical information may be best described as a failure to inform those whose decisions are impaired by the absence of the information. From the standpoint of the ethics of respect for persons, this is a serious impairment of moral agency. From the standpoint of utilitarian thinking, the failure of engineers to ensure that technical information is available to those who need it is especially wrong where disasters can be avoided.

Dan Applegate was Convair's senior engineer directing a subcontract with McDonnell Douglas in 1972.[14] The contract was for designing and building a cargo hatch door for the DC-10. The design for the cargo door's latch was known to be faulty. When the first DC-10 was pressure tested on the assembly line, the cargo hatch door blew out and the passenger cabin floor buckled, resulting in the destruction of several hydraulic and electrical power lines. Modifications in the design did not solve the problem. Later, a DC-10 flight over Windsor, Ontario, had to make an emergency landing in Detroit after the cargo hatch door flew open and the cabin floor again buckled. Fortunately, no one was injured.

In light of these problems, Applegate wrote a memo to the vice president of Convair, itemizing the dangers of the design. However, Convair managers decided not to pass this information on to McDonnell Douglas because of the possibility of financial penalties and litigation if accidents occurred. Applegate's memorandum was prophetic. Two years later, in 1974, a fully loaded DC-10 crashed just outside Orly Field in Paris, killing all 346 passengers. The crash happened for the reasons that Applegate had outlined in his memorandum. There were genuine legal impediments to disclosing the dangers in the DC-10 design to the federal government or to the general public, but this story emphasizes the fact that failure to disclose information can have catastrophic consequences.

In this case, most of us would probably say that Dan Applegate's professional responsibility to protect the safety of the public required that he do something to make known his professional concerns about the DC-10. In requiring engineers to notify employers "or such other authority as may be appropriate" if their "professional judgment is overruled under circumstances where the safety, health, property, or welfare of the public are endangered," the NSPE code seems to imply this (II.1.a). Using almost identical language, the NCEES Model Rules of Professional Conduct require registrants to "notify their employer or client and such other authority as may be appropriate when their professional judgment is overruled under circumstances where the life, health, property, and welfare of the public is endangered" (I.c). Applegate's memo was a step in the right direction. Unfortunately, his superiors did not pass his concerns on to the client (McDonnell Douglas). Who bears responsibility for the client never receiving this information is another matter. However, the failure to alert others to the danger resulted in massive expense and loss of life and denied passengers the ability to make an informed decision in accepting an unusual risk in flying in the aircraft.

Similar issues are raised in another well-known case involving the Ford Pinto gas tank in the early 1970s. At the time the Pinto was introduced, Ford was making every effort to compete with the new compact Japanese imports by producing a car in less than two years that weighed less than 2,000 pounds and cost less than $2,000.[15] The project engineer, Lee Iacocca, and his management team believed that the American public wanted the product they were designing. They also believed that the American public would not be willing to pay the extra $11 to eliminate the risk of a rupturing gas tank. The engineers who were responsible for the rear-end crash tests of early prototype models of the Pinto knew that the Pinto met the current regulations for safety requirements in rear-end collisions; however, they also knew that the car failed the new higher standards that were to go into effect in just two years. In fact, the car failed 11 of 12 rear-end collisions at the newly prescribed 20-miles-per-hour crash tests. In the new crashes, the gas tanks ruptured and the vehicles caught fire. Thus, many engineers at Ford knew that the drivers of the Pinto were subject to unusual risks of which they were unaware. They also knew that management was not sympathetic to their safety concerns. One of the engineers working on the Pinto test program found that the ignorance of potential drivers about the car's dangers was unacceptable and decided to resign and make the information public. The engineer thus gave car buyers the knowledge they needed to purchase the Pinto with informed consent.

There is evidence that Ford management did not necessarily have a callous disregard for safety. Only a few years earlier, Ford management voluntarily reported that some line employees, in a misguided show of company loyalty, had falsified EPA emissions data on new engines to bring Ford into compliance with EPA regulations on a new model. As a result of this honest disclosure, Ford was required to pay a stiff fine and had to substitute an older model engine on the new car at even greater expense.

The obligation of engineers to protect the health and safety of the public requires more than refraining from telling lies or simply refusing to withhold information. It sometimes requires that engineers aggressively do what they can to ensure that the consumers of technology are not forced to make uninformed decisions regarding the use of that technology. This is especially true when the use of technology involves unusual and unperceived risks. This obligation may require engineers to do what is necessary to either eliminate the unusual risks or, at the very least, inform those who use the technology of its dangers. Otherwise, their moral agency is seriously eroded. Placing yourself in the position of the seven *Challenger* astronauts, you probably would have wanted to hear all of the relevant engineering facts about the risky effects of low temperatures on the rocket booster O-ring seals before giving permission for liftoff. Similar considerations apply to those who flew the DC-10 or drove Pintos.

5.11 CONFLICTS OF INTEREST

The final area of concern about trust and reliability we will consider in this chapter is conflicts of interest. The National Society for Professionals Engineers' Board of Ethical Review is asked to review ethical cases of all sorts in engineering. Their task is to comment on these cases in light of the NSPE code of ethics. Far and away, more cases are submitted that raise questions about conflicts of interest than any other area addressed by the code. Yet, nowhere does the code offer an analysis of the concept of a conflict of interest. We believe that having one in mind can greatly help in discussing cases involving conflicts of interest (Box 5.5).

Philosopher Michael Davis provides a very useful analysis of conflicts of interest. Using a modified version of Davis' definition, we shall say that a conflict of interest exists for a professional when, acting in a professional role, he or she has interests that tend to make a professional's judgment less likely to benefit the customer or client than the customer or client is justified in expecting.[16] Now consider this case. John is employed as a design engineer at a small company that uses valves. In recommending product designs for his company's clients, he usually specifies valves made by a relative, even when valves made by other companies might be more appropriate. Should his company's clients discover this, they might well complain that John is involved in a conflict of interest. What does this mean?

In this example, John has allowed his interest in maintaining a good relationship with his relative to unduly influence

BOX 5.5 Conflicts of Interest

- **What is a conflict of interest?** A conflict between an obligation to exercise good judgment and interest(s) that may compromise that judgment.
- **Potential conflict of interest:** A situation in which *if* one does x, there will be an actual conflict of interest.
- **Appearance of a conflict of interest:** A situation in which others might think that there is a conflict of interest, even if there isn't really one.
- **Avoiding conflicts of interest:** Most engineering codes of ethics require the avoidance of conflicts of interest or even the appearance of conflicts of interest, insofar as this is possible.

his professional judgment. He has betrayed the trust that his clients have placed in his professional judgment by serving his personal interest in his relative rather than the interests of his clients as he is paid to do.

Conflicts of interest can strike at the heart of professionalism. This is because professionals are paid for their expertise and unbiased professional judgment in pursuing their professional duties and conflicts of interest threaten to undermine the trust that clients, employers, and the public place in that expertise or judgment. When a conflict of interest is present, there is an inherent conflict between a professional actively pursuing certain interests and carrying out his or her professional duties as one should.

Engineering codes of ethics usually have something to say about conflicts of interest. Fundamental Canon 4 of the NSPE code addresses the idea that engineers should act as "faithful agents or trustees" in performing their professional duties. The first entry under the heading is that engineers should disclose all "known" or "potential" conflicts of interest to their employers or clients. Section III on professional obligations specifies some specific prohibitions:

5. Engineers shall not be influenced in their professional duties by conflicting interests.
   a. Engineers shall not accept financial or other considerations, including free engineering designs, from material suppliers for specifying their product.
   b. Engineers shall not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with clients or employers for the Engineer in connection with work for which the Engineer is responsible.

In considering these prohibitions and conflicts of interest more generally, however, several important points must be kept in mind. First, a conflict of interest is not just any set of conflicting interests. An engineer may like tennis and swimming and cannot decide which interest is more important to her. This is not a conflict of interest in the special sense in which this term is used in professional ethics because it does not involve a conflict that is likely to influence professional judgment.

Second, simply having more commitments than one can satisfy in a given period of time is not a conflict of interest. Overcommitment can best be characterized as a conflict of commitment. This, too, should be avoided. However, a conflict of interest involves an inherent conflict between a particular duty and a particular interest, regardless of how much time one has on one's hands. For example, serving on a review panel for awarding research grants and at the same time submitting a grant proposal to that review panel creates an inherent conflict between one's interest in being awarded a grant and one's responsibility to exercise impartial judgment of proposal submissions.

Third, the interests of the client, employer, or public that the engineer must protect are restricted to those that are morally legitimate. An employer or a client might have an interest that can be served or protected only through illegal activity (e.g., fraud, theft, embezzlement, and murder). An engineer has no professional duty to serve or protect such interests. On the contrary, the engineer may have a duty to expose such interests to external authorities.

Fourth, a distinction is sometimes made between *actual* and *potential* conflicts of interest. The following are examples. *Actual*: John has to recommend parts for one of his company's products. One of the vendors is Ajax Suppliers, a company in which John has heavily invested. *Potential*: Roger will have a conflict of interest if he agrees to serve on a committee to review proposals if he has already submitted his own proposal to be reviewed.

The first hypothetical case illustrates something very important about conflicts of interest. Having a conflict of interest need not, in itself, be unethical. John has a conflict of interest, but he has not necessarily done anything wrong—yet. What he does about his conflict of interest is what matters. If he tries to conceal from others that he has the conflict of interest and then recommends Ajax, he will have engaged in ethically questionable behavior. But he could acknowledge the conflict of interest and refrain from recommending in this case. Thus, his conflict of interest would not result in his judgment being compromised.

Fifth, even though it is best to avoid conflicts of interest, sometimes this cannot reasonably be done. Even then, the professional should reveal the existence of the conflict rather than wait for the customer or the public to find out about it on their own. In line with this, Fundamental Canon 4 of the NSPE code states:

> a. Engineers shall disclose all known or potential conflicts of interest to their employers or clients by promptly informing them of any business association, interest, or other circumstances which could influence or appear to influence their judgment or the quality.

After disclosure, clients and employers can decide whether they are willing to risk the possible corruption of the professional's judgment that such a conflict of interest might cause. Thus, the free and informed consent of clients and employers is preserved.

What if an engineer is convinced that he or she does not have a conflict of interest even though others may think otherwise? Two comments should be stated regarding this issue. First, self-deception is always possible. In a case in which there actually is a conflict of interest, one may have some motivation not to acknowledge this to oneself. Second, it is important to realize that even the appearance of a conflict of interest decreases the confidence of the public in the objectivity and trustworthiness of professional services and thus harms both the profession and the public. Therefore, it is best for engineers to use caution regarding even the appearance of a conflict of interest.

An important part of any professional service is professional judgment. Allowing this to be corrupted or unduly influenced by conflicts of interest or other extraneous considerations can lead to another type of misusing the truth. Suppose engineer Joe is designing a chemical plant and specifies several large pieces of equipment manufactured by a company whose salesperson he has known for many years. The equipment is of good quality, but newer and more innovative lines may actually be better. In specifying his friend's equipment, Joe is not giving his employer or client the benefit of his best and most unbiased professional judgment.

5.12 CHAPTER SUMMARY

Recognizing the importance of trust and reliability in engineering practice, codes of ethics require engineers to be honest and impartial in their professional judgments. Forms of dishonesty include not only lying and deliberate deception but also withholding the truth and failing to seek out the truth. From the standpoint of the ethics of respect for persons, dishonesty is wrong because it violates the moral agency of individuals by causing them to make decisions without informed consent. From the utilitarian perspective, dishonesty is wrong because it can undermine the relations of trust on which a scientific community is founded, as well as informed decision-making, thus impeding the development of technology. From the virtue perspective, dishonesty is a departure from the fundamental virtue of honesty, a character trait that is committed to truthfulness.

Dishonesty on campus accustoms a student to dishonesty, which can carry over into his or her professional life. There are, in fact, exact counterparts in the scientific research and engineering communities to the types of dishonesty exhibited by students on campus.

An engineer should respect professional confidentiality. The limits of confidentiality are controversial and often difficult to determine in engineering as in most professions. Decisions regarding the proper use of intellectual property with regard to trade secrets, patents, and copyrighted material are often difficult to make because they may involve varying degrees of use of intellectual property. The line-drawing method is useful in resolving these problems.

Integrity in expert testimony requires engineers to take cases only when they have adequate time for preparation, to refuse to take cases when they cannot testify in good conscience on behalf of their client, to consult extensively with the lawyer regarding the technical and legal details of the case, to maintain an objective and unbiased demeanor, and always to be open to new information. Engineers should inform employers, clients, and the public of relevant information, especially when this information concerns the health, safety, and welfare of the public.

A conflict of interest exists for professionals when, acting in their professional roles, they have other interests that, if actively pursued, threaten to compromise their professional judgment and interfere with satisfactorily fulfilling their professional duties.

NOTES

1. This account is based on a *Detroit News* article, "VW engineer's guilty pleas could signal more indictments," Sept. 9, 2016, authored by Jennifer Chambers, Michael Wayland, Melissa Burden, and Robert Snell.
2. William F. May, "Professional Virtue and Self-Regulation," in *Ethical Issues in Professional Life*, ed. Joan Callahan (Oxford: Oxford University Press, 1988), p. 408.
3. Ibid.
4. This is based on a story that appeared in *The Seattle Times*, July 24, 2000.
5. Sissela Bok, *Lying: Moral Choice in Public and Private Life* (New York: Vintage Books, 1999), p. 31.
6. This case is based on Molly Galvin, "Unlicensed *Engineer* Receives Stiff Sentence," *Engineering Times,* 16, no. 10, October 1994, pp. 1 and 6.
7. We are indebted to our student, Ray Flumerfelt, Jr., for this case. Names have been changed to protect those involved.
8. The controversy over Millikan's reporting of his work is discussed in Gerald Holton, "Subelectrons, Presuppositions, and the Millikan-Ehrenhaft Dispute," *Historical Studies in the Physical Sciences,* 9, 1978, pp. 161–224.
9. For an account of this case, see Robert L. Sprague, "The Voice of Experience," *Science and Engineering Ethics*, 4, no. 1, 1998, p. 33.

10. Alan Poling, "The Consequences of Fraud," in *Research Fraud in the Behavioral and Biomedical Sciences*, eds. David Miller and Michel Hersen (New York: Wiley, 1992), pp. 140–157.
11. We are indebted to Mark Holtzapple for this example.
12. *Opinions of the Board of Ethical Review*, Vol. VI (Alexandria, VA: National Society of Professional Engineers, 1989), p. 15.
13. See "Plaintiffs to Get $15.4 Million," *Miami County Republic* [Paola, Kansas], April 27, 1992, p. 1.
14. Paul Eddy, *Destination Disaster: From the Tri-Motor to the DC-10* (New York: Quadrangle/New York Times Book Company, 1976), pp. 175–188. Reprinted in Robert Baum, *Ethical Problems in Engineering*, Vol. 2 (Troy, NY: Center for the Study of the Human Dimensions of Science and Technology, 1980), pp. 175–185.
15. Grimshaw v. Ford Motor Co., App., 174 Cal. Rptr. 348, p. 360.
16. Michael Davis, "Conflict of Interest," in *Ethical Issues in Engineering*, ed. Deborah Johnson (Englewood Cliffs, NJ: Prentice Hall, 1991), p. 234. For further discussion of conflicts of interest, see Michael Davis and Andrew Stark, eds., *Conflicts of Interest in the Professions* (New York: Oxford University Press, 2001); and Michael S. Pritchard, *Professional Integrity: Thinking Ethically* (Lawrence: University Press of Kansas, 2006), pp. 60–66.

CHAPTER SIX

The Engineer's Responsibility to Assess and Manage Risk

Main Ideas in This Chapter

- **Engineers impose risks on the public in design and in management of engineered systems and infrastructure and have an obligation to assess and manage these risks.**
- **Engineers and risk experts define risk as the product of the probability of a harm and the magnitude of that harm.**
- **In quantifying risks, engineers and risk experts have traditionally considered only harms that are relatively easily quantified, such as economic losses, bodily injury, or the number of lives lost.**
- **In a new version of the way engineers and risk experts deal with risk, the "capabilities" approach focuses on the broader effects of risks and disasters on the capabilities of people to live the kinds of lives they value.**
- **The public is concerned about informed consent and the just distribution of risk.**
- **Engineers have techniques for estimating the causes and likelihood of harm, but their effectiveness is limited.**

ON THE FOGGY SATURDAY MORNING of July 28, 1945, a twin-engine U.S. Army Air Corps B-25 bomber lost in the fog crashed into the Empire State Building 914 feet above street level. It tore an 18-by-20-foot hole in the north face of the building and scattered flaming fuel into the building. New York firemen put out the blaze in 40 minutes. The crew members and 10 persons at work perished.[1] The building was repaired and still stands.

Just 10 years later, in 1955, the leaders of the New York City banking and real-estate industries got together to initiate plans for the New York City World Trade Center (WTC), which would later become known as the Twin Towers, the world's tallest buildings at the time.[2] However, as the plans emerged, it became clear that the buildings required new construction techniques.

On September 11, 2001, terrorists attacked the Twin Towers by flying two hijacked Boeing 727 passenger jets into them, each jet smashing approximately two-thirds of the way up its respective tower. A significant consequence of the attack was the fire that started over several floors fed by the spilled jet fuel. The fires isolated more than 2,000 workers in the floors above them. Only 18 of the more than 2,000 were able to descend the flaming stairwells to safety. Most of the 2,000 perished in the subsequent collapse of the buildings. By comparison, almost all of the workers in the floors below the fire were able to make it down to safety before the towers collapsed. Differences in high-rise building construction techniques as well as the difference in the quantity of fuel involved are factors in the very different performance of these newer structures compared to the Empire State Building.

In the hour following the plane crashes that destroyed or damaged many exterior columns and removed the fire protection from others, the prolonged and intense heat of the flames (more than 1,000 degrees Fahrenheit) caused the structural steel members to lose strength, resulting in beams sagging and an inward deflection of the remaining exterior columns. As a result, the floor structures broke away from the exterior columns. As the top floors fell, they created impact loads on the lower floors that the columns could not support and both buildings progressively collapsed.[3]

For an engineer, 9/11 raises questions of how these structural failures could have happened, why the building codes did not better protect the public, and how to reduce the risk of such disasters in the future. There are even larger questions about acceptable risk and the proper approach to risk as an issue of public policy.

6.1 INTRODUCTION

The concern for safety is ever-present in engineering. How should engineers deal with issues of safety and risk, especially when they involve possible liability for harm? Changes in building technology from the time of the Empire State Building, which withstood the impact and fire caused by the B-25 aircraft, until the time of the design and construction of the World Trade Center, have been hypothesized as factors in the very different performance of the two towers under similar events. The Empire State Building involved much heavier construction with significant masonry cladding compared to the lighter glass cladding of the WTC towers. Most importantly, the steel columns of the Empire State building were protected from fire by an 8 in. thick layer of concrete that also served to carry part of the axial loads and the stairwells were designed to be "fireproof," which allowed most occupants safe egress. The lighter construction techniques in the WTC reduced construction costs for taller buildings and required less massive columns for comparable heights. The lighter columns were certainly an important difference in increasing the vulnerability to both impact and fire damage, compared to the Empire State Building. This illustrates an important fact: engineering necessarily involves risk and risk changes as technology changes. One cannot avoid risk simply by remaining with tried and true designs, but new technologies involve risks that may not be as well understood, potentially increasing the chance of failure or even introducing a previously unknown mode of failure. Without new technology, there is no progress. A bridge or building is constructed with new materials or with a new design. New machines are created and new compounds synthesized, always without full knowledge of their long-term effects on humans or the environment. Even new hazards can be found in products, processes, and chemicals that were once thought to be safe. Thus, risk is inherent and dynamic in engineering.

While engineering and construction practices change gradually over time, engineering practices also change as risks change or as our understanding of risks changes. The International Code Council's (ICC) 2009 edition of the International

Building Code (IBC), which is a model code that is adopted by many jurisdictions, includes several significant changes in rules for design and construction and in fire protection representing lessons learned from the collapse of the World Trade Center buildings. And, these changes happened much faster than the evolutionary changes in building practices and building construction methods which were by comparison gradual between the time of design and construction of the Empire State Building and the World Trade Center buildings.

As noted in Chapter 1, now virtually all engineering codes of ethics give a prominent place to safety, stating that engineers must hold paramount the safety, health, and welfare of the public. The first Fundamental Canon of the National Society of Professional Engineers Code requires members to "hold paramount the safety, health, and welfare of the public." Section III.2.b instructs engineers not to "complete, sign, or seal plans and/or specifications that are not in conformity with applicable engineering standards." Section II.1.a instructs engineers that if their professional judgment is overruled in circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate. Although "such other authority as may be appropriate" is left undefined, it probably includes those who enforce local building codes and regulatory agencies.

Safety and risk obviously are related ideas; engineers work to make their designs safer. However, no activity or system is perfectly risk free and making any engineered system safer generally means increasing the cost of that system. Engineered systems that are too expensive are not affordable to the taxpaying public or to the purchasing consumer, which means cost constraints are very real. Designing engineers must try to achieve acceptably safe designs that are still affordable and engineers operating engineered systems must work to operate those engineered systems in ways that are acceptably safe, which is to say in ways that do not introduce unacceptable risks. Generally acceptable levels of safety are codified in design codes for the product or system in question and the designing engineer only has to adhere to accepted practice as described in the design codes. However, if the designer develops an innovative design that deviates from accepted practice in some way, the resulting innovative design may introduce previously unidentified risks.

Engineers are concerned with many kinds of risks. Engineers of course face the same risks of everyday living as everyone else, including financial and personal safety, and sometimes there are job site risks or other specific risks to personal safety associated with specific tasks. Many engineers are also businessmen or businesswomen, and in that role they are certainly concerned with the organizational and financial risks associated with running a business. However, in this chapter we focus on the risks imposed on the public by engineering work, which has a role-specific ethical dimension. We will present an engineering definition of risk and look at the different ways that engineering work can affect risks to the public. We will examine how engineers can identify and assess the risks imposed by their work and discuss the moral questions related to determining which risks are acceptable.

6.2 THE ENGINEER'S APPROACH TO RISK

An Engineering Definition of Risk

To assess a risk of harm, an engineer must identify it and quantify it. Engineers often define risk as the product of the probability (p_i) of a harm and the magnitude (h_i) of that harm as in Equation 6.1. The units of risk defined in this way are the units of the harm being considered, so risks with different harms can't be added or directly compared. The summation notation then implies the summation of all risk components with similar harms. For example, it is possible to estimate the risk of death by electrocution for a utility lineman performing a specific maintenance operation and it is possible to estimate the risk of economic loss resulting from a bridge collapse, but a comparison of these two different calculated risks is not meaningful because they have different harms, and thus units. However, the risk of death in a bridge collapse could be compared with, or added to, the risk of lineman death in power line maintenance operations.

$$Risk = \sum_{i=1}^{n} p_i h_i \tag{6.1}$$

Engineers have traditionally thought of harms in terms of things that can be relatively easily quantified, such as loss of life, personal injury or illness, and damage to property or the environment. Increasingly, engineers are also considering impairment of "capabilities" that allow us to live the kind of life we enjoy. We will discuss this new view of risk in more detail later.

How Engineers Impose and Manage Risks

Risk is imposed, and managed, in different ways in different engineering tasks. Risk is managed in engineering design by design codes—rules proven to produce designs consistent with accepted engineering practice and which do not introduce unacceptable risks. These design rules usually focus on proportioning the system so that the capacity (strength) of the design exceeds the demands (loads) by a specified margin, but design rules sometimes also invoke some basic engineering principles, such as redundancy, the design for failure modes that give visible or audible warnings, or load-limiting devices. For example, highway bridge design rules promulgated by the American Association of State Highway and Transportation Officials (AASHTO) were modified to require more redundancy in a class of fracture-critical highway bridges after the 1967 rush-hour collapse of the Silver Bridge, an eyebar-chain suspension bridge over the Ohio River that resulted in 46 deaths. That failure also triggered more stringent bridge inspection and maintenance requirements for all highway bridges.

Risk is also managed in the operation of engineering systems by development of and adherence to proven operational and maintenance rules. Consider the 1979 crash of American Airlines Flight 191 in Chicago. During takeoff, the left engine and pylon separated from the wing, damaging hydraulic lines and leading to an uncontrolled crash resulting in 273 deaths and loss of the DC-10 aircraft. The failure was caused by unapproved maintenance procedures used to service the spherical bearings connecting the pylon to the wing, which caused cracks in the wing structure. The nonstandard procedure, involving removal of the engine and pylon as a unit, was an innovative effort by several airline maintenance forces because it eliminated the need to disconnect and reconnect many hydraulic, fuel, and electrical lines connecting the engine to the pylon and saved about 200 man-hours per aircraft compared to standardized procedures. But, in the process of removing the engine plus pylon, excess force was applied to mounting points causing cracks in the wing structure.

Operation of a nuclear power plant offers similar but much more complex challenges and with the potential for even greater problems. Continuous training and adherence to standardized processes is critical and frequent review of those processes is very important. Engineers operating any engineered system should be especially wary about shortcuts and always be watchful for potential weaknesses in the systems they operate. Suppose an operations engineer, thinking broadly about safety, had noticed the vulnerability to tsunami flooding of the backup generators at the Fukushima Nuclear Plant and initiated improvements—perhaps one of the greatest disasters of our time might have been averted.

Sources of Risks Managed by Engineers

The sources of risks that engineers are concerned with include environmental loadings resulting from weather events, seismic events, or even cosmic events, and human actions, both unintentional and intentional. Human error in the design process leading to faulty design of a building can result in collapse with economic losses to the owner, perhaps injury or death for some occupants, and reduction of the tax base for the whole community. Increasingly, engineers are also concerned with attacks on engineered facilities, including both kinetic actions by terrorists and cyberattacks. Assessment of risks resulting from terrorist attack can involve more attributes than probability and harms. Such risk analyses should also include identification of both threats and vulnerabilities, because it can be presumed that in the presence of threats the probability of attack can increase with increasing vulnerability. "Soft" targets are more likely to be attacked while "hardened" facilities and systems can decrease the probability of an attack. In contrast, good seismic engineering does not reduce the probability of an earthquake (although it does reduce the harm of the earthquake). Even without considering the possibility of human error or terrorist attack, good engineering design requires an estimate of the most severe environmental loadings that can reasonably be expected (wind, snow, earthquake, solar storms) and our ability to predict such events is imperfect, which is one reason engineering designs can never be risk free.

Risks are dynamic; actual risks can change during the lifetime of an engineered system. Sometimes this is triggered by the use of new technology—consider the recent observations of dramatically increased seismic activity in areas where hydraulic fracturing is used to stimulate production in shale formations. Whether this will represent a significant new risk to nearby engineered facilities is not yet known. Likewise the risks of storm-induced flooding in coastal areas will increase if sea levels rise. In addition to the dynamic nature of the risk itself, our ability to assess risks and our delineation of acceptable or tolerable risks also change with time. In 2008, the improved understanding of seismic risks and methods to predict tsunami runout compared to the state of knowledge about these risks in the 1960s when the Fukushima Nuclear Plant was designed should have triggered additional risk-management measures at the Fukushima Nuclear Plant. Instead, plant managers did not accept as "realistic" a 2008 internal report suggesting the possibility of much more severe earthquakes and much higher tsunami runouts than the plant designers had considered. Acton and Hibbs[4] highlight the changing understanding of risks in their observation about the Fukushima incident:

> In the final analysis, the Fukushima accident does not reveal a previously unknown fatal flaw associated with nuclear power. Rather, it underscores the importance of periodically reevaluating plant safety in light of dynamic external threats and of evolving best practices....

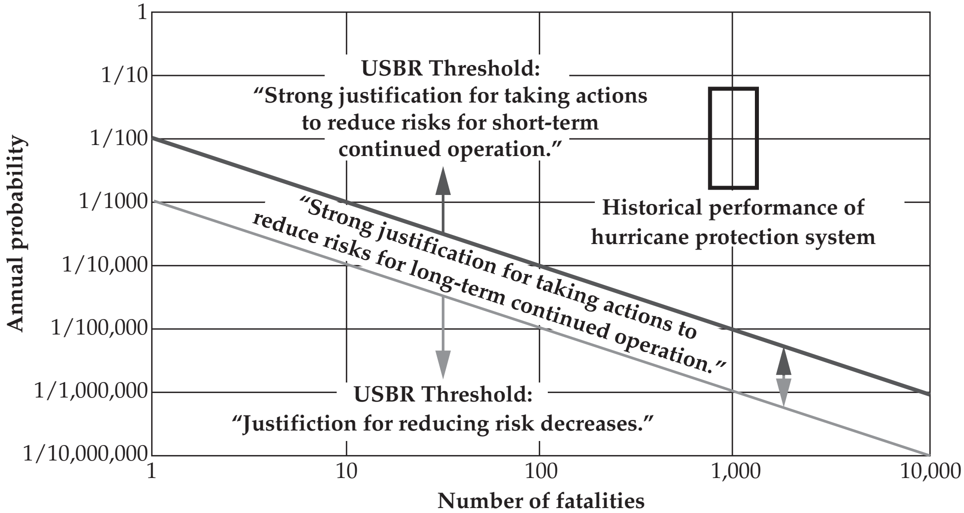
Risk is generally increased by innovation in both engineering design and in operations. Engineering educators encourage innovative solutions to engineering design problems, but sometimes fail to emphasize the important relationship between innovation and risk. Innovation, by definition, involves design features or details that are somehow outside the envelope of current practice. Design standards may not anticipate all the issues raised by a particular innovative solution. Thus, many more questions must be addressed by the engineer proposing an innovative solution to make sure newly introduced risks are identified and addressed. The design of the Citicorp building is recognized as a significantly innovative structural engineering solution to an unusual design constraint and the story of that building provides an important illustration of how an engineer is expected to respond when a new risk is identified. But the new risk arose only after the building was placed in service because the structural engineer did not anticipate all the risks introduced by his innovative framing method, which was outside the envelope of standard practice and therefore not anticipated in the design codes. The engineer did not identify and manage this new risk during the design process and we are very fortunate that the risk was even identified before the structure was subjected to design wind loads. In summary, the engineer who chooses to employ truly innovative details or systems has an additional responsibility to identify and address any new risks of failure introduced by the new detail or system. The ability and determination to fulfill this responsibility is an important virtue for an engineer who chooses such innovative solutions in safety-critical designs.

The U.S. Bureau of Reclamation has published recommendations for determining which risk levels justify additional efforts to reduce risks with respect to management of risks caused by dams. These recommendations were discussed in the ASCE's external review[5] of the Katrina flooding as a way to quantify and assess risks associated with the hurricane protection system at New Orleans. The USBR recommendations, presented in Box 6.1, divide the risk of death space (annual probability vs number of fatalities) into three regimes. The lowest risk regime, labeled "Justification for reducing risk decreases" is below an annual risk of death of 10^{-3} (a risk of one death every 1,000 years or 1,000 deaths every 1,000,000 years). The highest risk regime, labeled, "Strong justification for taking actions to reduce risks for short-term continued operation," is above an annual risk of death of 10^{-2}, a risk of one death every 100 years or 1,000 deaths every 100,000 years). Between these two regimes is a regime labeled, "Strong justification for taking actions to reduce risks for long-term continued operation." By comparison, based on its historical performance, the estimated risk of the New Orleans hurricane protection system was well above the higher threshold at a risk of 1,000 deaths every 100 years or an annual risk of death of 10 (one death every 0.1 year). If the USBR recommendations regarding acceptable risk for dams can also be applied to hurricane protection systems, even though they are very different from dams, the risks presented by the pre-Katrina hurricane protection system were unacceptably high and strongly justified additional risk-reducing investment.

One Engineering Approach to Defining Acceptable Risk

The engineering concept of risk focuses on the factual issues of the probability and magnitude of harm and contains no implicit evaluation of whether a risk is morally acceptable. In order to determine whether a risk is acceptable, engineers and risk experts considering engineering solutions often use a cost-benefit analysis that is fundamentally a utilitarian approach. The cost-benefit approach compares the costs,

BOX 6.1 Dam Safety Risk Management Guidelines



Source: U.S. Bureau of Reclamation

including the quantified costs of the imposed risks of the engineering actions under consideration, with the benefits of the actions. Then the engineering solution that maximizes net benefits (benefits minus costs) consistent with economic and other constraints is typically selected. For simplest comparison in a cost-benefit analysis, both the costs and benefits are expressed in equivalent monetary values. This cost-benefit approach to comparing alternative engineering actions has much in common with the utilitarian approach to choices between alternative actions in moral issues. The utilitarian approach to moral issues involves at least a qualitative, if not quantitative, comparison of the utility (benefits) with the harms (costs), allowing the selection of the alternative that results in the greatest good for the greatest number. Given the earlier definition of risk as the product of the probability and the magnitude of harm, we can state the engineer's criterion of acceptable risk in the following way: An acceptable risk is one in which the product of the probability and magnitude of the harm is equaled or exceeded by the product of the probability and magnitude of the benefit.

Consider a case in which a manufacturing process produces bad-smelling fumes that might be a threat to public health. From the cost-benefit standpoint, is the risk to the workers from the fumes acceptable? To determine whether this is an acceptable risk from the cost-benefit perspective, one would have to compare the cost associated with the risk to the cost of preventing or drastically reducing it. To calculate the cost of preventing the harms, we would have to include the costs of modifying the process that produces the fumes, the cost of providing protective masks, the cost of providing better ventilation systems, and the cost of any other safety measures necessary to mitigate the risk. Then we must calculate the cost of not preventing the deaths caused by the fumes. Here, we must include factors such as the cost of additional health care, the cost of possible lawsuits because of the deaths, the cost of bad publicity, the loss of income to the families of the workers, and other costs associated with the loss of life. If the total cost of preventing the loss of life is greater than the total cost of not preventing the deaths, then the current level of risk is acceptable. If the total cost of not preventing the loss of life is greater than the total cost of preventing the loss, then the current level of risk is unacceptable.

The utilitarian approach to risk embodied in cost-benefit analysis has undoubted advantages in terms of clarity, elegance, and susceptibility to numerical interpretation. Nevertheless, there are several limitations that must be kept in mind.

First, it may not be possible to anticipate all of the effects associated with each option. Insofar as this cannot be done, the cost-benefit method will yield an unreliable result.

Second, it is not always easy to translate all of the risks and benefits into monetary terms. How do we assess the risks associated with a new technology, with eliminating a wetland, or with destruction of habitat important to a particular species of bird in a Brazilian rain forest? Apart from doing this, however, a cost-benefit analysis is incomplete.

The most controversial issue in this regard is, perhaps, the monetary value that should be placed on human life. One way of doing this is to estimate the value of future earnings, but this implies that the lives of retired people and others who do not work commercially, such as housewives, are worthless. So a more reasonable approach is to attempt to estimate a monetary value associated with incremental risks. For example, people often demand a compensating wage to take a job that involves more risk. By calculating the increased risk and the increased pay that people demand for jobs involving greater risk, some economists say, we can derive an estimate of the monetary value people place on such incremental risks to their own lives. Alternatively, we can calculate how much more people would pay to reduce risks in an automobile or other things they use by observing how much more they are willing to pay for a safer car. Unfortunately, there are various problems with this approach. When there are few jobs, a person might be willing to take a risky job he or she would not be willing to take if more jobs were available. Furthermore, wealthy people are probably willing to pay more for increased safety than are poorer people.

Third, cost-benefit analysis in its usual applications makes no allowance for the actual distribution of costs and benefits. Suppose more overall utility could be produced by exposing workers in a plant to a risk of sickness and death. As long as the good of the majority outweighs the costs associated with the suffering and death of those few individual workers who actually are harmed, the risk might be justified by the cost-benefit analysis. Yet, most of us would probably find that an unacceptable account of acceptable risk.

Fourth, the cost-benefit analysis gives no place for informed consent to the risks imposed by technology. We shall see in our discussion of the lay approach to risk that most people think informed consent is one of the most important features of justified risk. As a result, the layperson sometimes disagrees with risk experts (engineers) in assessment of acceptable risks.

The case of the Ford Pinto is an instructive example where the distribution of benefits and harms was grossly inequitable and where the public disagreement about the acceptability of the risk became very obvious. Ford compared the costs and benefits of various upgrades to the fuel tank of the Pinto to reduce the risk of fire resulting from rear end collisions. Analysis of the risks included assignment of costs for medical treatment of burn victims and a cost of $200,000 for each resulting death. Numbers of accidents, burn victims, and deaths were inferred from the estimated production numbers of the vehicle, vehicle life, and vehicular accident rates. These costs were compared to the costs of an improved fuel tank and filler line system intended to reduce the chance of fuel spills and the cost-benefit calculations favored production of the Pinto without the improvements. While it may seem as if Ford's estimate of the value of human life ($200,000) was far too low, it should be pointed out that in 1970, one of the authors, then a recent engineering graduate with an annual salary of about $10,000, carried only a $5,000 life insurance policy (and drove a Ford Pinto). So it probably was not that particular valuation of human life that so frustrated the juries who heard initial product liability lawsuits and awarded millions to the plaintiffs. Rather, it was probably the fact that being burned alive in an otherwise survivable automobile accident probably ranked high on the jurors' list of unacceptable rights violations and the dramatically unfair distribution of the costs (injuries and deaths to a few unfortunate motorists) compared to the benefits (prices reduced by a few dollars to all purchasers of the Pinto).

Despite these limitations, cost-benefit analysis has a legitimate place in risk evaluation and may be decisive when no serious threats to individual rights are involved. Cost-benefit analysis is systematic, offers a degree of objectivity, and provides a way of comparing risks and benefits by the use of a common measure—namely, monetary cost. But the Pinto case teaches us that an engineer using the utilitarian approach (cost-benefit analysis) to risk assessment in design decisions should always, at the conclusion, consider the equitability of harm and risk distributions and ask him- or herself if a respect-for-persons approach should trump or limit the outcome of the cost-benefit analysis.

Expanding the Engineering Account of Risk: The Capabilities Approach to Identifying Harm and Benefit

As we have pointed out, engineers, in identifying risks and assessing acceptable risk, have traditionally identified harm with factors that are relatively easily quantified, such as economic losses and the number of lives lost.[6] However, four main limitations exist with this rather narrow way of identifying harm. First, often only the immediately apparent or focal consequences of a hazard are included, such as the number of fatalities or the number of homes without electricity. However, hazards can have auxiliary consequences or broader and more indirect harms to society. Second, both natural and engineering hazards might create opportunities, which should be accounted for in the aftermath of a disaster. Focusing solely on the negative impacts and not including these benefits may lead to overestimating the negative societal consequences of a hazard. Third, there remains a need for an accurate, uniform, and consistent metric to quantify the consequences (harms or benefits) from a hazard. For example, there is no satisfactory method for quantifying the nonfatal physical or psychological harms to individuals or the indirect impact of hazards on society. The challenge of quantification is difficult and complex, especially when auxiliary consequences and opportunities are included in the assessment. Fourth, current techniques do not demonstrate the connection between specific harms or losses, such as the loss of one's home and the diminishment of individual or societal well-being and quality of life. Yet, it is surely the larger question of effect on quality of life that is ultimately at issue when considering risk.

In their work on economic development, economist Amartya Sen and philosopher Martha Nussbaum have derived a notion of "capabilities" that the two scholars believe may be the basis of a more adequate way of measuring the harms (and sometimes the benefits) of disasters, including engineering disasters.[7] Philosopher Colleen Murphy and engineer Paolo Gardoni have developed a capabilities-based approach to risk analysis, which focuses on the effect of disasters on overall human well-being. Well-being is defined in terms of individual capabilities or "the ability of people to lead the kind of life they have reason to value." Specific capabilities are defined in terms of functionings or what an individual can do or become in his or her life that is of value. Examples of functionings are being alive, being healthy, and being sheltered. A capability is the real freedom of individuals to achieve a functioning and it refers to the real options he or she has available. Capabilities are constituent elements of individual well-being.

Capabilities are distinct from utilities, which refer to the mental satisfaction, pleasure, or happiness of a particular individual. Often, people's preferences or choices are used to measure satisfaction. Utilities are assigned to represent a preference function. In other words, if an individual chooses A over B, then A has more utility than B. Using utilities to measure the well-being of individuals, however, is problematic because happiness or preference satisfaction is not a sufficient indicator of an individual's well-being. For example, a person with limited resources might learn to take pleasure in small things, which are only minimally satisfying to a person with ample means. The individual in a poverty-stricken situation might have all of his or her severely limited desires satisfied. From the utilitarian standpoint, the person would be described as happy and be said to enjoy a high standard of living. Yet, this individual might still be objectively deprived. The problem here is that utilitarianism does not take into account the number and quality of options that are available to individuals, which is precisely what capabilities capture.

From the capabilities standpoint, a risk is the probability that individuals' capabilities might be reduced due to some hazard. In determining a risk, the first step is to identify the important capabilities that might be damaged by a disaster. Then, to quantify the ways in which the capabilities might be damaged, we must find some "indicators" that are correlated with the capabilities. For example, an indicator of the impairment of the capability for play might be the loss of parks or gym facilities. Next, the indicators must be scaled onto a common metric so that the normalized values of the indicators can be compared. Then, a summary index is constructed by combining the information provided by each normalized indicator, creating a hazard index (HI). Finally, to put the HI into the relevant context, its value is divided by the population affected by the hazard, creating the hazard impact index, which measures the hazard impact per person.

According to its advocates, there are four primary benefits of using the capabilities-based approach in identifying the societal impact of a hazard. First, capabilities capture the adverse effects and opportunities of hazards beyond the consequences traditionally considered. Second, since capabilities are constitutive aspects of individual well-being, this approach focuses our attention on what should be our primary concern in assessing the societal impact of a hazard. Third, the capabilities-based approach offers a more accurate way to measure the actual impact of a hazard on individuals' well-being. Fourth, rather than considering diverse consequences, which increase the difficulty of quantification, the capabilities-based approach requires considering a few properly selected capabilities.[8]

In addition to identifying more accurately and completely the impact of a hazard, its advocates believe the capabilities-based approach provides a principled foundation for judging the acceptability and tolerability of risks.[9] Judgments of the acceptability of risks are made in terms of the impact of potential hazards on the capabilities of individuals. Thus, according to the capabilities approach, a risk is acceptable if the probability is sufficiently small that the adverse effect of a hazard will fall below a threshold of the minimum level of capabilities attainment that is acceptable in principle. The "in principle" qualification captures the idea that, ideally, we do not want individuals to fall below a certain level. We might not be able to ensure this, however, especially immediately after a devastating disaster. In practice, then, it can be tolerable for individuals to temporarily fall below the acceptable threshold after a disaster, as long as this situation is reversible and temporary and the probability that capabilities will fall below a tolerability threshold is sufficiently small. Capabilities can be a little lower, temporarily, as long as no permanent damage is caused and people do not fall below an absolute minimum.

6.3 DIFFICULTIES IN DETERMINING THE CAUSES AND LIKELIHOOD OF HARM: THE CRITICAL ATTITUDE

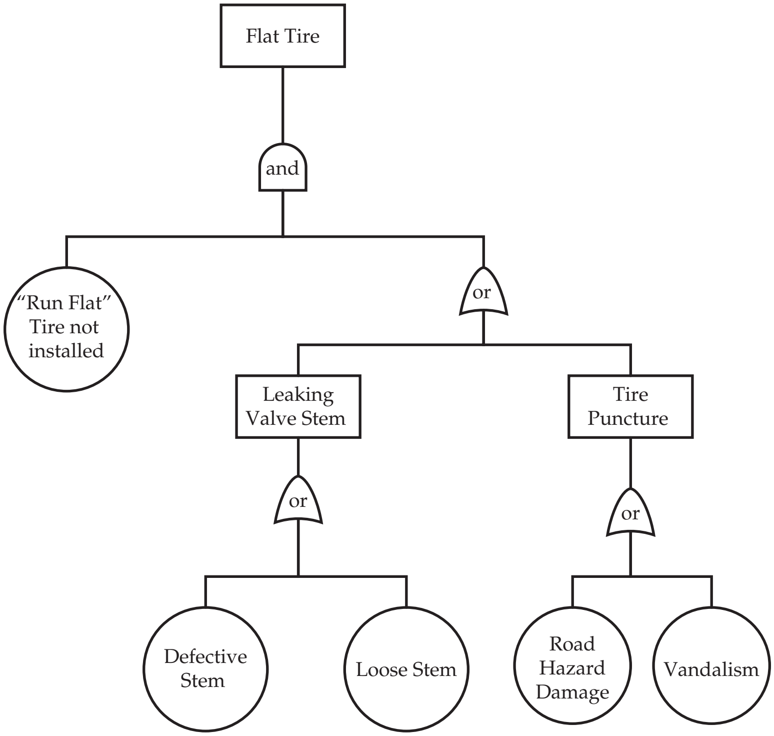
Estimating risk, no doubt defined as estimating the probabilities and magnitudes of some harms, has been described by one writer as looking "through a glass darkly."[10] It would be highly desirable, of course, to be able to accurately predict both the possible harms and the probability of each harm resulting from engineering work. Instead, engineers can only estimate probability and magnitude of any anticipated harm. To make matters worse, often engineers cannot even make estimates satisfactorily. In actual practice, therefore, estimating risk (or "risk assessment") involves an educated guess at the possible undesirable consequences and an uncertain prediction of the probability of each consequence. In this section, we consider some of the methods of estimating risk, the uncertainties in these methods, and the value judgments that these uncertainties necessitate.

Limitations in Identifying Failure Modes

With respect to new technologies, engineers and scientists must have some way of estimating the risks that they impose on those affected by them. One of the methods for assessing risk involves the use of a fault tree analysis (FTA), a formal backward looking deductive analysis, to determine the immediate and basic causes of some undesirable event. In a fault tree analysis, for each identified undesirable event (consequence), Boolean logic is used to identify first the immediate causes of that event and then the basic causes. A probabilistic risk assessment (PRA) can then be conducted to estimate the probabilities of each basic and immediate cause, allowing an estimation of the probability of the event with improved confidence.

Fault trees such as the example illustrated in Box 6.2 are often used to anticipate hazards for which there is little or no direct experience, such as nuclear meltdowns. They enable an engineer to analyze systematically different events or failure modes that could produce the undesirable end result. A failure mode is a way in which a structure, mechanism, system, or process can malfunction. For example, a structural member can fail in tension, crush or buckle in compression, crack or rupture in bending, suffer loss of section and strength because of corrosion or abrasion, burst

BOX 6.2 Fault Tree Example



Fault Tree Analysis of flat tire: A flat tire on your new car can have several causes. If "Run Flat" tires are installed as intended by the manufacturer, then the problem is prevented. But if ordinary tires are instead installed, they can leak at any punctures or through the valve stem. Those two intermediate causes each show two fundamental causes. If probabilities are estimated for the likelihood of each of the basic causes, the probability of a flat tire can be estimated and the risk assessed. If the risk is deemed excessive, the probabilities of some of the basic causes might be reduced by more frequent inspection and/or maintenance or by improved security (parking in a secure garage to reduce the probability of vandalism).

because of excessive internal pressure, or lose strength or even burn because of excessive temperature.

Fault tree analysis has been criticized as offering too optimistic a perspective, most significantly because the fault tree analysis is the estimation of the aggregate probability of identified failure modes. It is sometimes the case that failure modes causing harm are not identified during these analyses. As a result, their risks are not estimated. In such a case, the analysis can be misleading, implying a lower risk than actually exists.

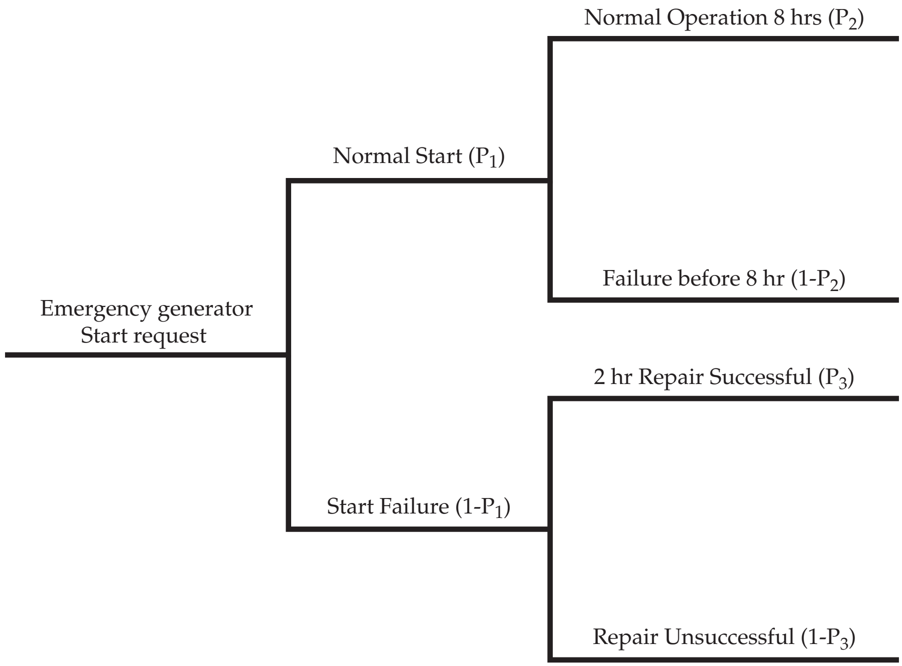
The March 2011 failure and meltdown of the reactors at the Fukushima Nuclear Power Plant is a case in point. The disaster was caused by a tsunami closely following a significant earthquake. The reactors shut down automatically following the earthquake, according to the usual protocol, but the consequent tsunami destroyed the backup electrical generators providing power for the emergency cooling systems. The subsequent delay in providing power to the emergency cooling systems led to meltdowns in three reactors. This failure highlights the need for continued reassessment of design standards for operational plants. According to the World Nuclear Association,

> The tsunami countermeasures taken when Fukushima Daiichi was designed and sited in the 1960s were considered acceptable in relation to the scientific knowledge then, with low recorded run-up heights for that particular coastline. But through to the 2011 disaster, new scientific knowledge emerged about the likelihood of a large earthquake and resulting major tsunami. However, this did not lead to any major action by either the plant operator, TEPCO, or government regulators, notably the Nuclear & Industrial Safety Agency (NISA). The tsunami countermeasures could also have been reviewed in accordance with IAEA [International Atomic Energy Agency] guidelines which required taking into account high tsunami levels, but NISA continued to allow the Fukushima plant to operate without sufficient countermeasures, despite clear warnings.[11]

A different approach to a systematic examination of failure modes is event tree analysis (ETA), a forward looking, inductive approach as illustrated in Box 6.3. In ETA, we reason forward from a hypothetical initiating event to determine what consequences that initiating event might have and then estimate the probabilities of these consequences.

Although engineers rightly believe that it is necessary to go through such analyses to ensure that they have taken into account as many failure modes as possible, the analyses

BOX 6.3 Event Tree Analysis Example



Event Tree Analysis of Emergency Power Failure: This analysis facilitates an estimation of the probability that emergency power supply will not be available for the duration of an 8 hour demand. If the resulting risk of loss of emergency power failure is unacceptable, the risk can be reduced by increasing P_1 (perhaps by increased inspection and preventive maintenance or by adding redundant systems) or by increasing P_3 (perhaps by improved training of maintenance forces or stockpiling of additional repair parts).

have severe limitations. First, it is not possible to anticipate all of the mechanical, physical, electrical, and chemical problems that might lead to failure. For example, the possibility of terrorist attacks has added a new dimension to risk analysis and estimation.

Second, it is never possible to anticipate all of the types of human error that could lead to failure. Third, the probabilities assigned to the failure modes are often highly conjectural and not always based on solid experimental testing. We are not, for example, going to melt down a nuclear reactor to determine the probability of such an occurrence leading to a chain reaction fission explosion. In many cases, we do not know the probability of the behavior of materials at extremely elevated temperatures.

Limitations due to Tight Coupling and Complex Interactions

Sociologist Charles Perrow[12] confirms some of these problems by arguing that there are two characteristics of high-risk technologies that make them especially susceptible to accidents and allow us to speak of "normal accidents." These two features are the "tight coupling" and "complex interactions" of the parts of a technological system. These two factors make accidents not only more likely but also more difficult to predict and control. This, in turn, makes risk more difficult to estimate.

In tight coupling, the temporal element is crucial. Processes are tightly coupled if they are connected in such a way that one process is known to affect another and will usually do so within a short time. In tight coupling, there is usually little time to correct a failure and little likelihood of confining a failure to one part of the system. As a result, the whole system is damaged. A chemical plant is tightly coupled because a failure in one part of the plant can quickly affect other parts of the plant. A university, by contrast, is loosely coupled because if one department ceases to function, then the operation of the whole university is usually not threatened.

In complex interaction, the inability to predict consequences is crucial. Processes can be complexly interactive in that the parts of the system can interact in unanticipated ways. No one dreamed that when X failed, it would affect Y. Chemical plants are complexly interactive in that parts affect one another in feedback patterns that cannot always be anticipated. A post office, by contrast, is not so complexly interactive. The parts of the system are related to one another for the most part in a linear way that is well understood and the parts do not usually interact in unanticipated ways that cause the post office to cease functioning. If a post office ceases to function, it is usually because of a well-understood failure.

Examples of complexly interactive and tightly coupled technical systems include not only chemical plants but also nuclear power plants, electric power grid networks, space missions, and nuclear weapons systems. Being tightly coupled and complexly interactive, they can have unanticipated failures and there is little time to correct the problems or keep them from affecting the entire system. This makes accidents difficult to predict and disasters difficult to avoid once a malfunction appears.

Unfortunately, it is difficult to change tightly coupled and complexly interactive systems to make accidents less likely or even easier to predict. To reduce complexity, decentralization is required to give operators the ability to react independently and creatively to unanticipated events. To deal with tight coupling, however, centralization is required. To avoid failures, operators need to have command of the total system and to be able to follow orders quickly and without question. It may not be possible, furthermore, to make a system both loosely coupled and noncomplex. Engineers know that they can sometimes overcome this dilemma by including localized and autonomous automatic controls to protect against failures due to complexity and couple them with manual overrides to protect against tight coupling failures. Nevertheless, according to Perrow, some accidents in complex, tightly coupled systems are probably inevitable and, in this sense, "normal."

The following is an example of an accident in a system that was complexly interactive and tightly coupled. In the summer of 1962, the New York Telephone Company completed heating system additions to a new accounting building in Yonkers, New York. The three-story, square-block building was a paradigm of safe design, using the latest technology.

In October 1962, after the building was occupied and the workers were in place, final adjustments were being made on the building's new, expanded heating system located in the basement. This system consisted of three side-by-side, oil-fired boilers. The boilers were designed for low pressures of less than 6.0 psi and so were not covered by the boiler and pressure vessel codes of the American Society of Mechanical Engineers. Each boiler was equipped with a spring-loaded safety relief valve that had been designed to open and release steam into the atmosphere if the boiler pressure got too high. Each boiler was also equipped with a pressure-actuated cutoff valve that would cut off oil flow to the boiler burners in the event of excessive boiler pressure. The steam pressure from the boilers was delivered to steam radiators, each of which had its own local relief valve. Finally, in the event that all else failed, a 1-foot-diameter pressure gauge with a red "Danger Zone" marked on the scale and painted on the face sat on the top of each boiler. If the pressure got too high, the gauge was supposed to alert a custodian who operated the boilers so he could turn off the burners.

On October 2, 1962, the following events transpired:[13]

1. The building custodian decided to fire up boiler 1 in the heating system for the first time that fall. The electricians had just wired the control system for the new companion boiler (boiler 3) and successfully tested the electrical signal flows.
2. The custodian did not know that the electricians had left the fuel cutoff control system disconnected. The electricians had disconnected the system because they were planning to do additional work on boiler 3 the following week. They intended to wire the fuel cutoffs for the three boilers in series (i.e., high pressure in any one would stop all of them).
3. The custodian mechanically closed the header valve because it was a warm Indian summer day and he did not want to send steam into the radiators on the floors above. Thus, the boiler was delivering steam pressure against a blocked valve and the individual steam radiator valves were out of the control loop.
4. As subsequent testing showed, the relief valve had rusted shut after some tests the previous spring in which the boilers had last been fired. (Later, laws were enacted in New York State that require relief valves for low-pressure boiler systems to be operated by hand once every 24 hours to ensure that they are not rusted shut. At the time, low-pressure boiler systems were not subject to this requirement.)
5. This was on Thursday, the day before payday, and the custodian made a short walk to his bank at lunch hour to cash a check soon after turning on boiler 1.
6. The cafeteria was on the other side of the wall against which the boiler end abutted. Employees were in line against the wall awaiting their turn at the cafeteria serving tables. There were more people in line than there would have been

on Friday because on payday many workers went out to cash their paychecks and eat their lunches at local restaurants.

7. Boiler 1 exploded. The end of the boiler that was the most removed from the wall next to the cafeteria blew off, turning the boiler into a rocket-like projectile. The boiler lifted off its stanchions and crashed into the cafeteria, after which it continued to rise at great velocity through all three stories of the building. Twenty-five people were killed and almost 100 seriously injured.

The events that led to this disaster were complexly interrelated. There is no possible way that fault tree or event tree analyses could have predicted this chain of events. If the outside temperature had been cooler, the custodian would not have closed the header valve and the individual steam radiator valves in each upstairs room would have opened. If the relief valve had been hand operated every day, its malfunction would have been discovered and probably corrected. If the time had not been noon and the day before payday, the custodian might have stayed in the basement and seen the high-pressure reading and turned off the burners. If it had not been lunch time, the unfortunate victims would not have been in the cafeteria line on the other side of the wall from the boiler.

The events were also tightly coupled. There was not much time to correct the problem once the pressure started to rise and there was no way to isolate the boiler failure from a catastrophe in the rest of the building. There was one engineering design change that, if adopted, could have broken the chain of events and prevented the accident. It would have been a simple matter to include a fuel flow cutoff if the fuel cutoff system were in any way disabled. However, in complex interconnected systems such as this one, hindsight is always easier than foresight.

Normalizing Deviance and Self-Deception

Still another factor that increases risk and also decreases our ability to anticipate harm is increasing the allowable deviations from proper standards of safety and acceptable risk. Sociologist Diane Vaughn refers to this phenomenon as the "normalization of deviance."[14]

Every design carries with it certain predictions about how the designed object should perform in use. Sometimes these predictions are not fulfilled, producing what are commonly referred to as anomalies. Rather than correcting the design or the operating conditions that led to anomalies, engineers or managers too often do something less desirable. They may simply accept the anomaly or even increase the boundaries of acceptable risk. Sometimes this process can lead to disaster.

This process is dramatically and tragically illustrated by the events that led to the *Challenger* disaster.[15] Neither the contractor, Morton Thiokol, nor NASA expected the rubber O-rings that sealed the joints in the solid rocket booster (SRB) to be touched by the hot gases of motor ignition, much less to be partially burned. However, because previous shuttle flights showed damage to the sealing rings, the reaction by both NASA and Thiokol was to accept the anomalies without attempting to remedy the problems that caused the anomalies.

The following are examples of how deviance was normalized before the disaster:

1. In 1977, test results showed that the SRB joints would rotate open at ignition, creating a larger gap between the tang and clevis. According to NASA engineers, the

gap was large enough to prevent the secondary seal from sealing if the primary O-ring failed late in the ignition cycle. Nevertheless, after some modifications, such as adding sealing putty behind the O-rings, the joint was officially certified as an acceptable risk, even though the joint's behavior deviated from design predictions.[16]

2. Another anomaly was discovered in November 1981 after flight STS-2, which showed "impingement erosion" of the primary O-ring in the right SRB's aft field joint.[17] The hot propellant gases had moved through the "blow holes" in the zinc chromate putty in the joints. The blow holes were caused by entrapped air introduced at the time the putty was installed. Even though this troubling phenomenon was not predicted, the joints were again certified as an acceptable risk.
3. A third anomaly occurred in 1984 with the launch of STS-41-B when, for the first time, two primary O-rings on two different joints were eroded.[18] Again, the erosion on two joints was termed an acceptable risk.[19]
4. Another anomaly occurred in 1985 when "blow-by" of hot gases had reached the secondary seal on a nozzle joint. The nozzle joints were considered safe because, unlike the field joints, they contained a different and quite safe secondary "face seal." The problem was that a similar malfunction could happen with the field joint with the danger much more serious and these problems were not dealt with.
5. Perhaps the most dramatic example of expanding the boundaries of acceptable risk was in the area of the acceptable temperature for launch. Before the *Challenger* launch, the lowest temperature of the seals at launch time was 53 degrees Fahrenheit. (At that time, the ambient temperature was in the high 60s.) On the night before the launch of the *Challenger*, however, the temperature of the seals was expected to be 29 degrees and its ambient temperature below freezing. Thus, the boundaries for acceptable risk were expanded by 24 degrees.

The result of (1) accepting these anomalies without making any adequate attempt to remedy the basic problem (poor seal design) and (2) lowering the temperature considered acceptable for launch was the tragic destruction of the *Challenger* and the loss of its crew. Vaughn argues that these kinds of problems cannot be eliminated from technological systems and that, as a result, accidents are inevitable. Whether or not this is the case, there is no question that technology imposes risk on the public and that these risks are often difficult to detect and eliminate.

The case also illustrates how the self-deception involved in normalizing deviance can limit the ability of engineers to correctly anticipate risk. Some of the engineers, and especially engineering managers, repeatedly convinced themselves that allowing still one more deviation from design expectations would not increase the chance of failure or was at least an acceptable risk. The result was a tragic disaster.

6.4 THE PUBLIC'S APPROACH TO RISK

Expert and Layperson: Differences in Factual Beliefs

Engineers and other experts on risk often believe that the public is confused about risk, sometimes because the public does not have the correct factual information about the likelihood of certain harms. A 1992 National Public Radio story on the

Environmental Protection Agency (EPA) began with a quote from EPA official Linda Fisher that illustrated the risk expert's criticism of public understanding of risk:

> A lot of our priorities are set by public opinion, and the public quite often is more worried about things that they perceive to cause greater risks than things that really cause risks. Our priorities often times are set through Congress … and those [decisions] may or may not reflect real risk. They may reflect people's opinions of risk or the Congressmen's opinions of risk.[20]

Fisher believes that whereas both members of the U.S. Congress and ordinary laypeople may be confused about risk, the experts know what it is. Risk is something that can be objectively measured—namely, the product of the likelihood and magnitude of harm.

The profound differences between the engineering and public approach to risk have been the sources of miscommunication and even acrimony. Two questions then arise: Why does an engineer need to understand these differences? And what are the grounds for these profound differences in outlook on risk?

With respect to the first question, the answer is that the engineer, when quantifying risks and benefits, must remember to think about the public's understanding and acceptance of the risks that the engineer's work will impose and know that it may be very different from the way engineers assess risks. If the engineer makes decisions about the acceptability of a certain risk and somehow miscalculates the public's perception, and if harms should occur from risks considered acceptable in an engineering assessment, the public may view the engineer's actions from a different perspective and unsympathetically. The public, we should remember, sometimes is manifested in groups of 12 serving as juries and charged with evaluating whether engineers have made these decisions about risk in an acceptable manner.

With respect to the second question, the first difference is that engineers and risk experts believe that the public is sometimes mistaken in estimating the probability of death and injury from various activities or technologies. Recall EPA official Linda Fisher's reference to "real risk," by which she meant the actual calculations of probability of harm. Risk expert Chauncey Starr has a similarly low opinion of the public's knowledge of probabilities of harm. He notes that people tend to overestimate the likelihood of low-probability risks associated with causes of death and to underestimate the likelihood of high-probability risks associated with causes of death. The latter tendency can lead to overconfident biasing or *anchoring*. In anchoring, an original estimate of risk is made—an estimate that may be substantially erroneous. See Box 6.4 for important factors in assessing risk acceptability. Even though the estimate is corrected, it

BOX 6.4 Important Factors in Assessing Risk Acceptability

- Laymen have a very different perspective and assessment than risk experts.
- New or unfamiliar risks are more likely to be unacceptable to the public than familiar risks.
- Voluntarily assumed risks are more likely to be considered acceptable than involuntarily imposed risks.
- Jobs involving higher risks generally demand higher wages.
- Free and informed consent, equity, and justice are important factors in acceptability of risk.

is not sufficiently modified from the original estimate. The original estimate anchors all future estimates and precludes sufficient adjustment in the face of new evidence.[21]

Other scholars have reported similar findings. A study by Slovic, Fischhoff, and Lichtenstein shows that although even experts can be mistaken in their estimations of various risks, they are not as seriously mistaken as laypeople.[22] The study contrasts actual versus perceived deaths per year.[23] Experts and laypeople were asked their perception of the number of deaths per year for such activities as smoking, driving a car, driving a motorcycle, riding in a train, skiing, and so on. On a graph that plots perceived deaths (on the vertical axis) against actual deaths (on the horizontal axis) for each of several different risks, if the perception (by either laypeople or experts) of deaths were accurate, then the result would be a 45-degree line. In other words, actual and perceived deaths would be the same for the plots of the perceptions of either laypersons or experts. Instead, the experts were consistently approximately one order of magnitude (i.e., approximately 10 times) low in their perceptions of the perceived risk and the lay public was still another order of magnitude (i.e., approximately 100 times) too low, resulting in lines of less than 45 degrees for experts and even less for laypersons.

"Risky" Situations and Acceptable Risk

It does appear to be true that the engineer and risk expert, on the one hand, and the public, on the other hand, differ regarding the probabilities of certain events. The major difference, however, is in the conception of risk itself and in beliefs about acceptable risk. One of the differences here is that the public often combines the concepts of risk and acceptable risk—concepts that engineers and risk experts separate sharply. Furthermore, public discussion is probably more likely to use the adjective "risky" than the noun "risk."

We can begin with the concepts of "risk" and "risky." In public discussion, the use of the term "risky," rather than referring to the probability of certain events, more often than not has the function of a warning sign, a signal that special care should be taken in a certain area.[24] One reason for classifying something as risky is that it is new and unfamiliar. For example, the public may think of the risk of food poisoning from microbes as being relatively low, whereas eating irradiated food is "risky." In fact, in terms of probability of harm, there may be more danger from microbes than radiation, but the dangers posed by microbes are familiar and commonplace, whereas the dangers from irradiated foods are unfamiliar and new. Another reason for classifying something as risky is that the information about it might come from a questionable source. We might say that buying a car from a trusted friend who testifies that the car is in good shape is not risky, whereas buying a car from a used car salesman whom we do not know is risky.

Laypeople do not evaluate risk strictly in terms of expected deaths or injury. They consider other factors as well. For example, they are generally willing to take voluntary risks that are 1,000 times (three orders of magnitude) as uncertain as involuntary risks. Thus, voluntarily assumed risks are more acceptable than risks not voluntarily assumed. The amount of risk people are willing to accept in the workplace is generally proportional to the cube of the increase in the wages offered in compensation for the additional risk. For example, doubling wages would tend to convince a worker to take eight times the risk. But laypeople may also separate by three orders of magnitude the risk perceived to be involved in involuntary exposure to danger (e.g., when a corporation places a toxic waste dump next door to one's house) and the risk involved in voluntary exposure (e.g., smoking). Here, voluntarily assumed risks are viewed as inherently less risky, not simply more acceptable. Laypeople also seem to be content with spending different amounts of money in different areas to save a life. In his study of 57 risk-abatement programs at five different government agencies in Washington, DC, including the EPA and the Occupational Safety and Health Administration (OSHA), Starr shows that such programs vary greatly in the amount of money they spend to save a life. Some programs spend $170,000 per life, whereas others spend $3 million per life.[25]

Another researcher, D. Litai, has separated risk into 26 risk factors, each having a dichotomous scale associated with it.[26] For example, a risk may have a natural or a human origin. If the risk has a human origin, Litai concludes from an analysis of statistical data from insurance companies that the perceived risk is 20 times greater than a risk with a natural origin. An involuntarily assumed risk, whether of natural or human origin, is perceived as being 100 times greater than a voluntarily assumed risk. An immediate risk is perceived as being 30 times greater than an ordinary one. By contrast, a regular risk is perceived as being just as great as an occasional one and necessary risk is just as great as a luxury-induced one. Here again, there is evidence of the amalgamation of the concepts of risk and acceptable risk.

Two issues in the public's conception of risk and acceptable risk have special moral importance: free and informed consent and equity or justice. These two concepts follow more closely the ethics of respect for persons than utilitarianism. According to this ethical perspective, as we have seen, it is wrong to deny the moral agency of individuals. Moral agents are beings capable of formulating and pursuing purposes of their own. We deny the moral agency of individuals when we deny their ability to formulate and pursue their own goals or when we treat them in an inequitable manner with respect to other moral agents. Let us examine each of these concepts in more detail.

Free and Informed Consent

To give free and informed consent to the risks imposed by technology, three things are necessary. First, a person must not be coerced. Second, a person must have the relevant information. Third, a person must be rational and competent enough to evaluate the information. Unfortunately, determining when meaningful and informed consent has been given is not always easy, for several reasons.

First, it is difficult to know when consent is free. Have workers given their free consent when they continue to work at a plant with known safety hazards? Perhaps they have no alternative form of employment.

Second, people are often not adequately informed of dangers or do not evaluate them correctly. As we have seen, sometimes laypeople err in estimating risk. They underestimate the probability of events that have not occurred before or that do not get their attention, whereas they overestimate the probability of events that are dramatic or catastrophic.

Third, it is often not possible to obtain meaningful informed consent from individuals who are subject to risks from technology. How would a plant manager obtain consent from local residents for his plant to emit a substance into the atmosphere that causes mild respiratory problems in a small percentage of the population? Is the fact that the residents do not protest sufficient evidence that they have consented?

What if they do not know about the substance, do not know what it does, do not understand its effects correctly, or are simply too distracted by other things?

In light of the problems in getting free and informed consent, we could compensate individuals after the fact for actual harms done to them through technology. For example, people could be compensated for harms resulting from a defective design in an automobile or a release of a poisonous gas from a chemical plant. This approach has the advantage that consent does not have to be obtained, but it also has several disadvantages. First, it does not tell us how to determine adequate compensation. Second, it limits the freedom of individuals because some people would never have consented. Third, sometimes there is no adequate compensation for a harm, as in the case of serious injury or death.

There are problems with both informed consent and compensation as ways of dealing with the ethical requirement to respect the moral agency of those exposed to risk because of technology. Nevertheless, some effort must be made to honor this requirement. Now let us return to the second requirement of the respect-for-persons morality with regard to risk.

Equity and Justice

The ethics of respect for persons places great emphasis on respecting the moral agency of individuals, regardless of the cost to the larger society. Philosopher John Rawls expresses this concern:[27] "[E]ach member of society is thought to have an inviolability founded upon justice … which even the welfare of everyone else cannot override." As an example of the requirement for justice derived from the ethics of respect for persons, consider the following example from Cranor,[28] quoting a woman describing how her husband's health had been severely damaged by byssinosis caused by cotton dust:

> My husband worked in the cotton mill since 1937 to 1973. His breath was so short he couldn't walk from the parking lot to the gate the last two weeks he worked.
>
> He was a big man, liked fishing, hunting, swimming, playing ball, and loved to camp. We liked to go to the mountains and watch the bears. He got so he could not breathe and walk any distance, so we had to stop going anywhere. So we sold our camper, boat, and his truck as his doctor, hospital, and medicine bills were so high. We don't go anywhere now. The doctor said his lungs were as bad as they could get to still be alive. At first he used tank oxygen about two or three times a week, then it got so bad he used more and more. So now he has an oxygen concentrator, he has to stay on it 24 hours a day. When he goes to the doctor or hospital he has a little portable tank.
>
> He is bedridden now. It's a shame the mill company doesn't want to pay compensation for brown lung. If they would just come and see him as he is now, and only 61 years old.

A utilitarian might be willing to trade off the great harm to Mr. Talbert that resulted from a failure to force cotton mills to protect their workers from the risk of byssinosis for the smaller advantages to an enormous number of people. After all, such protection is often highly expensive and these expenses must eventually be passed on to consumers in the form of higher prices for cotton products. Higher prices also make U.S. cotton products more expensive and thus less competitive in world markets, thereby depriving U.S. workers of jobs. Regulations that protect workers might even force many (perhaps all) U.S. cotton mills to close. Such disutilities might well outweigh the disutilities to the Mr. Talberts of the world.

From the standpoint of the ethics of respect for persons, however, such considerations must not be allowed to obscure the fact that Mr. Talbert has been treated unjustly. Although many people enjoy the benefits of the plant, only Mr. Talbert and a few others suffer the consequences of the unhealthy working conditions. The benefits and harms have been inequitably distributed. His rights to bodily integrity and life were unjustly violated. From the standpoint of the Golden Rule, probably few, if any, observers would want to be in Mr. Talbert's position.

Of course, it is not possible to distribute all risks and benefits equally. Sometimes those who endure the risks imposed by technology may not share the benefits to the same degree. For example, several years ago a proposal was made to build a port for unloading liquefied natural gas in the Gulf of Mexico off the coast of Texas. The natural gas would be shipped to many parts of the United States, so most citizens of the country would benefit from this project. Only those residents close to the port, however, would share the risks of the ships or storage tanks exploding.[29] Because there is no way to equalize the risk, informed consent and compensation should be important considerations in planning the project. Thus, informed consent, compensation, and equity are closely related considerations in moral evaluation.

Even though laypeople often combine the concept of risk with the concept of acceptable risk, we shall formulate a lay criterion of acceptable risk in the following way:

> An acceptable risk is one in which (1) risk is assumed by free and informed consent, or properly compensated, and in which (2) risk is justly distributed, or properly compensated.

We have seen that there are often great difficulties in implementing the requirements of free and informed consent, compensation, and justice. Nevertheless, they are crucial considerations from the layperson's perspective—and from the moral perspective.

6.5 COMMUNICATING RISK AND PUBLIC POLICY

Communicating Risk to the Public

The preceding sections show that different groups have somewhat different agendas regarding risk. Engineers are most likely to adopt the risk expert's approach to risk. They define risk as the product of the magnitude and likelihood of harm and are sympathetic with the utilitarian way of assessing acceptable risk. The professional codes require engineers to hold paramount the safety, health, and welfare of the public, so engineers have an obligation to minimize risk. However, in determining an acceptable level of risk for engineering works, they are likely to use, or at least be sympathetic with, the cost-benefit approach.

The lay public comes to issues of risk from a very different approach. Although citizens sometimes have inaccurate views about the probabilities of harms from certain types of technological risks, their different approach cannot be discounted in terms of simple factual inaccuracies. Part of the difference in approach results from the tendency to combine judgments of the likelihood and acceptability of risk. (The term "risky" seems to include both concepts.) For example, use of a technology is more risky if the technology is relatively new and if information about it comes from a source (either expert or nonexpert) that the public has come to regard as unreliable. More important, the lay public considers free and informed consent and equitable distribution of risk (or appropriate compensation) to be important in the determination of acceptable risk.

BOX 6.5 Communicating with the Public About Risks

- Use familiar terminology—"probability of harm" may be more clearly understood than "risk."
- Qualitatively compare "new" risks by comparison to "familiar" risks. "The probability of flooding related to the new development should not be greater than the present probability of flooding."
- Acknowledge uncertainty in risk assessments.
- Recognize that costs versus benefits are not the only factor in determining acceptability of risks.
- Be "objective and truthful" in all public statements.

In addition, government regulators, with their special obligation to protect the public from undue technological risks, are more concerned with preventing harm to the public than with avoiding claims for harm that turn out to be false. This bias contrasts to some extent with the agendas of both the engineer and the layperson. Although, as government regulators, they may often use cost-benefit analysis as a part of their method of determining acceptable risk, they have a special obligation to prevent harm to the public, and this may go beyond what cost-benefit considerations require. See Box 6.5 for different approaches when communicating with the public. On the other hand, considerations of free and informed consent and equity, while important, may be balanced by cost-benefit considerations.

In light of these three different agendas, it is clear that social policy regarding risk must take into consideration wider perspectives than the risk expert approach would indicate.

At least two reasons exist for this claim. First, the public and government regulators will probably continue to insist on introducing their own agendas into the public debate about technological risk. In a democracy, this probably means that these considerations will be a part of public policy regarding technological risk, whether or not engineers and risk experts approve. This is simply a fact to which engineers and risk experts must adjust. Second, we believe the two alternative approaches to risk each have a genuine moral foundation. Free and informed consent, equity, protecting the public from harm—these are morally legitimate considerations. Therefore, public policy regarding risk should probably be a mix of the considerations we have put forth here as well as, no doubt, many others we have not discussed.

What, then, is the professional obligation of engineers regarding risk? One answer is that engineers should continue to follow the risk expert's approach to risk and let public debate take care of the wider considerations. We believe there is some validity to this claim and in the next section we return to a consideration of issues in typical engineering approaches to risk. However, as we have argued in Chapter 3 and elsewhere, we believe engineers have a wider professional obligation. Engineers have a professional obligation to participate in democratic deliberation regarding risk by contributing their expertise to this debate. In doing so, they must be aware of alternative approaches and agendas to avoid serious confusion and undue dogmatism. In light of this, we propose the following guidelines for engineers in risk communication[30]:

1. Engineers, in communicating risk to the public, should be aware that the public's approach to risk is not the same as that of the risk expert. In particular, "risky" cannot be identified with a measure of the probability of harm. Thus,

engineers should not say "risk" when they mean "probability of harm." They should use the two terms independently.

2. Engineers should be wary of saying, "There is no such thing as zero risk." The public often uses "zero risk" to indicate not that something involves no probability of harm but that it is a familiar risk that requires no further deliberation.
3. Engineers should be aware that the public does not always trust experts and believes that experts have sometimes been wrong in the past. Therefore, engineers, in presenting risks to the public, should be careful to acknowledge the possible limitations in their position. They should also be aware that laypeople may rely on their own values in deciding whether or not to base action on an expert's prediction of probable outcomes.
4. Engineers should be aware that government regulators have a special obligation to protect the public and that this obligation may require them to take into account considerations other than a strict cost-benefit approach. Although public policy should take into account cost-benefit considerations, it should take into account the special obligations of government regulators.
5. Professional engineering organizations, such as the professional societies, have a special obligation to present information regarding technological risk. They must present information that is as objective as possible regarding probabilities of harm. They should also acknowledge that the public, in thinking about public policy regarding technological risk in controversial areas (e.g., nuclear power), may take into consideration factors other than the probabilities of harm.

A major theme in these guidelines is that engineers should adopt a critical attitude toward the assessment of risk. This means that they should be aware of the existence of perspectives other than their own. The critical attitude also implies that they should be aware of the limitations in their own abilities to assess the probabilities and magnitude of harms. In the next section, we consider an example of these limitations and the consequent need for the critical attitude even in looking at the mode of risk assessment characteristic of engineering.

An Example of Public Policy: Building Codes

One of the most immediate ways in which public policy must rely on engineering expertise and engineering is in turn affected by public policy is through local building codes. The local building codes specify design rules that incorporate factors of safety and construction steps (e.g., fireproofing or material requirements) that are required in the area. Building codes have the status of law and may not be changed without public hearings and legislative action. The legislature will often appoint a committee of experts to propose a new building code or necessary changes in an existing one. For example, following the collapse of the World Trade Center's Twin Towers, there was a major multiagency investigative effort to identify the causes of the collapses and to propose changes in New York City's building codes that would improve egress and otherwise reduce risks of death.

One of the more important ways professional engineers show a concern for the general public (and their safety) is in carrying out the local building code requirements in designing such things as buildings, elevators, escalators, bridges, walkways, roads, and overpasses. When a responsible engineer recognizes a violation of a building code in a design and does not object to it, the engineer bears some responsibility for any injuries or deaths that result. Similarly, when an engineer learns of a proposed change in a building code that he or she is convinced creates danger for the public and does nothing to prevent this change, the engineer bears some responsibility for any harm done.

The Twin Towers case illustrates these issues.[31] The New York City building codes in place in 1945 required that all stairwells be surrounded with heavy masonry and concrete structure. Consequently, in 1945, firefighters were able to get to the area inside the Empire State Building immediately through the stairwells and put out the fire in 40 minutes. In the intervening years between the design of the Empire State Building and the World Trade Center Towers, building codes underwent a general change nationwide, with the "prescriptive" code requirements tending to be replaced by "performance" code requirements. One example is the way fireproofing coatings for steel structural members were specified in the early codes. Then, a certain thickness of concrete was specified, but as improved materials for fireproofing evolved that resulted in lower dead loads and more economical application methods, codes were changed to specify instead a certain level of performance. Similar changes in high-rise construction materials and methods, such as the use of lightweight concrete floor slabs and lighter floor joist systems, helped make taller structures more affordable. Some of these more economical and lighter weight building components may have been factors in the very different performance of the two newer towers compared to the much heavier Empire State Building and some critics have suggested we should revert to the older technology for tomorrow's buildings.

But reverting to 50-year-old practices is not the answer, nor is it even feasible. Rather it is up to today's engineers to help maintain performance standards in model building codes that will produce structures that are affordable without introducing unacceptable risk to the public they will serve. The Federal Emergency Management Agency (FEMA) and the Structural Engineering Institute of the American Society of Civil Engineers studied building code issues related to the WTC collapses and loss of life and concluded that the structures performed well in response to the crash impact loadings and continued standing even after the resulting severe damage, which is a testament to their design, but the resulting fire started by the approximately 10,000 gallons of burning jet fuel was further fed by building furnishings and materials of construction causing temperatures too high for the structural steel members given the mechanical damage to the fire protection systems. While the fire protection features of the design and construction were found to meet or exceed minimum code requirements, the study recommends more detailed evaluation of several features for future building code requirements, including floor truss systems and their robustness, impact resistant enclosures around egress paths, resistance of fire protection to physical damage, and location of egress paths. But the authors of the study did not recommend specific requirements to harden structures against aircraft impact, concluding that "it may not be technically feasible to develop design provisions that would enable all structures to be designed and constructed to resist the effects of impacts by rapidly moving aircraft, and the ensuing fires, without collapse."

As another example of a serious shortcoming of the New York City building codes, see the Citicorp building case in the Appendix. In this case, William LeMessurier designed the building's main load-carrying steel structure to a code-specified worst-case wind condition that was incorrect. Fortunately, LeMessurier recognized the error in the code and modified the already built structure to correct for it. The codes were subsequently corrected.

Building codes are one of the aspects of public policy that both directly affect engineers and most clearly require information from engineers in their formulation. They illustrate one of the most concrete and specific ways in which engineering expertise is needed in the formulation of public policy and in which public policy in turn vitally affects engineering design.

6.6 THE ENGINEER'S LIABILITY FOR RISK

We have seen that risk is difficult to estimate and that engineers are often tempted to allow anomalies to accumulate without taking remedial action and even to expand the scope of acceptable risk to accommodate them. We have also seen that there are different and sometimes incompatible approaches to the definition of acceptable risk as exhibited by risk experts, laypeople, and government regulators.

Another issue that raises ethical and professional concerns for engineers regards legal liability for risk. There are at least two issues here. One is that the standards of proof in tort law and science are different and this produces an interesting ethical conflict. Another issue is that in protecting the public from unnecessary risk, engineers may themselves incur legal liabilities. Let us consider each of these issues.

The Standards of Tort Law

Litigation that seeks redress from harm most commonly appeals to the law of torts, which deals with injuries to one person caused by another, usually as a result of fault or negligence of the injuring party. Many of the most famous legal cases involving claims of harm from technology have been brought under the law of torts. The litigation involving harm from asbestos is one example. In 1973, the estate of Clarence Borel,[32] who began working as an industrial insulation worker in 1936, brought suit against Fiberboard Paper Products Corporation:

> During his career he was employed at numerous places usually in Texas, until disabled from the disease of asbestosis in 1969. Borel's employment necessarily exposed him to heavy concentrations of asbestos generated by insulation materials. In a pretrial deposition Borel testified that at the end of the day working with insulation materials containing asbestos his clothes were usually so dusty that he could barely pick them up without shaking them. Borel stated, "You just move them a little bit and there is going to be dust and I blowed this dust out of my nostrils by the handfuls at the end of the day. I even used Mentholatum in my nostrils to keep some of the dust from going down my throat, but it is impossible to get rid of all of it. Even your clothes just stay dusty continuously, unless you blow it off with an air hose." In 1964, doctors examined Borel in connection with an insurance policy and informed him that x-rays of his lungs were cloudy. The doctors told Borel that the cause could be his occupation as an installation worker and advised him to avoid asbestos dust as much as he possibly could. On January 19, 1969, Borel was hospitalized and a lung biopsy was performed. Borel's condition was diagnosed as pulmonary asbestosis. Since the disease was considered irreversible Borel was sent home.... [His] condition gradually worsened during the remainder of 1969. On February 11, 1970, he underwent surgery for the removal of his right lung. The examining doctors determined that Borel had a form of lung cancer known as mesothelioma, which had been caused by asbestos. As a result of these diseases, Borel later died before the district case reached the trial stage.[33]

The federal district court in Texas decided in favor of the estate of Mr. Borel and the Fifth Circuit Court of Appeals upheld the decision.

The standard of proof in tort law is the preponderance of evidence, meaning that there is more and better evidence in favor of the plaintiff than the defendant. The plaintiff must show

> (1) that the defendant violated a legal duty imposed by the tort law, (2) that the plaintiff suffered injuries compensable in the tort law, (3) that the defendant's violation of legal duty caused the plaintiff's injuries, and (4) that the defendant's violation of legal duty was the proximate cause of the plaintiff's injuries.[34]

The standard of proof that a given substance was the proximate cause of a harm is less stringent than that which would be demanded by a scientist, who might well call for 95 percent certainty. It is also less stringent than the standard of evidence in criminal proceedings, which calls for proof beyond reasonable doubt.

As an illustration of this lower standard of evidence, consider the case of *Rubanick v. Witco Chemical Corporation and Monsanto Co.* The plaintiff's sole expert witness, a retired cancer researcher at New York's Sloan-Kettering Cancer Center, testified that the deceased person's cancer was caused by exposure to polychlorinated biphenyls (PCBs). He based his opinion on

> (1) the low incidence of cancer in males under 30 (the deceased person was 29), (2) the decedent's good dietary and nonsmoking habits and the absence of familial genetic predisposition to cancer, (3) 5 of 105 other Witco workers who developed some kind of cancer during the same period, (4) a large body of evidence showing that PCBs cause cancer in laboratory animals, and (5) support in the scientific literature that PCBs cause cancer in human beings.[35]

The court did not require the expert to support his opinion by epidemiological studies, merely that he demonstrate the appropriate education, knowledge, training, and experience in the specific field of science and an appropriate factual basis for his opinion.[36]

Courts in other better known cases, such as that of Richard Ferebee, who alleged that he suffered lung damage as a result of spraying the herbicide paraquat, also accepted standards of evidence for causal claims that would not have been acceptable for research purposes.[37]

Some courts, however, have begun to impose higher standards of evidence for recovery of damages through tort standards that are similar to those used in science. In the Agent Orange cases, Judge Jack B. Weinstein argued that epidemiological studies were the only useful studies having any bearing on causation, and that by this standard no plaintiff had been able to make a case. Bert Black,[38] a legal commentator, has taken a similar view. He believes that the courts (i.e., judges) should actively scrutinize the arguments of expert witnesses, demanding that they be supported by peer-reviewed scientific studies or at least have solid scientific backing. In some cases, he believes, they should even overrule juries who have made judgments not based on scientific standards of evidence.[39]

Even though this view represents a departure from the normal rules of evidence in tort law, it might in some cases be fairer to the defendants because some decisions in favor of plaintiffs may not be based on valid proof of responsibility for harm. The disadvantage is also equally obvious. By requiring higher standards of proof, the courts place burdens of evidence on plaintiffs that they often cannot meet. In many cases, scientific knowledge is simply not adequate to determine causal relationships, and this would work to the disadvantage of the plaintiffs. There are also problems with encouraging judges to take such an activist role in legal proceedings. The major ethical question, however, is whether we should be more concerned with protecting the rights of plaintiffs who may have been unjustly harmed or with promoting economic efficiency and protecting defendants against unjust charges of harm. This is the ethical issue at the heart of the debate.

The above discussion assumes it is the engineer's decision about what risk is acceptable that is challenged in court. It is also possible, and perhaps more common, that the claim does not dispute the engineer's decision about what risk is acceptable, but rather claims that the engineer has made a design error, or neglected to consider some factor affecting the risk, which has led to a greater than acceptable risk and to some injury.

Some Problems with Tort Law

The apparent ease with which proximate cause can be established in tort law may suggest that the courts should impose a more stringent standard of acceptable risk. But other aspects of the law afford the public less protection than it deserves. For example, the threat of legal liability can inhibit engineers from adequately protecting the public from risk. Engineers in private practice may face especially difficult considerations regarding liability and risk, and in some cases they may need increased protection from liability.

Consider, for example, the safety issues in excavating for foundations, pipelines, and sewers.[40] A deep, steep-sided trench is inherently unstable. Sooner or later, the sidewalls will collapse. The length of time that trench walls will stand before collapsing depends on several factors, including the length and width of the cut, weather conditions, moisture in the soil, composition of the soil, the method of excavation, and the nearby presence of heavy or vibrating equipment. People who work in deep trenches are subjected to considerable risk, and hundreds of laborers are injured or killed each year when the walls collapse.

To reduce the risk, construction engineers can specify the use of trench boxes in their designs. A trench box is a long box with an upside-down U-shaped cross section that is inserted inside the trench to protect the laborers. As long as workers remain inside the trench boxes, their risk of death or injury is greatly reduced.

Unfortunately, the use of trench boxes considerably increases the expense and time involved in construction projects. The boxes must be purchased or rented, and then they must be moved as excavation proceeds, slowing construction work and adding further expense. In addition, the handling of trench boxes introduces another risk of injury to workers involved. Engineers are placed in an awkward position with regard to the use of trench boxes, especially where the boxes are not required by building codes. If they do not specify the use of the boxes, then they may be contributing to a situation that subjects workers to a high risk of death and injury. If they do specify the use of boxes, then they may be incurring liability in case of an accident because of the use of trench boxes. With situations such as this in mind, the National Society of Professional Engineers has been actively lobbying the U.S. Congress to pass a law that specifically excludes engineers from liability for accidents where construction safety measures are specified by engineers but then are either not used or used improperly by others. This would enable engineers more effectively to protect the safety of workers. Unfortunately, the proposals have never become law.

The problem with trench boxes illustrates a more general issue. If engineers were free to specify safety measures without being held liable for their neglect or improper use, they could more easily fulfill one aspect of their responsibility to protect the safety of the public.

Protecting Engineers from Liability

Engineers face two problems in terms of their liability for injuries or damages under tort law. First, they may have to defend their assessment and management of a risk that they deemed to be acceptable, which has later resulted in an injury. Second, they may have to defend their work against a claim that they erred in some calculation or neglected to consider some aspect of a risk. An effective defense against either type of claim requires good records of engineering design and management decisions. A daily journal that records the essence of each meeting or conversation can be invaluable in demonstrating that errors were not made and important issues were not overlooked. And, the purchase of an "errors and omissions" insurance policy is important as protection for those instances in which such an error or omission does lead to a harm. After all, a responsible engineer would not want to be unable to compensate for damage or an injury resulting from an error or oversight.

It is also important that engineers understand and adhere to the "standard of care" expected in tort law to counter claims of negligence or incompetence. The standard of care is a legal standard for engineering decision-making defined by the ordinary skill, competence, and diligence exercised by qualified engineers practicing in a given field. Under the standard of care, engineers are not expected to be perfect or error-free, rather to be as competent and careful as other practitioners involved in the same work. Negligence, specifically failing to exercise the same diligence as other practitioners, is an important factor in establishing liability. It is also important to understand the standard of care when promoting engineering services. An engineer who describes his or her services using adjectives such as "leading edge" or touting "highest professional standards" of practice might invite an argument that a client was justified in expecting a higher standard of care.

6.7 BECOMING A RESPONSIBLE ENGINEER REGARDING RISK

The first step in the process of becoming ethically responsible about risk is to be aware of the fact that risk is often difficult to estimate and can be increased in ways that may be subtle and treacherous. The second step is to be aware that there are different approaches to the determination of acceptable risk. In particular, engineers have a strong bias toward quantification in their approach to risk, which may make them insufficiently sensitive to the concerns of the lay public and even the government regulators. The third step is to assume their responsibility, as the experts in technology, to communicate issues regarding risk to the public, with the full awareness that both the public and government regulators have a somewhat different agenda with regard to risk.

We conclude with an attempt to formulate a principle of acceptable risk. To formulate this principle, let us consider further some of the legal debate about risk.

The law seems to be of two minds about risk and benefits. On the one hand, some laws make no attempt to balance the two. The Chemical Food Additives Amendments to the Food, Drug and Cosmetics Act, enacted in 1958, require that a chemical "deemed to be unsafe" not be added to food unless it can be "safely used."[41] Safe use was defined by the Senate Committee on Labor and Public Welfare as meaning that "no harm will result" from its addition to food.[42] The well-known Delaney Amendment also prohibits the addition to food of any chemical known to cause cancer when ingested by animals.[43]

On the other hand, there is often an attempt to strike a balance between the welfare of the public and the rights of individuals. The Toxic Substances Control Act of 1976 authorized the EPA to regulate any chemical upon a finding of "unreasonable risk of injury to health or the environment."[44] But it is only "unreasonable risk" that triggers regulation, so some degree of risk is clearly tolerated. The report of the House Commerce Committee describes this balancing process as follows:

> Balancing the probabilities that harm will occur and the magnitude and severity of that harm against the effect of proposed regulatory action on the availability to society of the benefits of the substance or mixture, taking into account the availability of substitutes for the substance or mixture which do not require regulation, and other adverse effect which such proposed action may have on society.

Having said this, the report goes on to say that "a formal benefit-cost analysis under which monetary value is assigned to the risks … and to the costs of society" is not required.[45]

The Atomic Energy Act of 1954 continually refers to the "health and safety of the public" but makes little attempt to define these terms. The Nuclear Regulatory Commission's rules, however, use the expression "without undue risk" and seem to suggest again a balancing of risks and benefits.[46] In the words of one legal commentator, in practice, especially in the earlier years, "the acceptability of risk was measured largely in terms of the extent to which industry was capable of reducing the risk without jeopardizing an economic and financial environment conducive to continuing development of the technology."[47] Again, we have an attempt to balance protection of individuals and promotion of the public welfare.

Sometimes the conflict between these two approaches is evident in a single debate. In a Supreme Court case involving exposure to benzene in the workplace, OSHA took an essentially respect for persons standpoint, arguing that the burden of proof should be on industry to prove that a given level of exposure to benzene was not carcinogenic. In its rebuke of OSHA, the Supreme Court argued that in light of the evidence that current standards did not lead to harm to workers, risk must be balanced against benefits in evaluating more stringent standards and that the burden of proof was on OSHA to show that the more stringent standards were justified.[48]

Given these considerations, we can construct a more general principle of acceptable risk, which may provide some guidance in determining when a risk is within the bounds of moral permissibility:

> People should be protected from the harmful effects of technology, especially when the harms are not consented to or when they are unjustly distributed, except that this protection must sometimes be balanced against (1) the need to preserve great and irreplaceable benefits, and (2) the limitation on our ability to obtain informed consent.

The principle does not offer an algorithm that can be applied mechanically to situations involving risk. Many issues arise in its use; each use must be considered on its own merits. We can enumerate some of the issues that arise in applying the principle.

First, we must define what we mean by "protecting" people from harm. This cannot mean that people are assured that a form of technology is free from risk. At best, "protection" can only be formulated in terms of probabilities of harm and we have seen that even these are subject to considerable error.

Second, many disputes can arise as to what constitutes a harm. Is having to breathe a foul odor all day long harm? What about workers in a brewery or a sewage disposal plant? Here the foul odors cannot be eliminated, so the question of what harms should be eliminated cannot be divorced from the question of whether the harms can be eliminated without at the same time eliminating other goods.

Third, the determination of what constitutes a great and irreplaceable benefit must be made in the context of particular situations. A food additive that makes the color of frozen vegetables more intense is not a great and irreplaceable benefit. If such an additive were found to be a powerful carcinogen, then it should be eliminated. On the other hand, most people value automobiles highly and they would probably not want them to be eliminated, despite the possibility of death or injury from automobile accidents.

Fourth, we have already pointed out the problems that arise in determining informed consent and the limitations in obtaining informed consent in many situations. From the standpoint of the ethics of respect for persons, informed consent is a consideration of great importance. However, it is often difficult to interpret and apply.

Fifth, the criterion of unjust distribution of harm is also difficult to apply. Some harms associated with risk are probably unjustly distributed. For example, the risks associated with proximity to a toxic waste disposal area that is not well constructed or monitored are unjustly distributed. The risks associated with coal mining might also be conceded to be unjustly distributed, but the energy provided by coal may also be considered a great and irreplaceable benefit. So the requirement to reduce risk in the coal industry might be that the risks of coal mining should be reduced as much as possible without destroying the coal industry. This might require raising the price of coal enough to make coal mining safe and more economically rewarding.

Sixth, an acceptable risk at a given point in time may not be an acceptable risk at another point in time. Engineers with operational responsibilities as well as those with design responsibilities have an obligation to protect the health and safety of the public. This obligation requires engineers to reduce risk when new risks emerge or when risk awareness or acceptability changes or even when technological innovation allows further reduction of known risks. This obligation was not recognized or discharged by operators or regulators at the Fukushima nuclear power plant, where the improved predictions of tsunami risks should have triggered countermeasures.

6.8 CHAPTER SUMMARY

Risk is a part of engineering and especially of technological progress. The concept of "factors of safety" is important in engineering. Virtually all engineering codes give a prominent place to safety. Engineers and risk experts look at risk in a somewhat different way from others in society. For engineers, risk is the product of the probability and magnitudes of harm. Acceptable levels of risk represent public policy and are generally determined by groups of experts based on historical practices. Acceptable risks are implemented in building codes or design standards or in standardized operational practices. When other guidance is not available, an acceptable risk might be defined as one in which the product of the probability and magnitude of the harm is equaled or exceeded by the product of the probability and magnitude of the benefit and no other option exists where the product of the probability and magnitude of the benefit is substantially greater, although this approach might result in unacceptable inequities in risk distributions. In calculating harms and benefits, engineers have traditionally identified harm with factors that are relatively easily quantified, such as economic losses and loss of life. The "capabilities" approach attempts to make these calculations more sophisticated by developing a more adequate way of measuring the harms and benefits from disasters to overall well-being, which it defines in terms of the capabilities of people to live the kind of life they value. A risk is acceptable if the probability is sufficiently small that the adverse effect of a hazard will fall below a threshold of the minimum level of capabilities attainment that is acceptable in principle.

The public does not conceptualize risk simply in terms of expected deaths or injury but, rather, considers other factors as well, such as whether the harm in question is unacceptably severe, whether a risk is assumed with free and informed consent or whether the risk is imposed justly. Government regulators still take a different approach to risk because they have a special obligation to protect the public from harm. Consequently, they place greater weight on protecting the public than on benefiting the public. In light of these different agendas, social policy must take into account a wider perspective than that of the risk expert.

Engineers, and especially professional engineering societies, have an obligation to contribute to public debate on risk by supplying expert information and by recognizing that the perspectives in the public debate will comprise more than the perspective of the risk expert. Debates over building codes illustrate some aspects of this public debate over risk.

Estimating the causes and likelihood of harm poses many difficulties. Engineers use various techniques, such as fault trees and event trees. However, the phenomena of "tight coupling" and "complex interactions" limit our ability to anticipate disasters. The tendency to accept increasing deviations from expected performance can also lead to disasters.

Engineers need to protect themselves from undue liability for risk, but this need sometimes raises important issues for social policy. One issue is the conflict between the standards of science and tort law. The standard of proof in tort law for whether something causes a harm is the preponderance of evidence, but the standard of evidence in science is much higher. The lower standard of tort law tends to protect the rights of plaintiffs who may have been unjustly harmed, and the higher standard of science tends to protect defendants and perhaps promote economic efficiency. The problems engineers have in protecting themselves from unjust liabilities while protecting the public from harm are illustrated by the use of trench boxes. Finally, a principle of acceptable risk provides some guidance in determining when a risk is within the bounds of moral permissibility.

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CHAPTER SEVEN

Engineering and the Environment

Main Ideas in This Chapter

- **The modern environmental movement began in the 1960s and 70s. It has not only influenced law and policy throughout the world but also engineering practice.**
- **Life cycle analysis (or life cycle assessment) (LCA) is a useful basis for many types of engineering that affect the environment.**
- **Many formulations of the ideal of sustainability mandate care for the earth's resources for the sake of present and future generations and a economic development in less economically developed societies.**
- **Business firms exhibit a variety of attitudes toward environmental concerns, but some give evidence of a genuinely progressive attitude.**
- **The professional virtue of respect for the natural world should be cultivated, because it can motivate environmental concern on the part of engineers. Student members of organizations such as Engineers for a Sustainable World have probably already developed this virtue.**

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The mission of Willson's laboratories is to "create innovative energy solutions and entrepreneurial models that benefit the human condition and achieve global impact."[2]

7.1 INTRODUCTION

As this account demonstrates, many of Willson's projects have two themes: promoting environment-friendly engineering and helping the poor and disadvantaged of the world. A major theme of this book is that engineers have taken upon themselves a responsibility to promote human well-being. Given the importance of the environment to well-being, these two themes are often closely intertwined. In this chapter, Willson's environmental concerns are of special interest. The impact of technology on the environment should be a central concern of engineers. This is especially true because engineering has more effect on the environment than any other major profession.

Technology, which to a large extent is developed by engineers, has undoubtedly produced many environmental problems, such as air and water pollution, the destruction of wetlands, toxic chemicals, and many others. On the other hand, engineers can often modify technologies or create new ones that counteract these ill effects and enhance the quality of the environment and of human life. If engineers have contributed to some environmental problems, they can also contribute to their solution.

7.2 DEVELOPMENT OF THE MODERN ENVIRONMENTAL MOVEMENT

Silent Spring and Earth Day

There is some dispute about how and when the modern environmental movement began, but few dispute that Rachel Carson's *Silent Spring*, published on September 27, 1962, was one of the early landmarks in the movement. The opening chapter, "A Fable for Tomorrow," tells a fictional story of an idyllic community in rural America affected by DDT. The residents lived a wonderful life until a pesticide invaded their world.

> Then a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more and more puzzled by new kinds of sickness appearing among their patients. There had been several sudden and unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.
>
> There was a strange stillness. The birds, for example—where had they gone? Many people spoke of them, puzzled and disturbed. The feeding stations in the backyards were deserted. The few birds seen anywhere were moribund; they trembled violently and could not fly. It was a spring without voices. On the mornings that had once throbbed with the dawn chorus of robins, catbirds, doves, jays, wrens, and scores of other bird voices there was no sound; only silence lay over the fields and woods and marsh.[3]

Although this melodramatic introduction gives the book its name, it is not representative of the body of the work, which contains chapter after chapter of extensively footnoted documentation of the effect of pesticides, especially DDT, on the environment. In *Silent Spring*, *The Sea Around Us*, and other writings, Carson, a marine biologist by training, used her considerable writing skills to evoke both a love of the natural world and a horror of the damage humans have inflicted on it. Carson believed that we protect only what we love, so evoking a love of the natural world was a part of her agenda. While not calling for a ban on pesticides, the book evoked opposition from the chemical industry and other groups. Carson's critics were quick to point out the values of DDT, including its part in protecting American troops from malaria during World War II. Nevertheless, the book had an enormous effect on the public, perhaps somewhat like the effect of *Uncle Tom's Cabin* in galvanizing the North against slavery before the civil war.[4]

Some mark the birth of the modern environment movement, not with the publication of *Silent Spring*, but with the first Earth Day, on April 27, 1970. The idea of Earth Day came from Gaylord Nelson, senator from Wisconsin. The first Earth Day saw 20 million Americans take to the streets to demonstrate for a healthy environment. By the end of the year, the U.S. Environmental Protection Agency (EPA) had been established and the Clean Air Act, the first of a series of Congressional acts regarding the environment, was law.

7.3 ENVIRONMENTAL LAW AND POLICY

Environmental Law in the United States

Engineering concern for the environment must take into account the framework of the law. Engineers have a self-interested reason to know something about environmental law: to stay out of trouble. But they have a professional reason as well: to frame their work relating to the environment in an appropriate way. In the United States, state environmental law varies from one state to another, so we shall focus on federal law. Here is a brief summary of some of the major themes in federal environmental law in the United States.

Most federal environmental law focuses on diminishing or preventing pollution. In 1969, Congress passed the National Environmental Policy Act (NEPA), which may well be the single most important and influential environmental law in history. Congress then created the EPA to enforce its requirements. The law has served as a model for legislation not only in individual states in the United States but also in many other countries. The act inaugurated "a national policy which will encourage productive and enjoyable harmony between man and his environment." It attempts to "assure for all Americans safe, healthful, productive and aesthetically and culturally pleasing surroundings."[5]

One of the best-known mandates of the law is an environmental impact assessment, which is now required of federal agencies when their decisions affect the environment. The assessment is both complex and comprehensive, covering almost every imaginable way that a project could affect the environment. Contrary to widespread impressions, it covers the impact of a project on both the natural environment and the built environment. It mandates analyses of the impact of a project on air and water supplies and quality, on the production of hazardous wastes, on energy, plants and animals, endangered species, floodplains, coastal areas, geology, and wetlands. It also requires assessments of impacts on historic and archaeological sites, economic issues, neighborhoods, noise, and traffic. The assessment must also include a description of the scope of the assessment itself (e.g., how much land does the assessment cover), alternative ways the project could be implemented, and how negative effects could be eliminated. The assessment must include input from the public, in terms of hearings and evaluations of complaints.[6] Many statutes, such as the Clean Air Act (1970) and the Resource Conservation and Recovery Act (1976), commonly referred to as RCRA, expanded the jurisdiction of the federal government in environmental areas.

One other environmental law merits special attention. The Pollution Prevention Act of 1990 established pollution prevention as a national objective. The act requires the EPA to develop and implement a strategy to promote reduction of the pollutant's source. This law is in sharp contrast to most environmental protection laws, which simply attempt to manage pollutants once they have been created. This act establishes pollution prevention as the most desirable practice, followed by recycling, treatment, and disposal, in descending order of preference.

Faced with the challenge of interpreting environmental laws, the courts have usually adopted a middle path between extremes. On the one hand, as the famous Supreme Court decision regarding allowable levels of benzene in the workplace shows, "safe" does not mean "risk free."[7] On the other hand, as the 1986 decision of the Circuit Court in the District of Columbia shows, some costs to industry can be tolerated for the sake of environmental protection as long as they are not "grossly disproportionate" to the level of safety achieved.[8]

International Environmental Policy and Law

Many environmental issues cannot be resolved by individual countries, but require concerted action by many countries and preferably all of the earth's people. Examples are population, biodiversity, global climate change, ozone depletion, the fate of Antarctica, pollution of the oceans and threats to marine life, transboundary air and water pollution, and the growth of deserts. Concern for these issues began at the same time that environmental consciousness was rising in the United States.

The modern international focus on environmental issues can probably be dated from the United Nations Conference on the Human Environment, which the United Nations convened in 1972 in Stockholm and which is now annually celebrated as World Environment Day. At that time, Sweden was experiencing environmental pollution coming from other countries. The Stockholm conference emphasized principles such as producing renewable resources and sharing nonrenewable ones, safeguarding wildlife, and producing pollution only to the extent that the environment can clean itself. Another important conference was the United Nations Conference on the Environment and Development, held in Rio de Janeiro, Brazil, in 1992. Among major themes were sustainable development, environmental impact assessment, and the principle that the polluter should bear the cost of the pollution. The World Summit on Sustainable Development, held in Johannesburg, South Africa in 2002, reaffirmed a commitment to sustainable development. Another conference in Rio in 2012 reaffirmed yet again a commitment to sustainable development and also to a "green" economy.[9]

In addition to these major conferences, the number of multilateral environmental agreements has more than doubled since the Stockholm conference. Developments in international dispute settlement, especially in the field of transfrontier river pollution, have also taken place. Environment-related disputes have also been arbitrated under the General Agreement on Tariffs and Trade (GATT), including a dispute between Mexico and the United States (the *Tuna-Dolphin* case) and a dispute over environmental damages from the Gulf War.[10]

Applying Environmental Laws—Clean Enough?

The earlier phases of the environmental movement often focused on various kinds of environmental pollution, such as toxins in the earth, air, and water. When rivers were catching fire because of pollution, as the Cuyahoga River in Ohio did in 1969, it is understandable that citizens would have demanded action to clean up the environment. This raises the question of when the environment is acceptably clean—a question of great importance in the application of many environmental laws. Several criteria have been offered, all of them having a certain common-sense plausibility. We favor the last one.

(1) According to the *comparative criterion*, an aspect of the environment is sufficiently clean if and only if it imposes no greater threat to human life or health than do other risks that most people might consider reasonable. This is a defective criterion. It may often be the case that the public does not understand the seriousness of certain risks they accept. Furthermore, data about comparative risks are often difficult to obtain.

(2) According to the *normalcy criterion*, an aspect of the environment is sufficiently clean if and only if any pollutants present in it are normally present in it to the same degree. However, if the pollutants present in a river or the air are "normally" present, they could still pose a threat to human and animal health.

(3) According to the *optimal pollution reduction criterion*, an aspect of the environment is sufficiently clean if and only if funds required to reduce pollution further could be used in other ways that would produce more overall human well-being. According to this criterion, if funds necessary to make the Cuyahoga River sufficiently clean (e.g., by one of these criteria) could be better used to remediate an environmental problem somewhere else, the Cuyahoga River should be left in its present condition. This seems unsatisfactory.

(4) According to the *maximum protection criterion*, an aspect of the environment is sufficiently clean if and only if any identifiable risk from its pollution that poses a threat to human health has been eliminated, up to the limits of technology and the ability to enforce. This criterion could require all available funds to be spent on a single environmental remediation project if it were serious enough, leaving many other problems unaddressed.

(5) According to the *demonstrable harm criterion*, an aspect of the environment is sufficiently clean if and only if every pollutant that is demonstrably harmful to human health has been eliminated. Still stronger than the previous criterion, this criterion eliminates not only considerations of cost but also considerations of technical feasibility. It also requires proof of harm to human health, which is sometimes difficult to obtain. The criterion thus seems to be unrealistic.

(6) According to the *degree of harm criterion*, an aspect of the environment is sufficiently clean if and only if cost is not a factor in removing clear and pressing threats to human health, but when the degree of harm is uncertain, economic factors may be considered. This criterion may suggest the best balance of cost and health considerations and seems to be the closest to the position taken by many court decisions.

7.4 LIFE CYCLE ANALYSIS

Many environmentally concerned scientists and engineers believe that merely keeping environmental pollution within what some would consider acceptable limits does not go far enough in protecting the environment. Environment-friendly manufacturing must be based on a determination of the environmental effects of the materials or products being used, as well as the environmental effects of the manufacturing processes themselves. A useful method to this end is life cycle analysis (LCA)—also called life cycle assessment.[11] LCA is a "cradle-to-grave" analysis of the environmental impact of a product or a process. It covers the life history of a product or process from the extraction of raw materials from the earth, through manufacture and use, to its final disposal. According to one evaluator of LCA, it is not possible to make rational judgments on the relative environmental impact of various products, or the case for or against their recycling apart from the formal tool of LCA.[12]

LCA has many uses. It is often used by business as a basis for a claim that their products are "green" because they have minimal negative effects on the environment. It is also considered an essential tool in comparing environmental impacts of various products and processes, such as carpet tile versus vinyl tile, or polystyrene versus paper coffee cups, or diesel engines used on a bus fleet driven under urban conditions and diesel engines used in a truck fleet driven mainly on highways. The main goal in the last example was to determine whether it is beneficial from the environmental standpoint to use e-diesel fuels that contain ethanol rather than traditional fuels.[13] In another LCA, steel and plastic packaging were compared to determine which packaging has less environmental impact, what happens to the packaging after delivery to the end user, and what the differences are between packaging in Sweden and the rest of the world.[14]

BOX 7.1 Four Phases of Life Cycle Analysis

1. *Goal and Scope*. Defining the product or process, the context of the assessment, the boundaries of the analysis (geographical area, temporal boundaries of the study, and boundaries between this analysis and related life cycles of other systems), and the environmental effects.
2. *Inventory Analysis*. Relevant inputs and outputs of a product or process in terms of the energy, water, and materials used and identification and quantification of releases.
3. *Impact Assessment*. Identification and quantification of the most significant environmental impacts associated with the product, including resource use, human health and ecological consequences, and greenhouse gas emissions.
4. *Interpretation*. Evaluation of the results of the first three phases, along with evaluations of the assumptions made and the degree of uncertainty assumed. The best product or process is then selected.

The LCA method has four phases, as described in Box 7.1.

Despite the need for a tool such as LCA, it has multiple weaknesses.

First, a proper LCA is a long and time-consuming process. In the *inventory analysis* phase, the release of carbon dioxide and other greenhouse gases must be included. The data collection forms must be properly designed, and of course the data must be accurate. Data collection is the most resource-consuming part of the process. In the *impact assessment* phase, the potential human and ecological effect of the energy, water, and materials that are identified in the *inventory analysis* must be carefully addressed.

Second, there are many problems with obtaining useful and reliable data for an LCA. Only quantifiable data can be used. Critics argue that the data used in many LCAs can be questioned. Sometimes the data are obtained from "confidential" industry sources and are proprietary, so the sources are reluctant to give out full information. Assumptions about the life span of a product are often conjectural. Claims of accuracy are sometimes excessive. For example, some data are given with four decimal places—usually far beyond verifiable accuracy.[15]

Third, comparisons—one of the most important uses of LCAs—are often inconclusive. For example, according to one writer, disposable diapers produce 90 times more solid waste, but cloth diapers generate 10 times more water pollution and consume 3 times as much energy.[16] How should one decide whether disposable or cloth diapers are more harmful to the environment?

Despite these weaknesses, LCA is usually considered an essential tool in evaluating the environmental impact of buildings, products, and processes. The limitations, however, should be kept in mind.

7.5 SUSTAINABILITY: THE ENVIRONMENT VERSUS HUMAN DEVELOPMENT

Questions about environmental impact include not only questions about environmental damage and pollution but also, ultimately, about the effect on the long-term sustainability of human and nonhuman life. The effect on inanimate nature must also be considered. A major question here is: How can products and processes be improved from the standpoint of their demands on the resources of the earth? This brings us to the vexing and controversial, but nonetheless, vitally important, topic of sustainability.

According to the *Oxford English Dictionary*, one basic meaning of the verb "to sustain," is "to keep in being" or "to cause to continue in a certain state." We have seen that the concept of sustainability as applied to the environment is a prominent theme in United Nations environmental conferences. Several engineering codes also mention the concept of sustainability. The code of the National Society of Professional Engineers (NSPE) says that "Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations" (III, 2, d). The first canon of the code of the American Society of Civil Engineers (ASCE) says that "engineers shall…strive to comply with the principles of sustainable development in the performance of their professional duties." While neither provision imposes an absolute requirement on engineers (they are merely "encouraged" or told they should "strive"), they do indicate a commitment to the ideal of sustainability in engineering work.

What is sustainability? In October 2009, the ASCE Board of Direction defined sustainable development as "the process of applying natural, human, and economic resources to enhance the safety, welfare, and quality of life for all of society while maintaining the availability of remaining natural resources."[17] Notice that this definition reveals a tension between a concern for the environment and a concern for human development, a tension that pervades the discussions of sustainability.

This tension is even more evident in the best-known contemporary definition of the concept of sustainability. In fact, the definition is not of sustainability as such, but rather of "sustainable development," so that the tension is built into the definition of the concept itself. The definition is contained in a report of the World Commission on Environment and Development (WCED), commonly called the Brundtland Report, named after its chairperson, Norwegian diplomat, Grow Harlem Brundtland. According to the report, "sustainable development" is "development that meets the needs of the present without compromising the ability of future

BOX 7.2 Five Goals for Sustainable Development According to the Brundtland Report

1. Economic growth
2. Fair distribution of resources to sustain economic development
3. More democratic political systems
4. Adoption of lifestyles that are more compatible with living within the planet's ecological means
5. Population levels that are more compatible with the planet's ecological means.

generations to meet their own needs."[18] The report identifies five goals for sustainable development, listed in Box 7.2.

This definition contains many elements, but the basic fault line is clear: human-centered concerns for economic growth, fair distributions, and democracy (1–3) and environmental concerns for limiting consumption and population growth (4, 5). The immediate political motivations for these different goals are clear. Underdeveloped countries did not want limits imposed on their economic growth, which was needed to meet the needs of poor (sometimes desperately poor) populations. The claim for continued economic development was also fueled by a sense of injustice. From the standpoint of developing countries, developed countries have already done violence to the environment during their years of rapid economic and material growth since the Industrial Revolution, and now they want to deny the same option to them. They see this as unfair. By contrast, developed countries wanted to stop or diminish environmental degradation for the sake of both present and future generations. The Brundtland definition of sustainable development can be seen as a political compromise between these competing groups and interests. The arguments on both sides have considerable moral weight.

Several additional comments should be made about the WCED's definition of sustainable development and the associated goals.

First, one can ask whether sustainability and continued economic development are really compatible. As we have seen, the WCED attempted to combine the need of the developing world for continued economic development in order to raise their standard of living with the necessity of living in a way that is compatible with the limited resources of the earth and the needs of future generations. By combining the ideas of sustainability and development, the WCED implied that it is possible to have both sustainability for the sake of future generations and continued economic development for the sake of underdeveloped countries. Some have denied this possibility, even maintaining that the term "sustainable development" is a combination of two incompatible ideas.

Let us assume (as is surely the case) that the earth has a limited supply of nonrenewable resources, such as metals and oil, and that "development" implies increased use of these resources in order to supply the increasing needs of underdeveloped countries. We might also have to assume that the human population will continue to grow. Given these assumptions, how can development be sustainable? Indeed, how can any continued use of the finite supply of nonrenewable resources be sustained indefinitely?

Second, the reference to controlling population and changing lifestyles is idealistic and difficult to achieve. The best route to combining sustainability for future generations with improving the lot of the world's poor might indeed be (1) to limit or reduce the human population and (2) to change our consumption-driven lifestyle and our present modes of manufacturing, so that, instead of needing to take new materials from the earth, old materials would be reused. These goals appear highly idealistic at present, but we shall see that some progress is being made with respect to (2).

Third, why are equitable distribution of goods and democratic forms of government necessary for sustainability? As far as sustainability is concerned, what difference does it make whether material goods are given equally to everyone or owned disproportionally by a privileged few? And why might not an authoritarian regime be even more effective in enforcing the principles of sustainability than a democracy? The connection between equity and democracy in our own generation with sustainability for the future is not obvious.

Despite the many issues associated with this classic definition of "sustainable development," the goals of respecting the earth for the sake of present and future generations and for economic development, especially for the sake of the poor, have continued to be associated with the concept of sustainable development Perhaps, we should say that there are at least two ideals here, both important, even if not wholly compatible.

7.6 THE MORAL CASE FOR SUSTAINABLE DEVELOPMENT

Sustainable development has been embraced by many academic, business, and professional groups. What is its moral foundation? As with many moral issues involving general policies, it is useful to look at the claim from several ethical standpoints.

Before considering these arguments, however, we should make an important distinction. The arguments we consider below are *anthropocentric*. That is, they are made from the standpoint of the welfare of human beings, whether this be of the poor in developing countries, the more well-off in developed countries, or future generations, whether poor or wealthy. Another type of argument is *ecocentric*, in that it is made from the standpoint of the "interests" of the natural world, apart from considerations of human welfare. As the quotes around "interests" indicate, arguments from the ecocentric standpoint are generally more controversial and perhaps not appropriate to consider here. Does the natural world have interests, or rights, or is it in some way "intrinsically" valuable? Without attempting to resolve these controversial issues, we will focus on anthropocentric arguments.

Utilitarian, Respect for Persons, and Virtue Ethics Arguments for Sustainable Development

From the utilitarian standpoint in many of its formulations, future generations of humans (and even animals) should be included with the present generation in the audience over which utility is maximized.[19] If we say that all members of an audience, including future generations, have equal claim to moral consideration, we have an obligation to maximize the quality of life of members of future generations as well as our own, insofar as this is possible. Formulated negatively, we have an obligation not to decrease the quality of life of either present or future generations, insofar as this is possible.

The utilitarian formulation of our moral obligation raises several questions. First, what does this argument imply about the use of nonrenewable resources? If we use any nonrenewable resources at all, we cannot leave as much to future generations as we have ourselves. The utilitarian argument for sustainable development, then, can imply that we should reduce the use of new nonrenewable resources to zero, which may be impossible. Second, how can we know the needs of future generations? To be sure, technological and social developments might so modify the needs of future people that any prediction of future requirements could be wrong. However, we can say with reasonable assurance that humans will always need clean water and air, food, and fuel, and perhaps a few other necessities. Other than this, we can only use our best judgment as to the needs of future humans.

From the RP standpoint, we have an obligation, insofar as it is possible, to respect equally the rights of all people. This includes the rights of both present and future generations. The rights most relevant to sustainability are probably the rights to life and physical integrity, but we may think of others. As we have already suggested, the rights approach raises this question: If developed countries have achieved their present state of material prosperity by exploiting the resources of the earth, don't underdeveloped countries have the same right? Is it fair for developed countries to impose on underdeveloped countries restrictions that they themselves did not follow? A possible creative middle way is for developed countries to assist underdeveloped countries in complying with the same standards of sustainable development they impose on themselves, although this solution is controversial. At any rate, both utilitarian and RP morality suggest reasons for believing that we have moral obligations to the future.

From the standpoint of virtue ethics, the virtues of care and respect for nature come into special prominence. Care should extend to all members of the present generation as well as future generations, especially care for the poor and disadvantaged. Since care must be extended to all of these groups equally, this approach can justify balancing the application of care to these three groups. In addition, respect for the natural world can be a powerful motivator of environmental concern. At the end of this chapter, we address the virtue of respect for nature.

Environmental or Social Collapse?

Some of the classic arguments for environmental concern are indeed utilitarian and anthropocentric. What will happen if the human community fails to adopt some form of sustainable development? Nobody knows what the future holds, but advocates of sustainable development believe that the consequences of not pursuing sustainability might include environmental or social collapse. An early prophet of collapse was Thomas Malthus. His 1798 *An Essay on the Principle of Population* argued that populations grow geometrically, whereas food increases arithmetically or even linearly. The early Malthus believed that the population-food trap was inevitable and would produce horrible suffering, especially for the poor. The later Malthus believed that some factors, such as marrying later and death by disease or war might forestall the inevitable disaster, but only for a time.[20]

A well-known contemporary argument for disaster is provided by Garrett Hardin in his concept of the "tragedy of the commons."[21] Consider a village that has a "commons" area not owned by any individual, which any farmer can use for grazing his cattle. Acting in his own economic self-interest, each farmer puts as many animals on the commons as he can, in order to maximize profit. Eventually, the number of cattle exceeds the "carrying capacity" of the commons (the optimum number of animals the commons can support) and the animals fail to gain as much weight as before. The farmers respond by putting still more animals on the commons, so that eventually no animals can be supported, and everyone loses.

Resource collapse or near-collapse has already occurred as a result of overfishing in the North Atlantic, excessive use of ground water in the Midwest, and excessive harvesting of timber in the Pacific Northwest.[22] What, then, is to be done? The only answer is to adopt policies that provide for a sustainable use of the resources of the earth.

These considerations reinforce the plausibility of the *precautionary principle*, which holds that "where there is risk of irreversible or serious damage to the environment, lack of full scientific certainty shall not constitute a reason to postpone preventive or ameliorative action."[23] This principle has been invoked to justify action to slow or prevent climate change, but it is also relevant to justifying taking action to promote sustainability, even when all of the facts are not present.

7.7 SUSTAINABLE DEVELOPMENT AND ENGINEERING PRACTICE

Challenges of Implementation

Literal adherence to the goal of avoiding any reduction of nonrenewable resources might severely limit engineering work, since the engineer would only be able to use renewable energy such as wind and solar power to manipulate either renewable material or nonrenewable material already extracted from the earth. Paradoxically, this restraint might have impeded the development of many environment-friendly technologies. For example, manufacturing compact disks (CDs) requires aluminum and gold, which are nonrenewable. Unless the aluminum and gold could have been recovered from material already extracted from the earth, CDs could not have been developed and sold. Yet, CD technology paved the way for more environment-friendly technologies that stream music or the spoken word straight to computers, phones, and iPods.[24] Whether the less environment-friendly technology could be "skipped" is doubtful. Engineering practice at the present time, then, will probably depart from what might be called the pure ideal of sustainability. The goal remains, however, to approach this ideal as closely as possible. Here are two examples of increasing approximation to the ideal.

Cradle to Grave

According to the classic definition of sustainability in the Brundtland Report, humans should not compromise the ability of future generations to meet their needs. Taken in its most literal sense, this implies that humans must live in such a way that human and other forms of life can live on the planet indefinitely. This implies that, as a minimum, (a) humans must not pollute the earth in such a way that life processes can no longer flourish, and that (b) humans must not consume nonrenewable natural resources in such a way that they are exhausted and not available for future generations. At the present time, neither of these criteria is being satisfied. Contamination of the earth, air, and water continues, and any consumption of nonrenewable resources at all will eventually deplete them, thus threatening future generations. One might argue, however, for using nonrenewables as frugally as possible until alternatives using only renewable resources can be found, but even in this case, the precautionary principle requires that these issues be thought about now.

The ideal remedy for these problems is clear: Pollutants must be eliminated if they pose any environmental problem, and no additional nonrenewable resources should be extracted from the earth. Instead, those resources already extracted must be reused. This is indeed an ideal, and most descriptions of environmental programs implicitly recognize this by using terms such as "minimizing pollution," or becoming "more efficient" in the use of natural resources, or "minimizing waste." From the standpoint of strict sustainability, this is not enough, but we can look at some of the progress made in the direction of what we can call "partial sustainability."

Regarding pollution, there are two principal possibilities. Attempts to address environmental problems after the enactment of early environmental laws such as the NEPA were often devoted to controlling contaminants once they were produced. Hazardous substances generated by a manufacturing process were treated as a waste stream that must be contained and treated. A better approach, illustrated by the Pollution Prevention Pays (3P) program discussed later, is to design so that the production of as many pollutants as possible is reduced or even eliminated.

Regarding the use of nonrenewable resources, programs to minimize the use of new nonrenewable resources are often combined with attempts to reduce the material disposed of in dumps (the "grave"), including toxic substances. This can be done in part by recycling. Old tires can be made into sandals and other products of lower value, and plastic bottles can be turned into park benches. Toxic substances can either be eliminated in the production process itself or removed and perhaps reused before the disposal of the remaining material. Unfortunately, many toxic elements are still put in dumps and may reappear in recycled items. Changing sewage into fertilizers, for example, may not eliminate the heavy metals sewage contains. Furthermore, the "downcycling" of reused material results in a loss of economic value. Recycled steel may not be appropriate for making new cars, because the recycled steel is mixed with copper and other elements that diminish strength. Finally, many valuable materials are still lost. Dumps are full of copper and other valuable metals. As a result, more nonrenewable materials must be taken from the earth. This approach merely slows unsustainability rather than creating true sustainability.

Cradle to Cradle

The procedures discussed above are fundamentally linear, following a product from the extraction of raw materials from the earth to disposal of unused material in dumps or graves. It is probably the approach taken by most uses of LCA.

More visionary approaches attempt to follow natural processes, many of which are circular. This approach, sometimes called cradle to cradle (C2C), is often described as an application of *biomimicry*. Its advocates say that natural processes, which run on sunlight, are highly efficient, using only the energy they need. Further, nature recycles everything. There is, according to this view, no such thing as waste in nature. Cooperation, mutual dependence, and diversity are everywhere apparent.[25] Although these claims about natural processes can be criticized (e.g., most sunlight is wasted), the approach is highly influential and its adherents claim it should be the basis of true sustainability.

According to architect William McDonough and chemist Michael Braungart, humans don't have a pollution problem, they have a design problem. They design only for the first use of a product, instead of designing for uses after the first product breaks, crumbles, or otherwise becomes useless.[26] Look at a colony of ants. They handle their waste, grow and harvest their food, build their houses out of recyclable material, and make the soil healthier than it would otherwise be.[27] There is no waste. As McDonough and Braungart put it, "To eliminate the concept of waste means to design things—products, packaging, and systems—from the very beginning so that, at the end of a product's useful life, the inorganic (or 'technical') components can be separated from the organic components, the former being 'upcycled' into new products and the latter being returned to the earth for reuse in the natural cycle."[28]

The C2C approach is for the most part still only an ideal, but some manufacturing processes may be approaching the ideal ever more closely. In the manufacture of McDonough's and Braungart's book, *Cradle to Cradle*, the "paper" is a type of plastic and the ink is made of compostable and nontoxic materials. The book can be returned to the earth and decomposed without introducing toxic elements. The authors have also developed an upholstery material that can be thrown on the ground and decomposed when no longer needed.

McDonough and Braungart, as well as other writers, have held, however, that the ultimate roots of the problem of unsustainability reside in a certain mindset: a belief that human flourishing requires ever-greater acquisition of material possessions. The foundation of sustainability, by contrast, lies in turning away from what some have referred to as the addictive patterns of modern life.[29] Americans consume the equivalent of four earths and more and more people aspire to the American material standard of living. Even the proposals of McDonough and Braungart cannot eliminate the need for inner transformation. Bringing about such a transformation, for the most part, is beyond the professional obligation of engineers, although we return to this theme later in this chapter.

7.8 BUSINESS AND SUSTAINABLE DEVELOPMENT

Three Attitudes Toward the Environment

According to Joseph Petulla, industry attitudes toward the environment fall into roughly three groups. Although Petulla's survey is out of date, his three categories of industry attitudes, shown in Box 7.3, are still useful.[30]

7.9 CULTIVATING THE PROGRESSIVE ATTITUDE

"Good for business" usually means "good for enhancing a firm's public image" or "good for the bottom line"—or both. A team of three researchers has argued that sustainability is now the key driver of innovation in business and that it can increase a firm's profit and

BOX 7.3 Three Industry Attitudes Toward the Environment

- **The subminimal attitude** is associated with minimal compliance with environmental regulations and sometimes with doing even less than what is required. Firms that adopt this attitude often have no full-time personnel assigned to environmental issues, devote minimal financial resources to environmental matters, and sometimes refuse to comply with environmental regulations. If it is cheaper to pay the fines than make the mandated changes, this is what they will do. Managers in this group generally believe that the primary goal of business is to make money and that environmental regulations are merely an impediment to this goal.
- **The minimalist or compliance attitude** calls for compliance with governmental regulation as a cost of doing business, but their compliance is often without enthusiasm or commitment. Managers often have a great deal of skepticism about the value of environmental regulations. Nevertheless, these companies usually have established policies that regulate environment-related projects.
- **The progressive attitude** calls for responsiveness to environmental concerns, usually reflecting the personal commitment of the CEO. The companies have well-staffed environmental divisions, use state-of-the-art equipment, and generally have good relationships with governmental regulators. Managers probably believe that it is in the firm's long-term interest to go beyond legal requirements, because doing so generates goodwill in the community and avoids lawsuits. More than this, however, they may be genuinely committed to environmental protection and even sustainability, and have set up units devoted to these policies.

BOX 7.4 Stages in the Development of an Environment-Friendly Firm

1. Viewing compliance as a challenge to innovate and complying with the most stringent rules, so as to be ahead of other firms when the more stringent rules are enforced and believing that this approach can give them a market advantage.
2. Designing the firm's own products and services to be more sustainable.
3. Requiring suppliers to make their operations more sustainable by methods such as developing more fuel-efficient vehicles and machines.
4. Turning waste and pollutants into valuable products that can be sold for profit.
5. Questioning the implicit assumptions behind products and services and thereby thinking "outside the box." (Can we develop waterless detergents?)

reputation. They find that firms that start down the sustainability path go through five stages of change. We offer a limited summary of the five stages in Box 7.4.[31]

Many of the top 100 U.S. companies now publish annual sustainability reports and most companies in the Fortune 1000 claim to have adopted sustainable business practices. The most common reasons for adopting sustainable business practices are enhanced reputation, competitive advantage, and cost savings.[32] As an example of a lost competitive advantage, if Ford and Chrysler had embraced California's more stringent rules, they might have been ahead of competitors in the design cycle. As an example of a competitive advantage that was realized, Hewlett-Packard anticipated that lead would eventually be banned from solder, so it developed a nonlead solder which was in compliance with European standards. When the new standards were implemented, Hewlett-Packard was ahead of their competitors. As examples of cost savings, Cisco developed ways of recycling returned items, making a profit in doing it, and FedEx, in tandem with Kinko's chain of print shops, developed a document-delivery system that transmitted documents electronically and then produced a high-quality printed document at the end of the line. FedEx also developed a more fuel-efficient fleet of trucks and planes, saving millions of dollars in fuel costs.[33]

Another advantage is that being ahead of the regulatory curve not only puts firms on good terms with regulators, but sometimes enables them to actually shape the new regulations. Finally, probably most if not all of these innovations enhanced the reputations of the firms. Here are two more examples of the progressive attitude.

The CERES Principles

The CERES Principles exemplify the progressive attitude toward the environment. Formulated after the oil spill from the *Exxon Valdez*, they were originally called the Valdez Principles, but later renamed after Ceres, the Roman goddess of agriculture and fertility. We strongly suggest that you read this admirable set of principles for protecting the environment in their complete form at http://www.ceres.org/about-us/our-history/ceres-principles. The following is our summary of the ten principles:

1. *Protection of the biosphere*. Reduce and make progress toward the elimination of any environmentally damaging substance, safeguard habitats, and protect open spaces and wilderness, while preserving biodiversity.
2. *Sustainable use of natural resources.* Make sustainable use of renewable natural sources, such as water, soils, and forests, and make careful use of nonrenewable resources.
3. *Reduction and disposal of wastes.* Reduce and, if possible, eliminate waste, and handle and dispose of waste through safe and responsible methods.
4. *Energy conservation*. Conserve energy and improve the energy efficiency of all operations and attempt to use environmentally safe and sustainable energy sources.
5. *Risk reduction*. Strive to minimize environmental damage and health and safety risks to employees and surrounding communities and be prepared for emergencies.
6. *Safe products and services.* Reduce and, if possible, eliminate the use, manufacture, and sale of products and services that cause environmental damage or health or safety hazards, and inform customers of the environmental impacts of products or services.
7. *Environmental restoration*. Promptly and responsibly correct conditions the company has caused that endanger health, safety, or the environment, redress injuries, and restore the environment when it has been damaged.
8. *Informing the public*. Inform in a timely manner everyone who may be affected by the actions of the company that affect health, safety, or the environment and refrain from taking reprisals against employees who report dangerous incidents to management or appropriate authorities.

9. *Management commitment*. Implement these principles in a process that ensures that the board of directors and chief executive officer are fully informed about environmental issues and fully responsible for environmental policy, and make demonstrated environmental commitment a factor in selecting members of the board of directors.
10. *Audits and reports*. Conduct an annual self-evaluation of progress in implementing these principles and complete and make public an annual CERES report.

Corporate self-interest probably plays a role in motivating firms to adopt such policies. Many firms and industry groups have adopted progressive policies only after legal problems or strong and persistent public criticism. Probably one of the motivations for these policies is the desire to regain the trust of the public and avoid still more bad publicity. Whatever the corporate motivations, some believe that firms are increasingly adopting the progressive attitude.

The 3P Program

Minnesota Mining and Manufacturing (3M) illustrates some of the ideas discussed above. 3M is a firm with 90,000 employees and a list of over 60,000 products to its credit. In 1975, in the early days of the environmental movement, it launched the 3P program. Its goals were to (1) reduce or eliminate pollution, (2) benefit the environment through reduced energy use or more efficient use of manufacturing materials and resources, and (3) save money for the company. This latter goal could be accomplished by being able to avoid or defer buying pollution control equipment, reducing operating and materials expenses, or increasing sales.

Preventing pollution was to be accomplished by eliminating it at its source (in products and manufacturing processes) rather than removing it after it is created. 3M believes that this approach is more environmentally effective and cheaper than eliminating polluting chemicals after they are created. It further believes that this goal can be accomplished by techniques such as reformulating products, modifying processes, redesigning equipment, recycling, and waste recovery. In its first year in its U.S. operations alone, the 3P program produced reductions of 112,000 tons in air pollutants, 15,300 tons in water pollutants, 397,000 tons in sludge/solid waste, and 1 billion gallons in wastewater.

Here are three examples of the way the 3P program works. In a 3M facility in Alabama, both cooling water and waste water were disposed of together and both were considered "waste." By recycling the cooling water, the capacity of a planned wastewater treatment facility could be scaled down from 2,100 to 1,000 gallons/minute. The new recycling facility costs $480,000, but 3M saved $800,000 on the construction cost of the wastewater treatment plant because of the reduction in wastewater from 2,100 to 1,000 gallons/minute. In another project, new equipment was installed in a resin spray booth to minimize overspray. On a $45,000 investment, the company saved $125,000 on the cost of the resin used the first year alone.[34] In a 3M plant in St. Ouen l'Aumone, France, employees installed a new decking system in the trucks that transport finished products from the facility. The decking system allowed one truck to carry two levels of load without stacking the pallets on each other and damaging the products. Daily truckloads from the facility were reduced by 40 percent, saving about 12,500 gallons of fuel and $110,000/year.[35]

3M has framed a new set of goals to be realized in the decade from 2015 to 2025. Among the goals are developing more sustainable materials and products, reducing manufacturing waste by an additional 10 percent, attain "zero landfill" status at more than 30 percent of its manufacturing sites, indexed to sales, reduce global water use by an additional 10 percent, indexed to sales, and increase renewable energy to 25 percent of total electricity use. From 1975 to 2015, the 3P program eliminated the production of 2 million tons of waste and saved $1.9 billion.[36]

7.10 CULTIVATING THE VIRTUE OF RESPECT FOR NATURE

Rachel Carson is reported to have said that she hoped her writings would produce a love of the natural world, because we take care of what we love. In any case, motivating engineers to practice environment-friendly engineering is an important goal. Furthermore, as we saw in Chapter 2, engineers should have the professional virtue of respect for nature, meaning that engineers should "show consideration for, avoid violation of, and treat with deference" the natural world. Since a virtue has both a rational and emotional component, a person having the virtue of respect for nature will not only have the intellectual conviction that nature should be respected but also an emotional commitment. The emotional element includes not only having a love for the natural world but also being hurt or even disgusted by violations of it. Engaging with enthusiasm in environment-friendly engineering projects will not be simply because this may be required by one's superior, but because it is rooted in one's character.

How can the virtue of respect for nature be cultivated in the engineer or, for that matter, in anyone else? We suggest two ways, one having primarily to do with scientific arguments for the value of the experience of the natural world and the other having primarily to do with the more direct emotional effects of experiencing the natural world.

The Healing/Restoring Aspect of Nature

Recent research has confirmed that the effects of the environment on human psychology are remarkable. Taking a stroll through nature can boost performance on tasks requiring sustained focus, such as proofreading. Even looking at photos of nature can give a greater cognitive boost than actually walking in an urban environment. By contrast, spending all of one's time in a built environment may result in exhaustion and a loss of vitality and health. For example, people with access to nearby natural settings are healthier overall, having lower cholesterol and blood pressure.[37] Moreover, the quality of view from a hospital window is a significant factor in the recovery of patients.[38] Prison inmates visit health care facilities much less frequently if they have a good view from cell windows.[39] More extended exposures to nature can produce even more dramatic results. A four-day wilderness experience can increase creative thinking and insight problem solving by a whopping 50 percent.[40]

The explanation of these findings appears to be related to the reduction of mental fatigue, which results from overuse of what psychologists call "directed attention," a psychological process that involves effort and concentration. Mental fatigue can be eliminated or reduced by "restorative experiences," such as looking at passing clouds or enjoying nature in other ways. These experiences require less concentration and effort and allow one to "clear the head."[41]

The Emotional Effects of Experiencing the Natural World as Transcending Human Interests

Paradoxically, appreciating the natural world as transcending human interests can also contribute to human well-being and to the development of the virtue of respect for nature. This contribution is probably on a more emotional than intellectual level. Philosopher Daniel Haybron spent his summers as a boy in a remote village off the coast of the Carolinas. Here is a short description of what it was like to live on "the island."

> It could be a hard and sometimes cruel place to live. Even for part-time residents like ourselves, being there meant being a little uncomfortable much of the time—the bugs bit, it was hot, sandspurs caught on the soles of your feet, electricity was a hit or miss affair and television was virtually nonexistent, you drank rainwater out of a cistern when you could, and the nearest doctor was a half-day trip off-island. As near as I can tell, virtually all of us off-islanders and locals alike, loved it.[42]

It goes without saying that Haybron and his fellow residents also appreciated the great physical beauty of the place, but the islanders also experienced nature as overwhelming, as fundamentally beyond human control and not oriented toward fulfilling human desires. They experienced their bodies as fragile and vulnerable and health care was accessible only with considerable difficulty. The possibility of death must have always been lurking in the backs of their minds. Rather than being in a position of domination over nature, the islanders felt themselves dominated by nature. All of this contrasted sharply with what Haybron calls "a civilization dedicated to giving people what they want…a world tailored to each person's desires, rendering superfluous, to the extent possible, any need to connect with a reality independent of our own appetites."[43] He even wonders how people can find a world "bereft of mystery and texture as gratifying as the unruly offerings of the nonservice sector of the cosmos."[44]

Many have recognized the importance of such experiences. Psychologist Martin Seligman says that the ability of humans to reach out beyond themselves to something larger and more permanent is important for human well-being.[45] While Seigman appears to be concerned primarily with the importance of commitments to causes larger than ourselves, the remark is also applicable to the experience of what Haybron strikingly calls "the nonservice sector of the cosmos." Religious writers have long recognized the spiritual importance of the experience of nature.[46]

Haybron's experiences had a powerful effect on him as an adult and were a primary motivation in writing the book from which the discussed account is taken. Both Haybron and his father describe their profound sadness as they observed the island way of life being destroyed by development.

Engineers for a Sustainable World

Many engineering students are doubtless already motivated by a respect for nature as well as a concern for the well-being of future generations. Founded in 2002 at Cornell University, Engineers for a Sustainable World (ESW) consists of students, university faculty, and professionals who are committed to using their professional talents to creating a more sustainable world. This commitment results in projects on the campus, in local communities, and around the world. ESW members are also dedicated to educating the public about sustainability. ESW has about 1,000 members and operates primarily through approximately 50 chapters in North America, mostly on college campuses. While ESW is similar in many ways to the larger Engineers Without Borders (EWB) mentioned earlier, its special focus is on working with local organizations in promoting the sustainability aspects of such projects as providing water and food for underdeveloped communities. In Honduras, for example, working with local organizations has amplified ESW's efforts in providing fresh water, so that dozens of communities are affected, not just one.[47]

The creation of ESW reflects the interest of students and academic engineers in environmental issues and probably is motivated at least in part by respect for the natural world. The interest in sustainability must ultimately manifest itself in changes in engineering curricula. Integrating environmental considerations, and especially sustainability considerations, into engineering courses is sometimes challenging, however. Instructors may be reluctant to spend the time necessary to master the many topics covered in considerations of sustainability, such as environmental law, biology, LCA, and many others. Students may be unclear about the concept of sustainability and may not see its importance.[48]

7.11 CHAPTER SUMMARY

The modern environmental movement began in the 1960s and 70s with environmental advocates such as Rachel Carson and spawned many environmental laws in the United States and elsewhere as well as a series of international conferences sponsored by the United Nations on various environmental topics. The engineering response has included the development of formal tools, such as LCA, for determining the environmental impact of products and processes.

The concept of sustainability has come into prominence in the environmental movement and is cited in some engineering codes. Many definitions of sustainability, such as the one proposed in the Brundtland Report, reveal a tension between two ideals—protecting the environment for future generations and facilitating economic growth in less developed societies.

Engineering responses that move in the direction of sustainability include cradle-to-grave and cradle-to-cradle approaches. Business responses usually fall into three categories, the third and most positive one being the progressive attitude. The CERES principles and 3M's 3P program illustrate the progressive attitude.

The virtue of respect for nature is important in motivating engineers to engage in environment-friendly engineering. It can be cultivated by a more intellectual and scientifically-based appreciation of the value to humans of the experience of the natural world and by the direct experience of the transcendent aspect of nature. Engineers for a Sustainable World represents students who have probably already developed this virtue.

NOTES

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CHAPTER EIGHT

Engineering in the Global Context

Main Ideas in This Chapter

- **Some progress has been made in establishing international technical standards. Whether engineers worldwide think (or should think) of themselves as professionals is more controversial.**
- **Economic, cultural, and social differences between countries sometimes produce "boundary-crossing problems" for engineers. Solutions to these problems must avoid absolutism and relativism and should find a way between moral rigorism and moral laxism.**
- **Applying the standards of one's own country without modification or uncritically adopting the standards of the host country in which one is working are rarely satisfactory solutions to the moral issues that arise in international engineering.**
- **Adaptations of the methods and standards for resolving ethical problems discussed in Chapter 2 can be useful in resolving issues encountered in the international arena. Solutions involving creative middle ways are often particularly useful.**
- **Engineering work in the international arena can raise many ethical issues, including exploitation, bribery, extortion, grease payments, nepotism, excessive gifts, paternalism, and paying taxes in a country where taxes are negotiable.**

EMBRAER SA OF BRAZIL is the world's third largest commercial aircraft manufacturer, specializing in commercial and defense aircraft and executive jets. On October 24, 2016, the U.S. Securities and Exchange Commission, along with the U.S. Department of Justice and Brazilian authorities, announced a global settlement of $205 million in fines for bribery. Embraer would pay $107 million to the Department of Justice, $78 million to the Securities and Exchange Commission, and $20 million to Brazilian authorities. Frederico Curado, stepped down as CEO of Embraer, and the company's stock fell to a two-year low. The scandal involved paying bribes from Embraer's New York bank account, totaling more than $13 million, during the years 2009–2011, to highly placed governmental officials. The bribes secured contracts for aircraft purchases without competitive bidding in Saudi Arabia, Mozambique, the Dominican Republic, and India. Embraer made a profit of more than $83 million on the sales. Brazilian officials filed criminal charges against 11 individuals and Saudi officials have filed charges against two individuals. In the United States, the investigations were carried out under the U.S. Foreign Corrupt Practices Act (FCPA). In an attempt to conceal the bribes, Embraer created false books and now "deeply regrets" its past conduct.[1]

8.1 INTRODUCTION

Given the nature of Embraer's work as an aircraft manufacturer, it is likely that some of the officials involved in the scandal were engineers, or had an engineering background. In any event, the story illustrates one of the most common ethical issues faced by engineers, especially in the international arena, namely, bribery. As we shall see, however, bribery is far from the only problem engineers encounter in the new international environment. Interestingly, one issue is the globalization of engineering and the status of engineering professionalism itself in the globalized environment.

8.2 THE MOVENT TOWARD GLOBALIZED ENGINEERING EDUCATIONAL STANDARDS

One of the first steps in the globalization of engineering is establishing universal criteria for engineering education. The primary instrument for doing this is the Washington Accord. Established in 1989, the *Accord* is an agreement among bodies that have the authority to accredit engineering programs in their respective countries or jurisdictions. The Accreditation Board for Engineering and Technology (ABET), which has the responsibility for accrediting engineering programs in the United States, signed the accord for the United States. The primary purpose of the accord is to establish "substantial agreement" among the signatories in the requirements for engineering education, so that signatory countries or jurisdictions are able to accept the qualifications of engineers graduating from accredited institutions in other signatory countries or jurisdictions as equivalent. The engineers in the accredited jurisdictions are expected not only to meet minimal technical standards in their education but also to maintain their competency and abide by a code of conduct, although little is said about what these codes of conduct should contain.

The original signatories were the United Kingdom, Ireland, the United States, Canada, Australia, and New Zealand. The accord now has 18 signatories, with 6 provisional signatory organizations. In addition to the six original signatory organizations, the accord's full members now include China, Chinese Taipei, Hong Kong China, India, Japan, Korea, Malaysia, Russia, Singapore, South Africa, Sri Lanka, and Turkey. Other agreements have promoted similar mutual recognition in related areas. The Sydney Accord, initiated in 2001, recognized substantial equivalence in accreditation qualifications in engineering technology, and the Dublin Accord, initiated in 2002, recognized substantial equivalence in the qualifications for engineering technicians.[2]

A much older organization, the Fédération Européenne d'Associations Nationales d'Ingénieurs (FEANI), or the European Federation of National Engineering Associations, takes a different approach to the standardization of criteria for the competence of engineers. Rather than focusing on equivalent standards for engineering education, FEANI has established common standards in Europe for licensing individual engineers. FEANI awards the EUR ING professional title to engineers in an effort to "facilitate the mutual recognition of engineering qualifications in Europe and to strengthen the position, role, and responsibility of engineers in society." The EUR ING title is much like the PE in the United States. The organization celebrated its sixtieth anniversary in 2012.[3]

8.3 INTERNATIONAL PROFESSIONALISM AND ETHICS

Another step in the globalization of engineering is establishing a consensus on whether engineers are professionals and, if so, what professionalism might mean. Before asking whether engineers worldwide *are* professionals, however, let's ask whether engineering organizations worldwide *call* their members professionals. While simply calling members professionals is not sufficient for their being professionals, this is a good place to start. In fact, many official statements of engineering organizations do describe their members as professionals.

Do Engineering Societies Call Their Members Professional?

The Federation of Engineering Institutions of Asia and the Pacific (FEIAP) has as its goal "to encourage the application of technical progress to economic and social advancement throughout the world, to advance engineering *as a profession* in the interest of all people, and to foster peace throughout the world."[4]

The Japan Society of Professional Engineers was formed in September 2000 and has approximately 380 members. Its goal is the advocacy of "engineering and professional ethics integrated within the U.S. PE licensure system…." Its members hold the American P.E. or Engineer-in-Training certification and the organization is affiliated with the National Society of Professional Engineers (NSPE). The organization promotes ethics and professional conduct and endorses the obligation of engineers to promote the health, safety, and welfare of the public. It also advocates higher social status for Japanese engineers. Most of the organization's members now live in Japan, but many probably received at least a part of their education in the United States and probably speak English. How representative the organization is of Japanese engineers might be questioned, but the organization clearly considers its members to be professionals or at least on their way to becoming professionals.[5]

The Commonwealth Engineers Council (CEC) has members in 44 countries, many of them in Asia. It seeks to "advance the science, art, and practice of engineering for the benefit of mankind." The organization goes on to link engineering with "other professions." It holds that "engineering is at the heart of social and economic development. As engineers we recognize our responsibility and the importance of working closely with other professions and with the engineering community at large." The CEC is also committed to development that is sustainable.[6]

The World Federation of Engineering Organizations (WFEO) was founded in 1968, has 90 nations as members, and claims to represent 20 million engineers from around the world. Its *Code of Ethics* begins with the statement: "In the course of engineering practice, professional engineers will…" In addition to claiming professional status for their members, the *Code* makes other commitments typical of professional societies which we discuss later.[7]

BOX 8.1 Three Accounts of Professionalism

- **Sociological account**. Extensive training, knowledge, and skill vital to the public's well-being, monopoly over the provision of certain services, unusual autonomy in the workplace, and a claim to be regulated by ethical standards.
- **Social contract account**. An implicit contract between the professions and society, giving the public high-quality expertise and regulation by ethical standards, in return for social prestige and above-average pay.
- **Michael Davis' account**. A number of individuals in the same occupation voluntarily organized to earn a living by openly serving a common moral ideal in a morally permissible way beyond what law, market, morality, and public opinion would otherwise require.

Do Engineers Worldwide Have the Concept of "Professional?"

Many engineering societies around the world call their members professionals. Are they really professionals? Let's recall the three accounts of professionalism given in Chapter 1 to help in answering this question (Box 8.1).

Since most research related to professionalism outside Europe and North America focuses on Asia, we concern ourselves with this geographic region. Japanese scholar Tetsuji Iseda holds that the concept of "professionalism" is a Western idea which is not universally applicable and that the concept of "profession" has no historical roots in Japanese culture. Iseda believes the social contract account of professionalism does not apply in Japan because Japanese engineers do not enjoy the advantages of high pay and social prestige. They earn less pay than social scientists and they do not have the high prestige associated with many other occupational groups. It is doubtful, Iseda believes, that appeal to the concept of being a "professional" has much plausibility for Japanese engineers or that the appeal is sufficient to motivate engineers' compliance with the high standards of conduct associated with professionalism. In place of the concept of professionalism, Iseda proposes that Japanese engineers should be encouraged to comply with high standards of conduct by an appeal to an intrinsic pride in their work itself, regardless of its social recognition.[8]

Scholars Cao Nanyan, Su Junbin, and Hu Mingyan cite Michael Davis' account of professionalism and appear to take Davis' reference to the moral dimension of professionalism ("openly serving a moral ideal") as of special importance. Studying the constitutions of 48 Chinese national engineering societies, they found little concern with morality. Instead, the documents concern themselves with issues such as compliance with the law, economic and technical development, enhancing national and international communication, and insistence on democracy within societies. Few societies have formulated separate codes of ethics and there is little attention to issues such as the environment, or public health, safety, and well-being. While two organizations, the Chinese Academy of Engineering and the Chinese Computer Federation, do have separate ethics codes, the focus is on academic research ethics rather than engineering ethics. As the researchers put it, the emphasis overall is on "doing the thing right," rather than "doing the right thing." They conclude that "engineering societies in Mainland China lack awareness of the professional ethics of engineering."[9]

Michael Davis and Hengli Zhang come to a somewhat more positive conclusion. They submitted a questionnaire to 71 people engaged in what we might roughly call engineering work, although 28 percent of those interviewed did not claim a bachelor's degree. The answers would not generally support a claim that the interviewees subscribed to either the social contract or sociological accounts of professionalism. The compensation of interviewees was closer to factory workers (5,000 yuan) than university professors (12,000 yuan) and the interviewees tended to have little or no knowledge of professional codes or a sense of a contract with society. They did, however, appear to think of themselves as openly engaged in a common undertaking with other engineers that required "ethical norms or ethical codes." More than 90 percent of the engineers accepted responsibility for environmental problems and many appeared to recognize a moral ideal of engineering as, roughly, improving the material conditions of society. The surveyors concluded that "most interviewees, though probably not all, have the concept of profession" in the sense of Davis' definition. The number of individuals surveyed, of course, is small.[10]

From this limited research, we probably have to conclude that whether engineers in Asia qualify as professionals is still controversial and that any conclusion depends in part on which account of professionalism is used. We turn now to specific issues faced by engineers when they travel to countries with different ethical traditions and perhaps a different level of economic development.

8.4 BOUNDARY-CROSSING PROBLEMS

Let us call the problems encountered when one crosses national and cultural borders *boundary-crossing problems*. We shall refer to the country in which the engineers originally lived—in this case, the United States—as the *home country* and the country that they enter as the *host country*.

Simple solutions to boundary-crossing problems are attractive but often unacceptable. One simple solution is to hold to home-country values and ways of doing things, no matter how different they may be from host-country values. Call this the *absolutist solution* or the *imperialist solution*, because it requires importing values from the home country into a different society. Home-country standards, however, may pose serious, if not insurmountable, problems if applied in host countries. For example, customs regarding practices such as grease payments may be so pervasive and deeply entrenched in a host country that it may not be possible to do business in these countries without following the customs. Also, host-country values and standards might be just as defensible as home-country values and standards, just different.

The other extreme is the *relativist solution*, which follows the rule, "When in Rome, do as the Romans do." Using this approach, home-country citizens always follow host-country laws, customs, and values even if they are contrary to home-country standards. This solution can also produce severe problems. It might even lead to illegal actions. For example, the Foreign Corrupt Practices Act (FCPA), passed by the U.S. Congress in 1977, makes it illegal for U.S. citizens to engage in practices such as paying some kinds of bribes and making some kinds of extortion payments, although these may be common practices in the host country. Another problem is that certain practices in the host country might be so repugnant that a home-country engineer would have trouble following them. For example, the health and safety standards might be so low that they are clearly endangering the health and safety of workers and perhaps the engineers themselves.

Another related issue has to do with how standards should be applied rather than what standards should be adopted. One extreme is *moral laxism*, which holds that in some situations moral principles appear so far removed from the moral issue at hand that they cannot be applied with any precision, so that almost any action is permissible.[11] Thus, the moral laxist allows solutions to moral problems that may involve serious violations of moral standards—standards in either the home or host country. Suppose a government official in Country X who has the ability to give you a lot of government business wants you to come to his daughter's birthday party. You know you are expected to bring a large gift, but then people in Country X are accustomed to giving large gifts to friends. You are in a quandary about what to do and finally throw up your hands and say, "My country's standards are irrelevant here. I am going to do what's best for me and my company." So you bring a large gift.

The other extreme is *moral rigorism*, which holds that moral principles, whether they are those of the home country or host country, must be strictly applied in every situation.[12] The moral rigorist is unwilling to accept the fact that, although a given course of action is not ideal, it may be the most reasonable thing to do in the situation. Suppose your company rules do not allow employees to give or accept gifts over $25.00. Even if a $25.00 gift in Country X would be considered insultingly small, if you are a moral rigorist you will follow the company rule to the letter. This may not be the most reasonable thing to do.

Few moral solutions follow extreme forms of either rigorism or laxism, but the distinction is important in understanding the nature of many moral solutions, such as creative-middle-way solutions.

8.5 ETHICAL RESOURCES FOR GLOBALIZED ENGINEERING

The following account of resources should be considered a partial list of tools in a tool kit for thinking about how U.S. engineers can deal with issues encountered in other cultures and how non-U.S. engineers can construct standards appropriate for their professional work. The basic ideas will be familiar, but they have been adapted to the international arena. As always, one selects the approach most appropriate for a particular task.

Creative Middle Ways

Laura's firm operates a plant in Country X that produces fertilizer in an area where farmers live at subsistence levels. The plant produces relatively inexpensive fertilizer that the farmers can afford, but it also produces a considerable amount of pollution—far more than would be allowed in the United States, for example. The pollution does not violate the environmental standards in Country X. Remedying the pollution problem would require raising the price of fertilizer so much that the farmers could not afford it, probably resulting in the deaths of many people in the area. Should a U.S. engineer be involved in the plant's operation?

A creative middle way might be to participate in the operation of the plant, but with an energetic effort to find a more economical remedy to the pollution problem. Notice this is not an extreme moral rigorist solution from the perspective of U.S. laws and standards, because considerable pollution will be allowed, even pollution that may damage individuals and the environment. Neither is the solution extreme moral laxism, since it preserves concern for the environment and does not resort to mere self-interest.

The Golden Rule

Consider the same case again. From the standpoint of the Golden Rule, one asks, "If I were a citizen of Country X, would I be willing to accept the creative middle-way solution?" Given the many complexities in applying the Golden Rule that we have already identified, it should come as no surprise that it is especially difficult to put oneself in the position of a person in another country, where the culture, economic conditions, living conditions, and values may be different from one's own. Nevertheless, some assumptions can generally be made. It is difficult to imagine, however, that anyone would want to have their basic human dignity violated or to be deprived of the conditions necessary for their physical well-being. The twin themes of protecting human dignity and promoting social and economic development loom large in the international scene and are crucial in international ethics. As we have seen, protecting human dignity is especially associated with the respect for persons approach and promoting economic and social development is especially associated with the utilitarian approach. In the next two sections, we explore these two themes.

Dignity: Universal Human Rights

Concerns about human dignity are often expressed in terms of a set of human rights, and people in many countries, including non-Western countries, now appeal to human rights. "Rights talk" has become a near-universal vocabulary for ethical discourse. One measure of the cross-cultural nature of rights talk is the United Nations International Bill of Human Rights, adopted in 1948, and two later documents—the International Covenant on Economic, Social, and Cultural Rights and the International Covenant on Civil and Political Rights.[13] Box 8.2 lists some of these rights. (The groupings of the rights are our own.)

Notice that some of the rights are what we have called "positive rights." That is, they are not simply negative rights to noninterference from others, such as the rights not to be held in slavery or tortured, but rights to certain advantages, such as education, social security, and work. The positive rights require not only a negative duty to noninterference but also a positive duty to help others achieve such rights. Most of us would consider all of these rights highly desirable. The question is whether they should be considered as rights or simply desirable things to have.

James Nickel has proposed three criteria for determining when a right is what we shall call an *international right*—that is, a right that every country should, if resources and conditions permit, grant to

BOX 8.2 International Bill of Human Rights

- Life, liberty, security of person,
- Recognition before the law, an impartial trial,
- Marriage, property ownership,
- Freedom of thought, peaceful assembly, and participation in government,
- Social security and work,
- Education, participation in and forming trade unions,
- Nondiscrimination, a minimal standard of living.
- Freedom from slavery, torture, inhumane or degrading punishment, and forced marriages.

BOX 8.3 Criteria for Identifying International Rights

1. The right must protect something of very general importance.
2. The right must be subject to substantial and recurrent threats.
3. The obligations or burdens imposed by the right must be affordable in relation to the resources of the country, the other obligations the country must fulfill, and fairness in the distribution of burdens among its citizens.[14]

its citizens. In terms of generality and abstraction, an international right falls between the very abstract rights derived from respect for persons theory and the more specific rights guaranteed by laws and constitutions of individual governments. Nickel's conditions that are most relevant to our discussion are shown in Box 8.3.

Judged by these criteria, some or all of the rights in the United Nations' list may not qualify as genuine international rights. For example, some countries may not have the economic resources to support the claims to a minimal education however desirable these may be. Perhaps, we should say that these rights are desirable, insofar as a country is able to provide them.

While these rights have a decidedly Western orientation, we believe they are increasingly accepted throughout the world. Furthermore, it will be difficult for a Western engineer to participate in a fundamental violation of any right determined to be genuinely international by Nickel's standards, such as life, liberty, and security of person.

Development: Promoting Basic Human Well-Being

Another moral consideration for determining whether ethical solutions are satisfactory is whether a solution promotes the well-being of those affected. If a solution does not promote well-being, this is a strong argument against it. One of the most important ways in which engineering can promote well-being is through material and economic development. However, simple economic advancement may not be an adequate criterion. Economist Amartya Sen and philosopher Martha Nussbaum have addressed this issue. In particular, Nussbaum has proposed a set of "basic human functional capabilities"—that is, basic capabilities that a person needs to be able to satisfy to enjoy a reasonable quality of life.[15] Box 8.4 lists these capabilities.

Engineering is involved, either directly or indirectly, in many of these capabilities which, according to Nussbaum, contribute to human well-being. By providing clean water and sanitation, engineering makes an important contribution to health and longevity. Production of fertilizer and other aids to agriculture increases the ability of people to feed themselves. Technological development promotes greater wealth, which is important for the other capabilities mentioned by Nussbaum.

The Resources of Virtue Ethics

Since the fundamental human virtues are some of the most universally accepted criteria for moral thinking, appeal to the virtues and to moral exemplars who exhibit these virtues can sometimes be a useful tool for moral analysis, as well as moral exhortation. For example, bribery and extortion are usually kept secret, implying that they are forms of dishonesty; yet, most cultures endorse the virtue of honesty.

BOX 8.4 Nussbaum's Basic Human Functional Capabilities

1. Being able to live a human life of normal length.
2. Being able to enjoy good health, nourishment, shelter, sexual satisfaction, and physical movement.
3. Being able to avoid unnecessary and nonbeneficial pain and to have pleasurable experiences.
4. Being able to use the senses, imagine, think, and reason.
5. Being able to form loving attachments to things and persons.
6. Being able to form a conception of the good and to engage in critical reflection about the planning of one's life.
7. Being able to show concern for others and to engage in social interaction.
8. Being able to live with concern for and in relation to animals, plants, and the world of nature.
9. Being able to laugh, play, and enjoy recreational activities.
10. Being able to live one's own life and nobody else's.

What is going on here? Do those who practice bribery and extortion fail to realize the practices are dishonest? Do they think there is a legitimate exception in these cases? Do the individuals involved reject the virtue of honesty altogether?

Virtue ethics can often be a useful supplement to other methods of moral analysis. In particular, it can assist home- and host-country residents to determine whether they can personally live with solutions arrived at by other means. When we suggest creative-middle-way solutions to a moral issue, it is useful to ask whether a virtuous person would accept such a solution. Would a person of honesty or justice or compassion accept the solution? Are solutions to the problems of nepotism and paternalism compatible with, or in some cases perhaps required by, compassion or honesty? What about participating in tax negotiation that may have aspects that look like bribery? Will we return from our international experience feeling that our moral character has been compromised in an unacceptable way?

Codes of Engineering Societies

Engineering codes also provide guidance for individual engineers visiting host countries and for host-country engineers formulating guidelines for themselves and their fellow nationals. Some U.S. engineering codes are clearly intended to apply to their members wherever they live. The Institute of Electrical and Electronics Engineers (IEEE) is explicitly an international organization and its code opens with an acknowledgement of "the importance of our technologies in affecting the quality of life throughout the world." The code of the former American Society of Mechanical Engineers, now ASME International, makes similar references to the international environment. A 1996 decision (Case 96-5) by the board of ethical review of the NSPE held that a member of the NSPE is bound by its code of ethics, even in another country. In this case, the issue was whether a U.S. engineer could ethically retain a host-country engineer who would then offer bribes to a host-country official

BOX 8.5 Summary of Key Ideas in the *Code of Ethics* of the WFEO

- "Professional engineers" will avoid "fraudulent, corrupt, or criminal practices" and practice within their area of competence and in accordance with "accepted engineering practices."
- Engineers will "practice so as to enhance the quality of life in society" and "create and implement engineering solutions for a sustainable future."
- Engineers will "be mindful of the economic, societal, and environmental consequences of actions and projects" and "promote and protect the health, safety, and well-being of the community and the environment."
- With its prohibition of corrupt and criminal practices, the code prohibits bribery.
- The code refers to "quality of life" and "well-being," and requires being "mindful" of the environmental consequences of engineering work, and of considerations of sustainability and the environment.

to get a contract. The board held that the practice would violate the NSPE code and that it would be unethical for a U.S. engineer to be a party to such a practice. Codes of international engineering societies are also relevant. Box 8.5 summarizes some key ideas in the *Code of Ethics* of the WFEO.

Established professional codes give important guidance for individual engineers as they face ethical dilemmas in the international arena. They are also a source of guidance for engineers in host countries who are attempting to formulate their own codes and for engineers who are considering working in the international arena. In the following sections, we consider some of the more specific issues that such engineers may encounter. The code is interesting in what it does not say as well as what it says. It says nothing about exploitation or social justice, nor do engineering codes generally. For this reason, we must rely on the more general ethical concepts and methods mentioned earlier, as the next section illustrates.

8.6 ECONOMIC UNDERDEVELOPMENT: THE PROBLEM OF EXPLOITATION

Exploitation, especially of the weak and vulnerable, is a serious moral problem, and it is particularly likely to occur in economically underdeveloped countries, where workers have few options for jobs. According to Robert E. Goodin, the risk of exploitation arises when the following five conditions are present.[16] See Box 8.6.

Consider the following case. Engineer Joe's firm, Coppergiant, is the most powerful copper mining and copper smelting company in the world. It controls world prices and keeps competitors away from the most lucrative sources of copper. Joe works for Coppergiant in Country X, the firm's most lucrative source of copper. In Country X, Coppergiant buys copper at prices that are considerably below the world market and pays the workers the lowest wages for mining and smelting in the world. As a result, Coppergiant makes enormous profits. Because the company pays off government officials and has so much control over the world market in copper, no other mining and smelting company is allowed into the country. Country X is desperately poor and copper is the major source of foreign currency.

BOX 8.6 Conditions for Exploitation

- An imbalance of (usually economic) power between the dominant and subordinate or exploited party.
- The subordinate party needs the resources by the dominant party to protect his or her vital interests.
- For the subordinate party, the exploitative relationship is the only source of such resources.
- The dominant party in the relationship exercises discretionary control over the needed resources.
- The resources of the subordinate party (natural resources, labor, etc.) are used without adequate compensation.

This case meets all five of Goodin's criteria for exploitation. There is an asymmetrical balance of power between Coppergiant's employees (and even Country X) and Joe's firm. The workers in Country X desperately need jobs and Country X needs the foreign currency. Joe's firm is the only (or major) source of jobs and foreign currency for Country X. Joe's firm, through its control of the market, exercises discretionary control over the jobs and currency. Finally, the natural and labor resources of Country X are used without adequate compensation. This is a paradigmatic case of exploitation of Country X and its workers.

Exploitation is usually wrong because it violates several of the moral standards and tests we have mentioned. It violates the Golden Rule because it is doubtful that anyone in any culture in the world would, under normal circumstances, want to be the victim of exploitation. It violates virtue ethics because it does not manifest the virtue of compassion. It violates utilitarian considerations because it denies the citizens of Country X a minimal standard of living and it keeps the citizens of Country X from realizing many of the capabilities mentioned by Nussbaum. While it is possible to argue on utilitarian grounds that the exploitation is justified because it is the only way that Country X can undergo the economic development that will ultimately benefit all of its citizens, this argument is implausible because economic development could almost certainly occur without this kind of exploitation.

Since the exploitation described in this case cannot be justified, we must conclude that the situation it describes should be changed. It may be that raising wages and copper prices to market levels would still not provide the employees of Coppergiant with adequate compensation. At this point, a creative-middle-way perspective might justify this condition because any further increase in wages might result in the economic collapse of Coppergiant or its exit from the county. This might leave workers and the economy of Country X in worse shape than before. However, this is likely not the case. While an individual engineer, especially one not in a management position, has very limited power, Joe should be aware that his company is in a morally unjustified position.

Most real-world cases are not paradigmatic cases of exploitation, because they do not satisfy all of the criteria for exploitation. In particular, a firm may not exercise discretionary control over resources, because raising prices to fund higher wages, for example, might make the firm noncompetitive in the marketplace. Whether a given level of compensation is "adequate" may also raise difficult conceptual, application, and factual issues. Wages might be low by U.S. standards and yet adequate to provide a minimum standard of living by the standards of the host country. These are issues that no code or general statement can resolve, but the fundamental issue of exploitation is one that individual engineers must often face and that may deserve attention in an international engineering code.

8.7 PAYING FOR SPECIAL TREATMENT: THE PROBLEM OF BRIBERY

Bribery is one of the most common issues faced by U.S. engineers when they practice in host countries. In response to the problem of bribery, the U.S. Congress passed the FCPA in 1977. The act is limited in its scope. It only prohibits bribery of government officials and it allows some extortion payments to protect in-place property. Nevertheless, it was a landmark piece of legislation and has prompted similar legislation in other countries.

In engineering work, a bribe is typically made to a government official in exchange for violating some official duty or responsibility. The payment might result, for example, in an official's making a decision to buy a product because of a bribe, rather than because of its merits. The following is a typical or paradigmatic case of bribery. An executive of Company A hopes to sell 25 airplanes to the national airline of Country X. The deal requires the approval of the head of the ministry of transportation in Country X. The executive knows that the official, who has a reputation for honesty, can make a better deal elsewhere, but the official is also experiencing personal financial difficulties. So the executive offers the official $300,000 to authorize the purchase of the planes from Company A. The official accepts the bribe and orders the planes to be purchased.[17]

On the basis of this paradigm case of bribery, we can give the following definition of a bribe: "A bribe is a payment of money (or something of value) to another person in exchange for his giving special consideration that is incompatible with the duties of his office, position, or role."[18]

A bribe also induces one person (the person given the bribe) to give to another person (the person giving the bribe) something that he does not deserve. Keep in mind that bribes presuppose an agreement that the bribe must be in exchange for a certain kind of conduct. If this agreement is not present, then it is difficult to distinguish bribes from gifts or rewards.

Both giving and receiving bribes are forbidden by professional engineering codes, including the WFEO cited earlier in the text. There are several good reasons for this. First, if an engineer takes a bribe, she is creating a situation that will most likely corrupt her professional judgment and tarnish the reputation of the engineering profession. Second, if she offers a bribe, she engages in activity that will also tarnish the reputation of her profession if discovered, and probably violate her obligation to promote the well-being of the public. The person who takes the bribe, such as a government official, will also be guilty of wrongdoing by violating the obligation to act in the best interests of the citizens or clients. Third, bribery can undermine the efficiency of the market by inducing someone to buy products that are not the best for the price. Fourth, bribery can give someone an unfair advantage over his or her competitors, thus violating the standards of justice and fair play.

John T. Noonan, jurist and authority on the history of morality, argues that the opposition to bribery is becoming stronger throughout the world.[19] There is massive popular discontent with bribery in Japan, Italy, and other countries. The antibribery ethic is increasingly embodied in law. Even campaign contributions, which have many similarities with bribery, are becoming increasingly suspect. Although there are many points of dissimilarity between bribery and slavery, there is some basis for saying that just as slavery was once accepted and is now universally condemned, so too bribery is increasingly held to be morally unacceptable, even if still often practiced. Bribery, then, is something that should be avoided. In most cases, at least, no creative middle way is acceptable.

8.8 PAYING FOR DESERVED SERVICES: THE PROBLEM OF EXTORTION AND GREASE PAYMENTS

Extortion

Many actions that might appear to be bribery are actually cases of extortion. Consider a variation on the case of the executive of Company A described previously. Suppose he knows he is offering the best deal on airplanes to the official of Country X who has the authority to authorize purchases for his national airlines. The executive knows, however, that his bid will not even be considered unless he offers the official a large cash payment. The payment will not guarantee that Company A will get the contract, only that his bid will at least be considered. If the executive makes the cash payment, he will be paying extortion, not a bribe.

It is more difficult to construct a definition of extortion than bribery. Here is a proposed, but inadequate, definition: "Extortion is the act of threatening someone with harm (that the extorter is not entitled to inflict) to obtain benefits to which the extorter has no prior right."[20] This definition is inadequate because some actions not covered by the definition are still extortion. For example, it would be extortion if one threatened to expose the official misconduct of a government official unless he pays a large sum of money—even though exposing the official would be both morally and legally permissible. We find it impossible, however, to give a completely adequate definition of extortion. All we can say is that the definition offered previously gives a sufficient, although not a necessary, condition of extortion.

Sometimes it is difficult to know whether one is paying bribery or extortion. A customs inspector who demands a payoff from a businessperson to authorize a shipment of a product into his or her country may claim that the product does not meet the country's standards. Because the law is so complex, it may be difficult to know whether the customs official is lying and too expensive to find out. In this case, if the businessperson decides to make the payoff, she may not know whether she is paying a bribe or extortion. Of course, it may be irresponsible for the company to make no effort to find the truth.[21]

Many of the most famous cases of corruption seem to lie on the border between bribery and extortion. Between 1966 and 1970, for example, the Gulf Oil Corporation paid $4 million to the ruling Democratic Republican Party of South Korea. Gulf was led to believe that its continued flourishing in South Korea depended on these payments. If the payments gave Gulf special advantages over its competitors, the payments were bribes. If they would have been required of any competitor as a condition of operating without undeserved reprisals or restrictions, the payments were extortion.[22]

The moral status of paying extortion is different from the moral status of paying and accepting bribes for the following reasons. First, paying extortion will not usually corrupt professional judgment, while bribery often does. Second, although paying extortion can tarnish one's professional reputation, it will probably not do so as much as paying a bribe. The professional can argue that he had to pay the extortion to stay in business—that he was a victim rather than a criminal. Third, paying extortion will not cause one to act contrary to the best interests of one's employer or client by, for example, selecting an inferior product. It may, however, involve the use of a client's or employer's money in a way that is not the most desirable or productive. Fourth, paying extortion does not undermine the efficiency of the market by promoting the selection of inferior or more expensive products, although it does divert funds from their most productive use. Fifth, paying extortion does not give one an unfair advantage over others, except insofar as others do not or cannot pay the extortion. Paying extortion is sometimes a condition of doing business in a country. Assuming the business activity is good for the home and host countries and there are no serious violations of other moral standards, it may be justifiable in some cases.

Grease Payments

Grease payments are typically offered to facilitate routine bureaucratic decisions, such as hastening the passage of goods through customs or getting faster processing of permits. Grease payments usually involve relatively small amounts of money compared to many bribery and extortion payments. If a grease payment is required to get legitimate goods through customs or to prevent excessive or virtually permanent delays in the processing of a permit, they are forms of petty extortion. If they are payments to allow the passage of illegal goods or to enable one to get "to the head of the line" in a way that treats others unfairly, they are small bribes. Grease payments are sometimes tacitly condoned by governments. For example, in many countries government officials are poorly paid and the government may assume that officials will receive grease payments to supplement their salary, just as employers assume that waiters will supplement their salary with tips.

A moral rigorist might hold that making grease payments is impermissible, and it would surely be better if they were eliminated and replaced by more adequate salaries. Payment of salaries would be open and public rather than clandestine, as most grease payments are. Furthermore, as we have seen, grease payments are sometimes more like bribes because they enable the payer to get special considerations that he or she does not deserve. Still, if one is not a moral rigorist, he or she may sometimes find that, if other moral tests are not seriously violated, making grease payments is sometimes acceptable.

8.9 THE EXTENDED FAMILY UNIT: THE PROBLEM OF NEPOTISM

In many areas of the world, the primary unit of society is not the individual, as it is in the modern West, but some larger group. The larger group may be an extended family, which includes brothers and sisters and their families, aunts, uncles, cousins, and so forth. The group might even be a larger unit, such as a tribe. The relationship of the members of the group is one of mutual support. If a member of the group has fallen on bad times, the other members have an obligation to care for him or her. Similarly, if a member of the group has the good fortune to get a well-paying job, he or she has an obligation to find jobs for his or her relatives—perhaps a brother or sister, or their spouses or children. This custom, however, may produce problems for firms. Consider the following example, which is modeled on a real case.[23] You work for a steel company in India, which has the policy of partially compensating its employees with a promise to hire one of the employee's children. This policy is extremely popular with employees in a country where there is a tradition of providing jobs for one's children and the members of one's extended family. But to you, the policy is nepotism and in conflict with the more desirable policy of hiring the most qualified applicant. What should you do?

If one is not a moral rigorist, he or she may hold that this is an acceptable creative-middle-way solution in the context of Indian culture. The policy of hiring the most qualified applicant in every case is surely the most desirable approach. Hiring many members of an employee's family, regardless of qualifications, would be unacceptable, because it would seriously harm economic efficiency. Such a policy would also be too severe a violation of the virtue of justice and the rights of other applicants to nondiscrimination. The policy of hiring one, but only one, family member, by contrast, seems like an acceptable creative-middle-way solution. It makes a concession to the deeply held convictions of many people in a tradition-oriented culture and it promotes harmony in the workplace (and perhaps economic efficiency in this way). This solution again shows the need to take a middle way between moral rigorism and laxism.

8.10 BUSINESS AND FRIENDSHIP: THE PROBLEM OF EXCESSIVE GIFTS

For people in many cultures, business relationships are built on personal relationships. Two people first become friends and then they do business together. The rule "Don't mix business with pleasure," often accepted in the West, seems cold and inhuman. Furthermore, friendships are often cemented with gifts: the way to show affection and trust is to give a gift.

For many in the West, large personal gifts look too much like bribes. Is there a creative-middle-way solution to this problem? Jeffrey Fadiman has suggested an answer: Give the gifts to the community, not to individuals. In one of his examples, a firm planted a large number of trees in a barren area as a gift to a community. In another example, a firm gave vehicles and spare parts to a country that was having trouble enforcing its laws against killing animals in national parks. These gifts created good will, without being bribes to individuals. To some, of course, these gifts still have too much in common with bribes, even though they are certainly not paradigmatic bribes. If we perform a line-drawing analysis, we would have to show that gifts have some features in common with bribes. For example, gifts, like bribes, can buy influence by bestowing favors. Unlike bribes, however, they are public rather than secret and they are not given to individuals. Unless one is a moral rigorist who says anything that looks like a bribe in any sense is wrong, such solutions may be minimally acceptable in some circumstances. They are creative middle ways between the moral requirement to avoid bribery and the desirable goal of doing business in the host country. Since the option has some features in common with bribery, however, we would not consider it a completely satisfactory solution.

In contrast to the earlier discussed situations, sometimes gifts are given to individuals that are of substantial size, at least by U.S. standards. A "normal" gift in a host country might be "excessive" by U.S. standards. Suppose affluent members of Country X routinely give gifts of substantial size to one another as tokens of friendship and esteem. Because the gifts are routinely given and received by everyone, they do not command any special favors. Is this practice acceptable for an engineer doing business in Country X?

The following considerations are relevant. First, we must examine the gift-giving practices in the host country and determine whether the gift would be "excessive" by host-country standards. If a gift is routine by host-country standards, it would probably not command any special favors. Second, we must keep in mind the intent of the prohibition against excessive gifts: to prevent buying special favor and thus create unfairness in business competition. If this intent is not violated, this is an important consideration.

Texas Instruments (TI) has set a policy on gift-giving in non-U.S. countries that seem to embody these two considerations:

> TI generally follows conservative rules governing the giving and receiving of gifts. However, what we consider to be an excessive gift in the United States may differ from what local customs dictate in other parts of the world. We used to define gift limits in terms of U.S. dollars, but this is impractical when dealing internationally. Instead, we emphasize following the directive that gift-giving should not be used in a way that exerts undue pressure to win business or implies a quid pro quo.[24]

We consider this policy to be morally acceptable. It is a creative middle way between on the one hand merely rejecting the practices of the host country and perhaps not being able to do business there and on the other hand engaging in clear cases of bribery.

8.11 THE ABSENCE OF TECHNICAL-SCIENTIFIC SOPHISTICATION: THE PROBLEM OF PATERNALISM

Because of lower educational levels and the general absence of exposure to technology in their daily lives, citizens in less-industrialized countries can easily misunderstand many issues related to technology, especially those having to do with risk, health, safety, and the environment. This situation can give rise to either exploitation or paternalism. Exploitation occurs when individuals (including engineers), governments, or corporations take advantage of this ignorance to advance their own self-interest. For example, they can adopt policies that expose workers to unnecessary health and safety issues when the workers are not aware of the dangers.

Paternalism occurs when individuals (including engineers), governments, or corporations override the ability of others to decide what they should (or should not) do in the interests of those others. Because overriding the decisions of others is for their own good, this is paternalism, not exploitation. Paternalistic action has a very different motivation from exploitation: concern for the other rather than self-interest. Nevertheless, paternalistic action can give rise to serious moral concerns, because it requires overriding the decisions—or at least the ability to make decisions—of others.

Let us call the one who decides for another the *paternalist* and the person who is the object of paternalistic action the *recipient*. Here is an example of paternalism: Robin's firm operates a large pineapple plantation in Country X. The firm has been

BOX 8.7 Two Types of Paternalism

- **Weak paternalism**. The paternalist overrides the decision-making powers of the recipient when there is reason to believe the recipient is not able to exercise her moral agency effectively.
- **Strong paternalism**. The paternalist overrides the decision-making powers of the recipient, even when there is no reason to believe the recipient is not exercising his or her moral agency effectively.

having excessive problems with maintaining the health of its workers. Robin has determined that a major reason for the health problems of its workers is the unsanitary conditions of the traditional villages in which they live. To remedy this problem, Robin has required the workers to leave their traditional villages and live in small, uniform houses on uniformly laid-out streets. He believes that the workers can be "educated" to understand the relationship of their unsanitary traditional villages to the high incidence of disease and thus to appreciate the advantages of the new living conditions. The workers, however, are strongly objecting, because the new living conditions are boring and have destroyed much of their traditional way of life.

To discuss the moral status of Robin's action, we must distinguish between weak and strong paternalism, as shown in Box 8.7.

In weak paternalism, the paternalist believes the recipient is making "bad" decisions, because the recipient is not effectively functioning as a moral agent. In strong paternalism, the paternalist believes the recipient is making "bad" decisions, even though the recipient is effectively functioning as a moral agent.

From both utilitarian and respect for persons perspectives, weak paternalism can sometimes be justified. From the respect for persons perspective, weak paternalistic action safeguards the moral agency of the recipient. In exercising paternalistic control over the recipient, the paternalist is really protecting the moral agency of the recipient, not destroying it. From the utilitarian perspective, paternalistic action can better produce well-being for the recipient and perhaps others as well, since the recipient would otherwise act irrationally.

If any one of the following conditions within Box 8.8 is present, a person may not be able to exercise his or her moral agency effectively, so any one of them is sufficient to justify weak paternalism:

BOX 8.8 Conditions Justifying Weak Paternalism

- A person may be under undue emotional pressure, so he or she is unable to make a rational decision.
- A person may be ignorant of the consequences of his or her action, so he or she is unable to make a genuinely informed decision.
- A person may be too young to comprehend the factors relevant to his or her decision, so he or she is unable to make a rational and informed decision.
- Time may be necessary for the paternalist to determine whether the recipient is making a free and informed decision, so the paternalist may be justified in intervening to keep the recipient from making any decision until it is clear that the recipient is making a decision that is truly free and informed.

In strong paternalism, we assume that the recipient is making a free and informed decision, but the presumption is that the recipient is not making the "right" decision, from the standpoint of the paternalist. Strong paternalism probably cannot be justified from the respect for persons perspective, but it can sometimes be justified from a utilitarian standpoint. The argument is that the recipient is not making a decision that will maximize his or her own good, even though he or she may think that he or she is making the correct decision.

Now we can return to the example. From the short description given, it is not clear whether Robin is exercising weak or strong paternalism. If the workers do not fully understand the health risks associated with their traditional village life, Robin is exercising weak paternalism in forcing them to move into the more sanitary villages. If the workers do understand the consequences but still prefer more disease and perhaps even less health care to preserve their traditional way of life, Robin is exercising strong paternalism. Since strong paternalism is more difficult to justify than weak paternalism from the moral standpoint (because it overrides the decision-making powers of moral agents), the burden of proof to show Robin's action was justified is much greater.

Citizens of less-industrialized countries are particularly likely to experience the conditions that might justify weak paternalism, or even strong paternalism in some cases. A lower level of education and technological sophistication can render citizens in less-industrialized countries less able to make responsible decisions about their own well-being. In such cases, a rational person might consent to being treated paternalistically and in a few cases the overall good of recipients or even of many others might justify strong paternalistic action.

Here is an example in which weak paternalism is probably justified. John is employed by a large firm that sells infant formula in Country X. The firm is the only one that markets infant formula in Country X. Many mothers mix the formula with contaminated water because they do not understand the health dangers to their infants. In order to save money, they dilute the formula too much, unaware that this leads to malnutrition in their babies. John recommends that his firm stop selling the product in Country X. Management agrees and stops the sale of the product in Country X.[25]

In this case, at least one of the conditions sufficient to justify weak paternalism (ignorance of the consequences of action) is satisfied, so terminating the sales of the infant formula, thereby depriving the mothers in Country X of the option of using infant formula, is justified. Sufficient evidence existed that the mothers were not able to exercise their moral agency in a free and informed way.

8.12 DIFFERING BUSINESS PRACTICES: THE PROBLEM OF NEGOTIATING TAXES

Sometimes the business practices in host countries cause dilemmas for U.S. engineers and perhaps for engineers in the host countries as well. Consider the following case that illustrates the practices in a number of countries. James works for a U.S. firm in Country X, where it is customary for the government to assess taxes at an exorbitant rate because it expects firms to report only half their actual earnings. If a firm reported its actual earnings, the taxes would force it out of business. James' firm is considering whether it should adopt the local practice of dishonestly reporting its profits to Country X, even though it would be illegal to do this in the United States. Whatever its decision, it will continue to report its profits honestly to the U.S. government.

The practice in Country X is probably not the best way to collect taxes. It opens the way to bribery in the negotiating process and unfairness in the assessment of taxes since some firms may negotiate lower taxes (especially if they bribe the officials) than others. Nevertheless, it would probably be morally permissible for James' firm to report only half of its profits to the government of Country X, as long as the practice does not violate internal policies of the firm and the firm does not report its profit inaccurately to the U.S. government.[26] The practice does not appear to violate the Golden Rule since the firm would be willing for other firms to do the same thing. The practice does not seriously violate the rights of anyone and it may produce more overall good than any alternative, assuming the firm's work in Country X benefits its employees and the citizens of Country X. Furthermore, although this way of collecting taxes may not be the most desirable, it finances the legitimate activities of the government of Country X. Finally, the practice is not secret since it is generally known that every firm that survives in Country X follows the same practice.

8.13 CHAPTER SUMMARY

In its move toward globalization, the engineering profession is attempting to establish international standards for technical education. The Washington Accord, established in 1989, is an attempt to establish "substantial agreement" among the signatories in the requirements for engineering education. A much older organization, the FEANI, has established common standards in Europe for licensing individual engineers.

While many statements from engineering societies, especially in Asia, call engineers professionals, evidence as to whether engineers think of themselves as professionals or should be called professionals is less clear. Interpreting the evidence depends partly on what account of professionalism is used.

The problems faced by engineers when they cross cultural borders can be called *boundary-crossing problems*. They are not readily solved by simply importing one's own values into another culture or by accepting the standards of the other culture without evaluation. The ethical resources developed in Chapter 2, however, can be useful in resolving boundary-crossing problems, especially if they are adapted to the culture in a careful manner. Creative middle ways are especially useful in resolving boundary-crossing problems, but appeal to the Golden Rule, virtue ethics, universal human rights, conditions necessary for human well-being, and engineering codes can also be useful.

Among the problems faced by engineers in the international environment is exploitation of vulnerable people. Bribery is perhaps the most widespread problem. Paying extortion, which is giving money for something that one deserves anyhow, is perhaps less morally serious than bribery. Grease payments, which are smaller exchanges of money or something of value, may be either bribery or extortion, depending on the circumstances.

Practices and traditions in many countries require that family members secure jobs for other family members, even when the family members may not be the most qualified. Such problems of nepotism can sometimes be addressed with creative middle-way solutions. The practice of giving large gifts, common in many cultures, may not necessarily involve bribery or extortion. Adapting to this practice may require giving larger gifts than would be acceptable in the United States, but the gifts must not be used as bribes. The absence of technical-scientific sophistication can lead to paternalistic behavior that is often problematic. Generally, weak paternalism is easier to justify than strong paternalism. Finally, the practice of negotiating taxes can lead to bribery and other abuses, but the practice need not be rejected altogether.

NOTES

1. See various documents on the Internet, including "Embraer to pay $205 milliion to settle corruption probes." at https://www.bloomberg.com.
2. http://www.washingtonaccord.org.
3. http://www.feani.org/scte.
4. http://www.feiap.org. Emphasis added.
5. See http://www.jspe.org and related sites.
6. http://cec.ice.org.uk/
7. Google World Federation of Engineering Organizations.
8. Tetsuji Iseda, "How Should We Foster the Professional Integrity of Engineers in Japan? A Pride-Based Approach," *Science and Engineering Ethics*, 14, 2008, pp. 165–176.
9. C. A. O. Nanyan, S. U. Jonbin, and H. U. Mingyan, "Ethical Awareness in Chinese Professional Engineering Societies: Textual Research on Constitutions of Chinese Engineering Organizations," in Diane P. Michelfelder, Natasha McCarthy, and David. E. Goldberg, eds., *Philosophy and Engineering: Reflections on Practice, Principles and Process* (Dordrecht, Netherlands: Springer, 2013), p. 208.
10. Published online on 23 November, 2016, in *Science and Engineering Ethics.*
11. James F. Childress and John Macquarrie, eds., *The Westminster Dictionary of the Christian Church* (Philadelphia: Westminster Press, 1986), p. 499.
12. Ibid., p. 633.
13. *The International Bill of Human Rights*, with forward by Jimmy Carter (Glen Ellen, CA: Entwhistle Books, 1981). No author.
14. James W. Nickel, *Making Sense of Human Rights: Philosophical Reflections on the Universal Declaration of Human Rights* (Berkeley: University of California Press, 1987), pp. 108–109.
15. Martha Nussbaum and Jonathan Glover, eds., *Women, Culture, and Development* (Oxford: Clarendon Press, 1995), pp. 83–85.
16. Robert E. Goodin, *Protecting the Vulnerable: A Reanalysis of Our Social Responsibilities* (Chicago: University of Chicago Press, 1985), pp. 195–196.
17. This scenario is a modification of one presented by Michael Philips titled "Bribery" in Patricia Werhane and Kendall D'Andrate, eds., *Profit and Responsibility* (New York: Edwin Mellon Press, 1985), pp. 197–220.
18. Thomas L. Carson, "Bribery, Extortion, and the 'Foreign Corrupt Practices Act'," *Philosophy and Public Affairs*, 14, no. 1, 1985, pp. 55–90.
19. John T. Noonan, *Bribery* (New York: Macmillan, 1984).
20. Carson, "Bribery, Extortion, and the 'Foreign Corrupt Practices Act'" p. 73.
21. Ibid., p. 79.
22. Ibid., p. 75.
23. For this case and related discussion, see Thomas Donaldson and Thomas W. Dunfee, "Toward a Unified Conception of Business Ethics: Integrated Social Contract Theory," *Academy of Management Review*, 19, no. 2, 1994, pp. 152–284.
24. http://actrav-english/telearn/global/ilo/texas.html
25. J. Krasny, "Every Parent Should Know the Scandalous History of Infant Formula," *Business Insider*. June 25, 2012. Retrieved April 4, 2017, from http://www.businessinsider.com /nestles-infant-formula-scandal-2012-6?op=1
26. For a similar case with a similar conclusion, see Thomas Donaldson and Thomas W. Dunfee, *Ties That Bind: A Social Contracts Approach to Business Ethics* (Boston: Harvard Business School Press, 1999), pp. 198–207.

CHAPTER NINE

New Horizons in Engineering

Main Ideas in This Chapter

- **Technology is evolving rapidly and new technology presents many new technological and ethical challenges as well as new tools for engineers of the future.**
- **A few of these challenges are highlighted to stimulate the reader's thinking about the future of engineering.**

IN 1962, EMINENT ENGINEERING EDUCATOR Gordon S. Brown[1] pointed out a need for change in the education of engineers stemming from the increasing tempo of technological change and scientific understanding. He observed that "during the decade or so preceding World War II…engineering education was…based on the assumption that what students learned in college would serve them through most of their technological lives." He described that period as a time when engineering advances—application—often came in advance of scientific explanation—the theory behind those advances. But since that time he observed an increase in the tempo of development of new scientific theories that he believed would lead to numerous engineering advances yet to come. He predicted that this would place very different demands on the engineer of the future, who would be called on to design and implement engineered systems very different from what his engineering teachers and mentors had designed. Brown called for changes in engineering education, to include more emphasis on the engineering sciences and increased focus on engineering analysis and synthesis. He believed it would be essential for future engineers to be able to model and accurately predict the performance of new engineering systems without the benefit of data about past performance of such systems. He also recognized the growing importance of life-long learning for engineers of the future. Since that time, engineering education has indeed moved in the direction Brown encouraged, with a much greater emphasis on the importance of modeling as a tool for the designer which allows today's engineering graduates to model, design, and build new engineered systems based on new scientific principles.

9.1 INTRODUCTION

Today, as the tempo of technological change continues to accelerate, we observe another trend of change in engineering education—an increase in the focus on engineering ethics as an integral part of undergraduate engineering education. This trend is driven by our recognition of the way implementation of new technology into engineering systems introduces new ethical issues along with new technological issues and society's increasing expectations of the engineering profession. Just as Brown believed the way to give engineering students the ability to deal with technological problems unknown to their instructors was to increase their exposure to the sciences—the engineering sciences, and most importantly to methods for modeling engineering systems based on first principles, we believe the way to help future engineers cope with new ethical challenges is to increase their exposure to ethical theory as well as application.

Solutions to coming problems, such as the 14 "grand challenges" named by the National Academy of Engineering in 2008, will in almost every case raise ethical issues, sometimes new ethical issues. Envisioned solutions to these challenges will include resolution of conflicting obligations of protecting the public health, safety, or welfare, responsibilities to employer, sustainable development, protection of privacy, and social justice. Additional examples of the NAE's Grand Challenges for Engineering are found in Box 9.1.

BOX 9.1 NAE's Grand Challenges for Engineering

- Advance personalized learning
- Make solar energy economical
- Enhance virtual reality
- Reverse engineer the brain
- Engineer better medicines
- Advance health informatics
- Restore and improve urban infrastructure
- Secure cyberspace
- Provide access to clean water
- Provide energy from fusion
- Prevent nuclear terror
- Manage the nitrogen cycle
- Develop carbon sequestration methods
- Engineer the tools of scientific discovery NAE's Grand Challenges for Engineering

9.2 ENVIRONMENTAL RESPONSIBILITY AND SUSTAINABLE DEVELOPMENT

Both the profession and the public it serves increasingly believe that engineers have some special responsibility for the natural environment as well as the constructed environment. Every engineered system or product, from military systems to civilian transportation systems to infrastructure to consumer products, has some impact on the natural environment, and the designer can almost always reduce negative environmental impacts. The engineer's first responsibility a century ago was to his or her client or employer, but the profession has changed and now engineering codes of ethics state or imply that the engineer's paramount responsibility is to protect the public health, safety, and welfare. Perhaps, because of the increasing recognition of the importance of the environment on the public health and welfare, the engineering profession and the public increasingly believe engineers have a more direct responsibility to protect the environment than before. But, today there is not sufficient guidance to the engineer about the extent of the engineer's responsibility and how to balance the benefits of environmental protection with the associated costs. Does the engineer's responsibility go beyond laws and regulations designed to define some minimum level of responsibility for environmental protection, or are those laws and regulations sufficient as well as necessary design constraints? The profession, through evolving professional society codes of ethics, is trying to more fully define the engineer's responsibility for protection of the environment, most commonly in terms of engineering responsibilities for "sustainable development," linking the development of the constructed environment with the natural environment and formalizing the engineer's responsibility to future generations. Public policy regarding global warming will evolve in the next few decades; engineering input to this public policy will be critical. Engineers of the future should be encouraged to help frame the debate over this evolving public policy.

The NAE recognizes the importance of environmental issues with the challenges to "provide access to clean water," "manage the nitrogen cycle," and "develop carbon sequestration methods" along with the closely related challenges to "provide affordable energy," "make solar energy affordable," and "provide energy from fusion." The importance of the constructed environment is recognized in the challenge to "restore and improve urban infrastructure."

Surface transportation systems are a major component in the constructed environment. Today's highways and freeways represent huge investments in infrastructure that require continual maintenance and upgrading to meet the needs of a growing population, particularly in urban environments where the cost of adding lanes to streets and highways to increase capacity is magnified by higher real-estate prices, which sometimes make costly elevated and subsurface solutions competitive. Increasingly, transportation engineers are searching for ways to increase capacity without adding lanes, and "intelligent vehicle highway systems" (IVHS) featuring autonomous vehicles appear to be the coming solution. But IVHS and autonomous automobiles raise new and significant technical, legal, and societal questions.

9.3 AUTONOMOUS VEHICLE DEVELOPMENT

Even conditional-autonomous systems, such as the "autopilot" on the Tesla Model S raise ethical questions.[2] The Tesla owner and operator is repeatedly cautioned that the Tesla Autopilot system requires continuous hands-on, alert monitoring of the system by the driver, who must be always ready to take control back from the system. Yet, the NHTSB describes it as "foreseeable" that drivers will sometimes not do this. When a risk is "foreseeable," it is usually expected that it will be addressed by the engineer. Because of the human factors associated with designs that depend on a human driver to diligently monitor an automated system that may function without intervention for the large majority of the time, Ford has recently announced that it does not intend to develop vehicles designed to Society of Automotive Engineers' Level 3 criteria, and instead will focus on Levels 4 and 5 autonomous vehicles that will not rely on human monitoring and intervention. See Box 9.2 for different levels of taxonomy.

Fully autonomous vehicles, by definition[3] (SAE Levels 4 and 5), will not require driver monitoring or intervention. In principle, vehicles operating according to Level 5 standards might not even have controls that could be operated by a human driver. Such newly evolving engineering systems raise new ethical questions. When discussing the question of whether an autonomous vehicle should be programmed to cross a double line to avoid a maintenance crew or obey the law, engineering researcher Chris Gerdes explains, "We need to take a step back and say, 'Wait a minute, is that what we should be programming the car to think about? Is that even the

BOX 9.2 SAE Autonomous Vehicles Taxonomy

Level 0—No automated control (human driver)
Level 1—Driver assistance (i.e., adaptive cruise control)
Level 2—Partial automation (human driver must continually monitor and be ready to take over)
Level 3—Conditional automation (human driver on call)
Level 4—High automation (full computer control in some modes under some conditions)
Level 5—Full automation (no human input needed; full control by computer at all times)

right question to ask?' We need to think about traffic codes reflecting actual behavior to avoid putting the programmer in a situation of deciding what is safe versus what is legal."[4] Ethicist Patrick Lin[5] suggests that if ethics need be programmed into autonomous cars, might they even be programmed to be "user adjustable," so each driver can dial in his or her own personalized ethics settings? "[O]ne customer may set the car (which he paid for) to jealously value his life over all others; another user may prefer that the car value all lives the same and minimizes harm overall; yet another may want to minimize legal liability and costs for herself…" We should probably expect many more ethical questions to be raised as this new technology is developed.

9.4 INTERNET OF THINGS, BIG DATA, AND CYBER SECURITY

The increase of speeds and bandwidth possible in digital communications with the expected 2017 move to 5G will be essential for continued development of systems like autonomous vehicles, smart cities, medical technology, and other data hogs. But with the continued growth of the "Internet of Things" (IoT), in which much of our world is electronically connected, monitored, and controlled, the number of exploitable vulnerabilities is increasing significantly. While this poses a risk to individual personal privacy, it also allows those with malicious intent greater access to the cyber world. The population of potential hackers may include some who are simply intellectually curious, but also includes many interested in theft, and some interested in voyeurism, blackmail, vandalism, and waging electronic warfare. The number of doorways to the system is increasing exponentially with the IoT expected to include 50 billion connected devices by the year 2020.

The rapid development of new technology related to the IoT will certainly raise ethical issues for engineers working in this field. Loss of privacy and risk of cyberattack are both very real concerns that must be weighed against the usefulness of potential applications.

Other New Horizons for Engineering

A bit of reflection about the grand challenges identified by the NAE leads to the conclusion that there are many technological developments, perhaps unimaginable in scope and scale, in our near future that will cause concern, even for the technological optimist. Some nation states continue development of weapons of mass destruction without robust protections to prevent acquisition of the technology by terrorists. Concerns about nuclear terrorism (or terrorism with any weapon of mass destruction) will likely increase. Rapid advances in medicine and biomedical engineering will come with issues related to personal privacy, end-of-life practices, genetic selection, and so on. Expected developments in nanomaterials will cause new environmental concerns as these new materials find their way into our environment. Engineers of the future tasked with finding solutions to these problems will have their hands full.

Another fundamental area of new horizons in engineering includes continued educational and employment advocacy for women, minorities, and persons with disabilities, because it is generally believed that a larger and more diverse engineering profession is important in addressing future societal problems—larger, because more of society's problems will need engineering solutions; and more diverse, because a more diverse population of problem solvers can produce a more diverse universe of engineering solutions from which to choose. Many of the organizations historically created to encourage education and employment in these areas still exist and demonstrate that the need is still strong for diversity in engineering and other STEM (science, technology, engineering, and math) fields.

Promoting women in engineering in the United States has been traced to 1914 through the formation of local engineering chapters for women and some national outreach through universities. The strongest support for women in engineering is the Society for Women Engineers (SWE) which started in 1950. The mission of the organization is to "stimulate women to achieve full potential in careers as engineers and leaders, expand the image of the engineering profession as a positive force in improving the quality of life, and demonstrate the value of diversity."[6] The organization awards scholarships to members pursuing bachelors or graduate degrees. Numerous corporate and foundation sponsors assist in funding these scholarships.

Also advocating more careers and education for women and minorities in engineering is the National Science Foundation (NSF). *Women, Minorities, and Persons with Disabilities in Science and Engineering*[7] is a 2017 report issued by NSF to document and encourage education and employment in these groups. According to the report, women, persons with disabilities, and three racial and ethnic groups (Hispanics, blacks, and American Indians or Alaska Natives) are underrepresented in engineering and science.

The report states that women have reached equality with men in degree attainment. However, they are demonstrably smaller in percentages of employed scientists and engineers. The report indicates that although women constitute 47 percent of the U.S. work force, they represent 26 percent of those who work in the engineering and science areas.

The report also finds that Blacks, Hispanics, and American Indians or Alaska Natives have gradually increased their share of engineering and science degrees, but they remain vastly underrepresented in both employment and educational attainment in the science and engineering fields. The National Society of Black Engineers (NSBE) has a 10-year plan to increase the African-American engineering graduates to 10,000 by 2025; up from 3,501 graduates in 2014 (see http://www.nsbe.org/home.aspx).

The Society for Hispanic Professional Engineers was founded in 1974 and continues its main organizational goal today. Networking, mentoring, and creating role models for the Hispanic community are all central to their goals and mission.[8] "SHPE changes lives by empowering the Hispanic community to realize its fullest potential and to impact the world through STEM awareness, access, support, and development."[9]

These organizations have extensive presence on the web and also frequently publish reports on the status of constituency. SWE recently published the results of a study in which they examined gender and racial bias called *Climate Control: Gender and Racial Bias in Engineering*. The study involved 3,000 participants with two or more years of experience in the field. The results of the study demonstrated that large gender gaps were reported for several patterns of bias including: "Prove-It-Again Bias," "Tightrope Bias," and "Maternal Wall Bias."[10]

With "Prove-It-Again Bias," 61 percent of women reported that they have to prove themselves repeatedly to get the same levels of respect and recognition as their colleagues, compared with 35 percent of white men. Concerning "Tightrope Bias," women reported a narrower range of acceptable behavior than white men. Women tend to walk a tightrope, trying to find the balance between appearing "too masculine" or "too feminine." With "Maternal Wall Bias," almost 80 percent of men reported that having children did not affect how their colleagues viewed them, compared with 55 percent of women. Although these findings illustrate that problems still exist in these areas, it is encouraging that there are serious efforts being made to combat them.[11]

The engineers, men and women, who will work together to provide the needs and wants of a future society, including solving the challenges identified by the NAE, will be faced with new ethical challenges as unintended consequences of future technological development unfold. Just as engineering education has recognized the need to educate today's engineers to handle tomorrow's technological problems, we must equip today's engineers with the ability to recognize and resolve new, perhaps previously unrecognized, ethical issues, which will surely arise as tomorrow's technology is developed and implemented.

"The future is bright," says the technological optimist, "Or not…," says the pessimist. Either way, it will be up to the engineering community of tomorrow to continue to develop and use the materials and forces of nature for the needs and wants of mankind, in an ethical, economical, and sustainable way.

NOTES

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CASES

THE CASES LISTED HERE are presented for use in conjunction with materials in the book. They vary in length, complexity, and purpose. Some present factual events and circumstances. Others are fictional but realistic. Some present ethical problems for individual engineers. Others focus primarily on the corporate or institutional settings within which engineers work. Some, such as Case 28, "Where Are the Women?" focus on general problems within engineering as a profession. Others focus on large-scale issues such as global warming and the challenges and opportunities these issues pose for engineers, both individually and collectively. Some cases focus on wrongdoing and irresponsibility. Others illustrate exemplary engineering practice. A topical taxonomy of our cases appears next.

We have added several new cases, particularly discussing situations that have recently been newsworthy. Even though in some cases, such as the "Volkswagen Emissions Scandal," the full details have not yet been revealed in the court system, we believe a discussion of the developing case is important. Several cases presented in previous editions of our book are not included here. However, most of them, and many others, are readily available on the Internet. Both the Online Ethics Center (www.onlineethics.org) and Texas A&M's Engineering Ethics website (www.ethics.tamu.edu) include Michael S. Pritchard, ed., *Engineering Ethics: A Case Study Approach*, a product of a National Science Foundation (NSF)-sponsored project. More than 30 cases and commentaries are presented. The Texas A&M website presents these cases in their original form, along with a taxonomy of the cases in accordance with their leading topical focus (e.g., safety and health, conflicts of interest, and honesty). (The cases are accessed under "1992 NSF Sponsored Engineering Ethics Cases.") Also included is an introductory essay by Pritchard. The Online Ethics Center presents the same cases with different individual titles, along with brief statements about each listed case. Cases and essays from two NSF-supported projects directed by Charles E. Harris and Michael J. Rabins are available at the Texas A&M website. These are also accessible at the Online Ethics Center (*Numerical and Design Problems* and *Engineering Ethics Cases from Texas A&M*). These appear under the heading "Professional Practice" and the subheading "Cases." The Online Ethics Center contains a wealth of other cases and essays that can be used in conjunction with our book. Of special interest is *Professional Ethics in Engineering Practice: Discussion Cases Based on NSPE BER Cases*, which provides access to cases and commentaries prepared by the National Society for Professional Engineer's board of ethical review. These appear under the heading "Professional Practice" and the subheading "Cases" (*Discussion Cases from NSPE*).

LIST OF CASES

TAXONOMY OF CASES

Acknowledging Limitations and Mistakes

Careers

Communications in Engineering

Computer Programming, Computer Control, and Information Technology

Confidentiality

Conflicts of Interest

Dissent and Whistleblowing

Environmental Concerns

Ethics in Design

Exemplary Practice

Engineering Societies

Honesty

Loyalty

Organizational Communication

Social and Political Issues

Product Liability

Public Service

Safety and Health

CASES

CASE 1

Aberdeen Three

The Aberdeen Proving Ground is a U.S. Army facility where, among other things, chemical weapons are developed. The U.S. Army has used the facility to develop, test, store, and dispose of chemical weapons since World War II. Periodic inspections between 1983 and 1986 revealed serious problems with a part of the facility known as the Pilot Plant, including the following:

- Flammable and cancer-causing substances were left in the open.
- Chemicals that would become lethal if mixed were kept in the same room.
- Drums of toxic substances were leaking.

There were chemicals everywhere—misplaced, unlabeled, or poorly contained. When part of the roof collapsed, smashing several chemical drums stored below, no one cleaned up or moved the spilled substance and broken containers for weeks.[1] When an external sulfuric acid tank leaked 200 gallons of acid into a nearby river, state and federal investigators were summoned to investigate. They discovered that the chemical retaining dikes were in a state of disrepair and that the system designed to contain and treat hazardous chemicals was corroded, resulting in chemicals leaking into the ground.[2]

On June 28, 1988, after two years of investigation, three chemical engineers—Carl Gepp, William Dee, and Robert Lentz, now known as the "Aberdeen Three"—were criminally indicted for illegally handling, sorting, and disposing of hazardous wastes in violation of the Resource Conservation and Recovery Act (RCRA). Although the three engineers did not actually handle the chemicals, they were the managers with ultimate responsibility for the violations. Investigators for the Department of Justice concluded that no one above them was sufficiently aware of the problems at the Pilot Plant to be assigned responsibility for the violations. The three engineers were competent professionals who played important roles in the development of chemical weapons for the United States. William Dee, the developer of the binary chemical weapon, headed the chemical weapons development team. Robert Lentz was in charge of developing the processes that would be used to manufacture the weapons. Carl Gepp, manager of the Pilot Plant, reported to Dee and Lentz.

Six months after the indictment, the Department of Justice took the three defendants to court. Each defendant was charged with four counts of illegally storing and disposing of waste. William Dee was found guilty of one count, and Lentz and Gepp were found guilty on three counts each of violating the RCRA. Although each faced up to 15 years in prison and $750,000 in fines, they received sentences of 1,000 hours of community service and 3 years' probation. The judge justified the relatively light sentences on the grounds of the high standing of the defendants in the community and the fact that they had already incurred enormous court costs. Because the three engineers were criminally indicted, the U.S. Army could not assist them in their legal defense. This was the first criminal conviction of federal employees under RCRA.

CASE 2

Big Dig Collapse[3]

On July 10, 2006, a husband and wife were traveling through a connector tunnel in the Big Dig tunnel system in Boston. This system carries Interstate 93 beneath downtown Boston and extends the Massachusetts Turnpike to Logan Airport. As the car passed through, at least 26 tons of concrete collapsed onto it when a suspended concrete ceiling panel fell from above. The wife was killed instantly and the husband sustained minor injuries. The Massachusetts attorney general's office issued subpoenas next day to those involved in the Big Dig project. Soon, a federal investigation ensued.

The National Transportation Safety Board (NTSB) released its findings a year after the incident. The focus of the report was the anchor epoxy used to fasten the concrete panels and hardware to the tunnel ceiling. This product was marketed and distributed by Powers Fasteners, Inc., a company that specializes in the manufacturing and marketing of anchoring and fastening materials for concrete, masonry, and steel.

Investigators found that Powers distributed two kinds of epoxy: Standard Set and Fast Set. The latter type of epoxy, the one used in the collapsed ceiling tile, was susceptible to "creep," a process by which the epoxy deforms, allowing support anchors to pull free. The investigators concluded that this process allowed a ceiling tile to give way on July 10, 2006.

According to the NTSB report, Powers knew that Fast Set epoxy was susceptible to creep and useful for short-term load bearing only. Powers did not make this distinction clear in its marketing materials—the same materials distributed to tunnel project managers and engineers. Powers, the report continued, "failed to provide the Central Artery/Tunnel project with sufficiently complete, accurate, and detailed information about the suitability of the company's Fast Set epoxy for sustaining long-term tensile-loads." The report also noted that Powers failed to identify anchor displacement discovered in 1999 in portions of the Big Dig system as related to creep due to the use of Fast Set epoxy.

On the basis of the NTSB report, Powers was issued an involuntary manslaughter indictment by the Massachusetts attorney general's office just days after the release of the report. The indictment charged that "Powers had the necessary knowledge and the opportunity to prevent the fatal ceiling collapse but failed to do so."

The NTSB also targeted several other sources for blame in the incident (although no additional indictments were made). It concluded that construction contractors Gannett Fleming, Inc. and Bechtel/Parsons Brinkerhoff failed to account for the possibility of creep under long-term load conditions. The report indicated that these parties should have required that load tests be performed on adhesives before allowing their use and that the Massachusetts Turnpike Authority should have regularly inspected the portal tunnels. It asserted that if the Authority had conducted such inspections, the creep may have been detected early enough to prevent catastrophe.

The report provided recommendations to parties interested in the Big Dig incident. To the American Society of Civil Engineers, it advised the following:

> Use the circumstances of the July 10, 2006, accident in Boston, Massachusetts, to emphasize to your members through your publications, website, and conferences, as appropriate, the need to assess the creep characteristics of adhesive anchors before those anchors are used in sustained tensile-load applications.

To what extent must engineers educate themselves on the various materials being used and processes being employed in a project in order to ensure safety? If lack of knowledge played a part in causing the collapse, how might such understanding specifically help engineers to prevent an event like this in the future? How else might engineers work to avoid a similar catastrophe?

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CASE 3

Bridges[4]

On August 1, 2007, the I-35W bridge over the Mississippi River in Minneapolis, Minnesota, collapsed during rush hour, resulting in 13 deaths and a multitude of injuries. The bridge was inspected annually dating from 1993 and every two years before that since its opening in 1967. The most recent inspection, conducted on May 2, 2007, cited only minor structural concerns related to welding details. At that time, the bridge received a rating of 4 on a scale from 0 to 9 (0 = shutdown, 9 = perfect). The rating of 4, although signifying a bridge with components in poor condition, meant that the state was allowed to operate the bridge without any load restrictions.

A bridge rated 4 or less is considered to be "structurally deficient." According to the U.S. Department of Transportation, this label means that "there are elements of the bridge that need to be monitored and/or repaired. The fact that a bridge is 'deficient' does not imply that it is likely to collapse or that it is unsafe. It means it must be monitored, inspected, and maintained." In some cases, load restrictions are placed on structurally deficient bridges.

The failure, which happened during a roadway rehabilitation construction project, was attributed to a design error in which main truss gusset plates were not sufficiently thick for the loads applied. The NTSB report of the failure identified several factors that resulted in insufficient gusset plate thicknesses.[5] The designer, Sverdrup & Parcel and Associates, Inc., failed to specify proper thicknesses and the design quality control procedures failed to detect this problem. The NTSB noted that the "generally accepted practice among federal and state transportation officials of giving inadequate attention to gusset plates during inspections … and of excluding gusset plates in load rating analyses."

The incident raised important questions about the state of U.S. bridges. In Minnesota, there are 1,907 bridges that are structurally deficient, which means they have also received a rating of 4 or lower on inspection. Bridges may also be considered "functionally obsolete," a label that the American Society of Civil Engineers (ASCE) Report Card for America's Infrastructure defines as a bridge that has "older design features and, while it is not unsafe for all vehicles, it cannot safely accommodate current traffic volumes, and vehicle sizes and weights." In 2003, 27.1 percent of bridges in the United States were deemed either structurally deficient or functionally obsolete.

The ASCE urges that "America must change its transportation behavior, increase transportation investment at all levels of government, and make use of the latest technology" to help alleviate the infrastructure problem involving the bridge system. In order for Americans to answer this charge, they must be aware of the problem. What role should engineers and engineering societies play in informing the public about the state of U.S. bridges? Should engineers lobby for congressional support and appropriate amounts of federal spending to be allocated to bridge repairs and reconstruction?

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CASE 4

Citicorp[6]

William LeMessurier was understandably proud of his structural design of the 1977 Citicorp building in downtown Manhattan. He had resolved a perplexing problem in a very innovative way. A church had property rights to a corner of the block on which the 59-story building was to be constructed. LeMessurier proposed constructing the building *over* the church, with four supporting columns located at the center of each side of the building rather than in the four corners. The first floor began the equivalent of nine stories above ground, thus allowing ample space for the church. LeMessurier used a diagonal bracing design that transferred weight to the columns, and he added a tuned mass damper with a 400-ton concrete block floating on oil bearings to reduce wind sway.

In June 1978, LeMessurier received a call from a student at a nearby university who said his professor claimed the Citicorp building's supporting columns should be on the corners instead of midway between them. LeMessurier replied that the professor did not understand the design problem, adding that the innovative design made it even more resistant to quartering, or diagonal, winds. However, since the New York City building codes required calculating the effects of only 90-degree winds, no one actually worked out calculations for quartering winds. Then he decided that it would be instructive for his own students to wrestle with the design problem.

This may have been prompted by not only the student's call but also a discovery LeMessurier had made just one month earlier. While consulting on a building project in Pittsburgh, he called his home office to find out what it would cost to weld the joints of diagonal girders similar to those in the Citicorp building. To his surprise, he learned that the original specification for full-penetration welds was not followed. Instead, the joints were bolted. However, since this still more than adequately satisfied the New York building code requirements, LeMessurier was not concerned.

However, as he began to work on calculations for his class, LeMessurier recalled his Pittsburgh discovery. He wondered what difference bolted joints might make to the building's ability to withstand quartering winds. To his dismay, LeMessurier determined that a 40 percent stress increase in some areas of the structure would result in a 160 percent increase in stress on some of the building's joints. This meant that the building was vulnerable to total collapse if certain areas were subjected to a "16-year storm" (i.e., the sort of storm that could strike Manhattan on average once every 16 years). Meanwhile, hurricane season was not far away.

LeMessurier realized that reporting what he had learned could place both his engineering reputation and the financial status of his firm at substantial risk. Nevertheless, he acted quickly and decisively. He drew up a plan for correcting the problem, estimated the cost and time needed for rectifying it, and immediately informed Citicorp owners of what he had learned. Citicorp's response was equally decisive. LeMessurier's proposed course of action was accepted and corrective steps were immediately undertaken, although the public was not informed of the problem. As the repairs neared completion in early September, a hurricane was reported moving up the coast in the direction of New York. Fortunately, it moved harmlessly out over the Atlantic Ocean, but not without first causing considerable anxiety among those working on the building, as well as those responsible for implementing plans to evacuate the area should matters take a turn for the worse.

Although correcting the problem cost several million dollars, all parties responded promptly and responsibly. Faced with the threat of increased liability insurance rates, LeMessurier's firm convinced its insurers that because of his responsible handling of the situation, a much more costly disaster may have been prevented. As a result, the rates were actually reduced.

Identify and discuss the ethical issues this case raises.

CASE 5

Disaster Relief[7]

Among the 24 recipients of the John D. and Catherine T. MacArthur Foundation Fellowships for 1995 was Frederick C. Cuny, a disaster relief specialist. The fellowship program is commonly referred to as a "genius program," but it is characterized by MacArthur executives as a program that rewards "hard-working experts who often push the boundaries of their fields in ways that others will follow."[8] The program, says Catherine Simpson, director of the awards program, is meant to serve as "a reminder of the importance of seeing as broadly as possible, of being willing to live outside of a comfort zone and of keeping your nerve endings open."[9]

Cuny's award was unusual in two respects. First, at the time the award was announced, his whereabouts were unknown, and it was feared that he had been executed in Chechnya. Second, he was a practicing engineer. Most MacArthur awards go to writers, artists, and university professors.

Ironically, although honored for his engineering achievements, Cuny never received a degree in engineering. Initially planning to graduate from the ROTC program at Texas A&M as a marine pilot, he had to drop out of school in his second year due to poor grades. He transferred to Texas A&I, Kingsville, to continue his ROTC coursework, but his grades suffered there as well. Although he never became a marine pilot, he worked effectively with Marine Corps officers later in Iraq and Somalia.[10]

In Kingsville, Cuny worked on several community projects after he dropped out of school. He found his niche in life working with low income residents of barrios in Kingsville and formulated some common sense guidelines that served him well throughout his career. As he moved into disaster relief work, he understood immediately that the aid had to be designed for those who were in trouble in ways that would leave them in the position of being able to help themselves. He learned to focus on the main problem in any disaster to better understand how to plan the relief aid. Thus, if the problem was shelter, the people should be shown how to rebuild their destroyed homes in a better fashion than before. Similar approaches were adopted regarding famine, drought, disease, and warfare.

The first major engineering project Cuny worked on was the Dallas–Ft. Worth airport. However, attracted to humanitarian work, he undertook disaster relief work in Biafra in 1969. Two years later, at age 27, he founded the Intertect Relief and Reconstruction Corporation in Dallas. Intertect describes itself as

> "a professional firm providing specialized services and technical assistance in all aspects of natural disaster and refugee emergency management—mitigation, preparedness, relief, recovery, reconstruction, resettlement—including program design and implementation, camp planning and administration, logistics, vulnerability analysis, training and professional development, technology transfer, assessment, evaluation, networking and information dissemination."[11]

Intertect also prides itself for its "multidisciplinary, flexible, innovative, and culturally appropriate approach to problem-solving."[12] Obviously, such an enterprise requires the expertise of engineers. But it also must draw from social services, health and medical care professionals, sociology, anthropology, and other areas.

Fred Cuny was apparently comfortable working across disciplines. As an undergraduate he also studied African history. So, it is understandable that he would take a special interest in the course of the conflict between the Nigerian and Biafran governments in the late 1960s. In 1969, he announced to the Nigerian minister of the interior, "I'm from Texas. I'm here to study the war and try to suggest what can be done to get in humanitarian aid when it's over."[13] Rebuffed by the minister, Cuny then flew to Biafra and helped organize an airlift that provided short-term assistance to the starving Biafrans.

Cuny learned two important lessons from his Biafran work. First, food distribution in disaster relief often pulls people from their homes and working areas to distribution centers in towns and airports. Cuny commented, "The first thing I recognized was that we had to turn the system around and get people back into the countryside away from the airfield." Second, Cuny realized that public health is a major problem—one that can effectively be addressed only through careful planning. This requires engineering efforts to, for example, build better drains, roads, dwellings, and so on. At the same time, Cuny realized that relatively few engineers were in relief agencies; hence, the founding of Intertect. Concerned to share his ideas with others, in 1983, Cuny published *Disasters and Development* (Oxford University Press), which provides a detailed set of guidelines for planning and providing disaster relief. A major theme of his book is that truly helpful relief requires careful study of local conditions in order to provide long-term assistance.

Despite its small size, since its founding in 1971, Intertect has been involved in relief projects in nearly 70 different countries during Cuny's career. His work came to the attention of wealthy Hungarian philanthropist George Soros, who provided him with funding to work on a number of major disaster relief projects.

An especially daring project was the restoration of water and heat to a besieged section of Sarajevo in 1993.[14] Modules for a water filtration system were specially designed to fit into a C-130 airplane that was flown from Zagreb (Croatia's capital) into Sarajevo. (Cuny commented that there were only 3 inches to spare on each side of the storage area.) In order to get the modules unnoticed through Serbian checkpoints, they had to be unloaded in less than 10 minutes.

Clearly, the preparation and delivery of the modules required careful planning and courage in execution. However, prior to that someone had to determine that such a system could be adapted to the circumstances in Sarajevo. When Cuny and his associates arrived in Sarajevo, for many the only source of water was from a polluted river. The river could be reached only by exposing oneself to sniper fire, which had already injured thousands and killed hundreds. Thus, residents risked their lives to bring back containers of water whose contaminated contents posed additional risks. Noting that Sarajevo had expanded downhill in recent years, and that the newer water system had to pump water uphill to Old Town Sarajevo, the Cuny team concluded that there must have been an earlier system for Old Town.[15] They located a network of old cisterns and channels still in good working order, thus providing them with a basis for designing and installing a new water filtration plant. This $2.5 million project was funded by the Soros Foundation, which also provided $2.7 million to restore heat for more than 20,000 citizens of Sarajevo.

Cuny told author Christopher Merrill, "We've got to say, 'If people are in harm's way, we've got to get them out of there. The first and most important thing is saving lives. Whatever it takes to save lives, you do it, and the hell with national sovereignty.'"[16] This philosophy lay behind his efforts to save 400,000 Kurds in northern Iraq after Operation Desert Storm, in addition to thousands of lives in Sarajevo; however, this may be what cost him his own life in Chechnya in 1995.

Perhaps Cuny's single most satisfying effort was in northern Iraq immediately following Operation Desert Storm. As soon as Iraq signed the peace treaty, Saddam Hussein directed his troops to attack the Shiites in the south and the Kurds in the north. The 400,000 Kurds fled into the mountains bordering Turkey, where the Turks prevented them from crossing the border. Winter was coming and food was scarce. President Bush created a no-fly zone over northern Iraq and directed the Marine Corps to rescue the Kurds in what was called Operation Provide Comfort. The marine general in charge hired

Fred Cuny as a consultant, and Cuny quickly became, in effect, second in command of the operation.

When Operation Provide Comfort was regarded as no longer necessary, the Kurds held a farewell celebration at which the full marine battalion marched before joyous crowds, with one civilian marching in the first row—Fred Cuny. Cuny had an enlargement of a photo of that moment hung over his desk in Dallas. The photo has the signature of the marine general who led the parade.

Asked about his basic approach to disaster relief, Cuny commented: "In any large-scale disaster, if you can isolate a part that you can understand you will usually end up understanding the whole system."[17] In the case of Sarajevo, the main problems seemed to center around water and heat. So this is what Cuny and associates set out to address. In preparing for disaster relief work, Cuny was from the outset struck by the fact that medical professionals and materials are routinely flown to international disasters, but engineers and engineering equipment and supplies are not. So, his recurrent thought was, "Why don't you officials give first priority to, say, fixing the sewage system, instead of merely stanching the inevitable results of a breakdown in sanitary conditions?"[18]

It is unusual for engineers to receive the sort of public attention Fred Cuny did. We tend to take for granted the good work that engineers do. Insofar as engineers "make the news," more likely than not this is when an engineering disaster has occurred, a product is subjected to vigorous criticism, or an engineer has blown the whistle. Fred Cuny's stories are largely stories of successful humanitarian ventures.

Fred Cuny's untimely, violent death was tragic. In April 1995, while organizing a field hospital for victims in the conflict in Chechnya, Cuny, two Russian Red Cross doctors and a Russian interpreter disappeared. After a prolonged search, it was concluded that all four were executed. Speculation is that Chechens may have been deliberately misinformed that the four were Russian spies. Cuny's article in the *New York Review of Books* titled "Killing Chechnya" was quite critical of the Russian treatment of Chechnya, and it gives some indication of why his views might well have antagonized Russians.[19] Already featured in the *New York Times*, the *New Yorker Magazine*, and the *New York Review of Books*, Cuny had attained sufficient national recognition that his disappearance received widespread attention and immediate response from President Clinton and government officials. Reports on the search for Cuny and colleagues regularly appeared in the press from early April until August 18, 1995, when his family finally announced that he was now assumed dead.

Many tributes have been made to the work of Fred Cuny. Pat Reed, a colleague at Intertect, was quoted soon after Cuny's disappearance: "He's one of the few visionaries in the emergency management field. He really knows what he's doing. He's not just some cowboy."[20] At the Moscow press conference calling an end to the search, Cuny's son Chris said, "Let it be known to all nations and humanitarian organizations that Russia was responsible for the death of one of the world's great humanitarians."[21] William Shawcross fittingly concludes his article, "A Hero for Our Time," as follows:

> At the memorial meeting in Washington celebrating Fred's life it was clear that he had touched people in a remarkable way. He certainly touched me; I think he was a great man. The most enduring memorials to Fred are the hundreds of thousands of people he has helped—and the effect he has had, and will have, on the ways governments and other organizations try to relieve the suffering caused by disasters throughout the world.

An Afterword

It is certainly appropriate to make special note of extraordinary individuals such as Frederick C. Cuny for special praise. His life does seem heroic. However, we would do well to remember that even heroes have helpers. Cuny worked with others, both at Intertect and at the various other agencies with whom Intertect collaborated. There are unnamed engineers in Sarajevo with whom he worked. For example, his Sarajevo team was able to locate the old cisterns and channels through the assistance of local engineers (and historians).[22] Local engineers assisted in installing the water filtration system.

Furthermore, once the system was installed, the water had to be tested for purity. Here, a conflict developed between local engineers (as well as Cuny and specialists from the International Rescue Committee) and local water safety inspectors who demanded further testing. Convinced that they had adequately tested the water, the local engineers, Cuny, and the International Rescue Committee were understandably impatient. However, the cautious attitude of the water safety experts is understandable as well. Muhamed Zlatar, deputy head of Sarajevo's Institute for Water, commented, "The consequences of letting in polluted water could be catastrophic. They could be worse than the shelling. We could have 30,000 people come down with stomach diseases, and some of them could die."[23] Without presuming who might have been right, we might do well to remember Fran Kelsey, the FDA official who, in 1962, refused to approve thalidomide until further testing was done. That is, in our rush to do good, caution should not be thrown to the winds.

Identify and discuss the ethical issues raised by the story of Frederick C. Cuny.

CASE 6

Gilbane Gold

The fictional case study presented in the popular videotape *Gilbane Gold* focuses on David Jackson, a young engineer in the environmental affairs department of ZCORP, located in the city of Gilbane.[24] The firm, which manufactures computer parts, discharges lead and arsenic into the sanitary sewer of the city. The city has a lucrative business in processing the sludge into fertilizer, which is used by farmers in the area.

To protect its valuable product, Gilbane Gold, from contamination by toxic discharges from the new high-tech industries, the city has imposed highly restrictive regulations on the amount of arsenic and lead that can be discharged into the sanitary sewer system. However, recent tests indicate that ZCORP may be violating the standards. David believes that ZCORP must invest more money in pollution-control equipment, but management believes the costs will be prohibitive.

David faces a conflict situation that can be characterized by the convergence of four important moral claims. First, David has an obligation as a good employee to promote the interests of his company. He should not take actions that unnecessarily cost the company money or damage its reputation. Second, David has an obligation—based on his personal integrity, his professional integrity as an engineer, and his special role as environmental engineer—to be honest with the city in reporting data on the discharge of the heavy metals. Third, David has an obligation as an engineer to protect the health of the public. Fourth, David has a right, if not an obligation, to protect and promote his own career.

The problem David faces is this: How can he do justice to all of these claims? If they are all morally legitimate, he should try to honor all of them, and yet they appear to conflict in the situation. David's first option should be to attempt to find a creative middle-way solution, despite the fact that the claims appear to be incompatible in the situation. What are some of the creative middle-way possibilities?[25]

One possibility would be to find a cheap technical way to eliminate the heavy metals. Unfortunately, the video does not directly address this possibility. It begins in the midst of a crisis at ZCORP and focuses almost exclusively on the question of whether David Jackson should blow the whistle on his reluctant company. Another avenue to explore in *Gilbane Gold* is the attitude toward responsibility exhibited by the various characters in the story. Prominent, for example, are David Jackson, Phil Port, Diane Collins, Tom Richards, Frank Seeders, and Winslow Massin. Look at the transcript (available at www.niee.org/pd.cfm?pt=Murdough). What important similarities and differences do you find?

CASE 7

Greenhouse Gas Emissions[26]

On November 15, 2007, the Ninth Circuit Court of Appeals in San Francisco rejected the Bush administration's fuel economy standards for light trucks and sport utility vehicles. The three-judge panel objected that the regulations fail to take sufficiently into account the economic impact that tailpipe emissions can be expected to have on climate change. The judges also questioned why the standards were so much easier on light trucks than passenger cars. (The standards hold that by 2010 light trucks are to average 23.5 mpg, whereas passenger cars are to average 27.5 mpg.)

Although it is expected that an appeal will be made to the U.S. Supreme Court, this ruling is one of several recent federal court rulings that urge regulators to consider the risk of climate change in setting standards for carbon dioxide and other heat-trapping gas emissions from industry.

Patrick A. Parenteau, Vermont Law School environmental law professor, is quoted as saying, "What this says to me is that the courts are catching up with climate change and the law is catching up with climate change. Climate change has ushered in a whole new era of judicial review."[27]

One of the judges, Betty B. Fletcher, invoked the National Environmental Policy Act in calling for cumulative impacts analyses explicitly taking into account the environmental impact of greenhouse gas emissions. Acknowledging that cost–benefit analysis may appropriately indicate realistic limits for fuel economy standards, she insisted that "it cannot put a thumb on the scale by undervaluing the benefits and overvaluing the costs of more stringent standards."

Finally, Judge Fletcher wrote, "What was a reasonable balancing of competing statutory priorities 20 years ago may not be a reasonable balancing of those priorities today."

Given recent court trends, what implications are there for the responsibilities (and opportunities) of engineers working in the affected areas?

CASE 8

Halting a Dangerous Project

In the mid-1980s, Sam was Alpha Electronics' project leader on a new contract to produce manufactured weaponry devices for companies doing business with NATO government agencies.[28] The devices were advanced technology land mines with electronic controls that could be triggered with capacitor circuits to go off only at specified times, rather than years later when children might be playing in old minefields. NATO provided all the technical specifications and Alpha Electronics fulfilled the contract without problems. However, Sam was concerned that one new end user of this device could negate the safety aspects of the trigger and make the land mines more dangerous than any others on the market.

After the NATO contract was completed, Sam was dismayed to learn that Alpha Electronics had signed another contract with an Eastern European firm that had a reputation of stealing patented devices and also of doing business with terrorist organizations. Sam halted the production of the devices. He then sought advice from some of his colleagues and contacted the U.S. State Department's Office of Munitions Controls. In retrospect, he wishes he had also contacted the Department of Commerce's Bureau of Export Administration, as well as the Defense Department. He ruefully acknowledges that the issue would have been brought to a close much more quickly.

The contract that Sam unilaterally voided by his action was for nearly $2 million over 15 years. Sam noted that no further hiring or equipment would have been needed, so the contract promised to be highly profitable. There was a $15,000 penalty for breaking the contract.

On the basis of global corporate citizenship, it was clear that Alpha Electronics could legally produce the devices for the NATO countries but not for the Eastern European company. The Cold War was in full swing at that time.

On the basis of local corporate citizenship, it was clear that Alpha Electronics had to consider the expected impact on local communities. In particular, there was no guarantee regarding to whom the Eastern European company would be selling the devices and how they would end up being used.

Sam took matters into his own hands without any foreknowledge of how his decision would be viewed by his company's upper management, board of directors, or fellow workers, many of whom were also company stockholders. Happily, Sam was never punished for his unilateral action of halting production. He recently retired from Alpha Electronics as a corporate-level vice president. He was especially gratified by the number of Alpha employees who were veterans of World War II, the Korean War, and the Vietnam War who thanked him for his action.

Sam strongly believed his action was the right thing to do, both for his company and for the public welfare. What ideas typically covered in an engineering ethics course might support that conviction?

CASE 9

Highway Safety Improvements[29]

David Weber, age 23, is a civil engineer in charge of safety improvements for District 7 (an eight-county area within a midwestern state). Near the end of the fiscal year, the district engineer informs David that delivery of a new snowplow has been delayed, and as a consequence the district has $50,000 in uncommitted funds. He asks David to suggest a safety project (or projects) that can be put under contract within the current fiscal year.

After a careful consideration of potential projects, David narrows his choice to two possible safety improvements. Site A is the intersection of Main and Oak Streets in the major city within the district. Site B is the intersection of Grape and Fir Roads in a rural area.

Pertinent data for the two intersections are as follows:

	Site A	Site B
Main road traffic (vehicles/day)	20,000	5,000
Minor road traffic (vehicles/day)	4,000	1,000
Fatalities per year (3-year average)	2	1
Injuries per year (3-year average)	6	2
PD* (3-year average)	40	12
Proposed improvement	New signals	New signals
Improvement cost	$50,000	$50,000

*PD refers to property damage-only accidents.

A highway engineering textbook includes a table of average reductions in accidents resulting from the installation of the types of signal improvements David proposes. The tables are based on studies of intersections in urban and rural areas throughout the United States during the past 20 years.

	Urban	Rural
Percent reduction in fatalities	50	50
Percent reduction in injuries	50	60
Percent reduction in PD	25	–25*

*Property damage-only accidents are expected to increase because of the increase in rear-end accidents due to the stopping of highspeed traffic in rural areas.

David recognizes that these reduction factors represent averages from intersections with a wide range of physical characteristics (number of approach lanes, angle of intersection, etc.), in all climates, with various mixes of trucks and passenger vehicles, various approach speeds, various driving habits, and so on. However, he has no special data about sites A and B that suggest relying on these tables is likely to misrepresent the circumstances at these sites.

Finally, here is additional information that David knows:

1. In 1975, both the National Safety Council (NSC) and the National Highway Traffic Safety Administration (NHTSA) published dollar scales for comparing accident outcomes, as shown below:

	NSC	NHTSA
Fatality	$52,000	$235,000
Injury	3,000	11,200
PD	440	500

2. A neighboring state uses the following weighting scheme:

Fatality	9.5 PD
Injury	3.5 PD

3. Individuals within the two groups pay roughly the same transportation taxes (licenses, gasoline taxes, etc.).

Which of the two-site improvements do you think David should recommend? What is your rationale for this recommendation?

CASE 10

Hurricane Katrina

As we have noted in the text, until approximately 1970, nearly all engineering codes of ethics held that the engineer's first duty is fidelity to his or her employer and clients. However, soon after 1970, most codes insisted that "Engineers shall hold paramount the safety, health, and welfare of the public." Whatever may have precipitated this change in the early 1970s, recent events—ranging from the collapse of Manhattan's Twin Towers on September 11, 2001, to the collapse of a major bridge in Minneapolis/St. Paul on August 1, 2007—make apparent the vital importance of this principle. The devastation wreaked by Hurricane Katrina along the Gulf of Mexico coastline states of Louisiana, Mississippi, and Alabama in late August 2005 is also a dramatic case in point.

Hardest hit was Louisiana, which endured the loss of more than 1,000 lives, thousands of homes, damage to residential and nonresidential property of more than $20 billion, and damage to public infrastructure estimated at nearly $7 billion. Most severely damaged was the city of New Orleans, much of which had to be evacuated and which suffered the loss of more than 100,000 jobs. The city is still recovering, apparently having permanently lost much of its population and only slowly recovering previously habitable areas.

At the request of the U.S. Army Corp of Engineers (USACE), the American Society of Civil Engineers (ASCE) formed the Hurricane Katrina External Review Panel to review the comprehensive work of USACE's Interagency Performance Evaluation Task Force. The resulting ASCE report, *The New Orleans Hurricane Protection System: What Went Wrong and Why*, is a detailed and eloquent statement of the ethical responsibilities of engineers to protect public safety, health, and welfare.[30]

The ASCE report documents engineering failures, organizational and policy failures, and lessons learned for the future. Chapter 7 of the report ("Direct Causes of the Catastrophe") begins as follows:[31]

> What is unique about the devastation that befell the New Orleans area from Hurricane Katrina—compared to other natural disasters—is that much of the destruction was the result of engineering and engineering-related policy failures.

From an engineering standpoint, the panel asserts, there was an overestimation of soil strength that rendered the levees more vulnerable than they should have been, a failure to satisfy standard factors of safety in the original designs of the levees and pumps, and a failure to determine and communicate clearly to the public and the city leaders the level of hurricane risk to which the city and its residents were exposed. The panel concludes,[32]

> With the benefit of hindsight, we now see that questionable engineering decisions and management choices, and inadequate interfaces within and between organizations, all contributed to the problem.
>
> This might suggest that blame-responsibility is in order. However, the panel chose not to pursue this line, pointing out instead the difficulty of assigning blame:[33]
>
> No one person or decision is to blame. The engineering failures were complex, and involved numerous decisions by many people within many organizations over a long period of time.

Rather than attempt to assign blame, the panel used the hindsight it acquired to make recommendations about the future. The report identifies a set of critical actions the panel regards as necessary. These actions fall under one of four needed shifts in thought and approach:[34]

- Improve the understanding of risk and firmly commit to safety.
- Re-evaluate and repair the hurricane protection system.

- Reorganize the management of the hurricane protection system.
- Insist on engineering quality.

The first recommended action is that safety be kept at the forefront of public priorities, preparing for the possibility of future hurricanes rather than allowing experts and citizens alike to fall into a complacency that can come from the relative unlikelihood of a repeat performance in the near future. In addition, the panel recommended making clear and quantifiable risk estimates and communicating them to the public in ways that enable nonexperts to have a real voice in determining the acceptability or unacceptability of those risks.

Recommended actions related to re-evaluating and repairing damaged components of the existing infrastructure include a broad look at the whole infrastructure system, identifying weak links, and repairing damaged components and where needed, repurposing components to work better as a system.

The next set of recommendations concerns rethinking the haphazard, uncoordinated hurricane protection "system" with a truly organized, coherent system. This, the panel believes, calls for "good leadership, management, and someone in charge."[35] It is the panel's recommendation that a high-level licensed engineer, or a panel of highly qualified, licensed engineers, be appointed with full authority to oversee the system:[36]

> The authority's overarching responsibility will be to keep hurricane-related safety at the forefront of public priorities. The authority will provide leadership, strategic vision, definition of roles and responsibilities, formalized avenues of communication, prioritization of funding, and coordination of critical construction, maintenance, and operations.

The panel also recommended improving interagency coordination. The historical record thus far, the panel maintains, is disorganization and poor mechanisms for interagency communication:[37]

> Those responsible for maintenance of the hurricane protection system must collaborate with system designers and constructors to upgrade their inspection, repair, and operations to ensure that the system is hurricane-ready and flood-ready.

Recommendations intended to "demand engineering quality" relate to the upgrading and review of design procedures. The panel points out that "ASCE has a long-standing policy that recommends independent external peer review of public works projects where performance is critical to public safety, health, and welfare."[38] This is especially so where reliability under emergency conditions is critical, as it clearly was when Hurricane Katrina struck. The effective operation of such an external review process, the panel concludes, could have resulted in a significant reduction in the amount of (but by no means all) destruction in the case of Hurricane Katrina.

The panel's final recommendation is essentially a reminder of our limitations and a consequent ethical imperative to "place safety first":[39]

> Although the conditions leading up to the New Orleans catastrophe are unique, the fundamental constraints placed on engineers for any project are not. Every project has funding and/or schedule limitations. Every project must integrate into the natural and man-made environment. Every major project has political ramifications.
>
> In the face of pressure to save money or to make up time, engineers must remain strong and hold true to the requirements of the profession's canon of ethics, never compromising the safety of the public.

The panel concludes with an appeal to a broader application of the first Fundamental Canon of ASCE's Code of Ethics. Not only must the commitment to protect public safety, health, and welfare be the guiding principle for New Orleans' hurricane protection system but also "it must be applied with equal rigor to every aspect of an engineer's work—in New Orleans, in America, and throughout the world."[40]

Reading the panel's report in its entirety would be a valuable exercise in thinking through what ASCE's first Fundamental Canon requires not only regarding the Hurricane Katrina disaster but also regarding other basic responsibilities to the public that are inherent in engineering practice.

A related reading is "Leadership, Service Learning, and Executive Management in Engineering: The Rowan University Hurricane Katrina Recovery Team," by a team of engineering students and faculty advisors at Rowan University.[41] In their abstract, the authors identify three objectives for the Hurricane Katrina Recovery Team Project:

> The main objective is to help distressed communities in the Gulf Coast Region. Second, this project seeks to not only address broader social issues but also leave a tangible contribution or impact in the area while asking the following questions: What do we as professional engineers have as a responsibility to the communities we serve, and what do we leave in the community to make it a better, more equitable place to live? The last objective is the management team's successful assessment of the experience, including several logistical challenges. To this end, this article seeks to help other student-led projects by relaying our service learning experience in a coherent, user-friendly manner that serves as a model experience.

Corporate Responses

Supportive corporate responses to the Hurricane Katrina were swift. By mid-September 2005, more than $312 million worth of aid had been donated by major corporations, much of it by those with no plants or businesses in the afflicted areas.[42] Engineers have played a prominent role in these relief efforts, as they did after the 9/11 Twin Towers attack and the Asian tsunami disaster. Hafner and Deutsch comment,[43]

> With two disasters behind them, some companies are applying lessons they have learned to their hurricane-related philanthropy. GE is a case in point. During the tsunami, the company put together a team of 50 project engineers—experts in portable water purification, energy, health care, and medical equipment.
>
> After Hurricane Katrina, GE executives took their cues from Jeffrey R. Immelt, GE's chief executive, and reactivated the same tsunami team for New Orleans. "Jeff told us, 'Don't let anything stand in the way of getting aid where it's needed,'" said Robert Corcoran, vice president for corporate citizenship.

Discuss how, with corporate backing, engineers who subscribe to Fred Cuny's ideas about effective disaster relief in his *Disasters and Development* (Oxford University Press, 1983) might approach the engineering challenges of Katrina.

CASE 11

Hyatt Regency Walkway Disaster

Approximately four years after its occurrence, the tragic 1981 Kansas City Hyatt Regency walkway collapse was in the news again. The collapse of two suspended walkways in the lobby claimed the lives of 114 people and injured 200 more while they were attending a dance at the hotel. A November 16, 1985, *New York Times* article reported the decision of Judge James B. Deutsch, an administrative law judge for Missouri's administrative hearing commission.[44] Judge Deutsch found the hotel's structural engineers guilty of gross negligence, misconduct, and unprofessional conduct.

Judge Deutsch is quoted as saying that the project manager displayed "a conscious indifference to his professional duties as the Hyatt project engineer who was primarily responsible for the preparation of design drawings and review of shop drawings for that project."[45] The judge also cited the chief engineer's failure to closely monitor the project manager's work as "a conscious indifference to his professional duties as an engineer of record."[46]

The American Society for Civil Engineers (ASCE) may have influenced this court ruling. Just before the judge made his decision, ASCE announced a policy of holding structural engineers responsible for structural safety in their designs. This policy reflected the recommendations of an ASCE committee that convened in 1983 to examine the disaster.

The court case shows that engineers can be held responsible not only for their own conduct but also for the conduct of others under their supervision. It also holds that engineers have special *professional* responsibilities.

Discuss the extent to which you think engineering societies should play the sort of role ASCE apparently did in this case. To what extent do you think practicing engineers should support (e.g., by becoming members) professional engineering societies' attempts to articulate and interpret the ethical responsibilities of engineers?

The Truesteel Affair is a fictionalized version of circumstances similar to those surrounding the Hyatt Regency walkway collapse. View this video and discuss the ethical issues it raises. (This film is available from Fanlight Productions, 47 Halifax St., Boston, MA 02130. 1-617-524-0980.)

For a detailed account of the walkway collapse, see "Hyatt Regency Walkway Collapse," Engineering.com, October 24, 2006. Also, see "Hyatt Regency Walkway Collapse (Texas A&M University Engineering Ethics Cases)" Online Ethics Center for Engineering, February 16, 2006, National Academy of Engineering, www.onlineethics.org/Resources/Cases/hyatt_walkway.aspx.

CASE 12

Hydrolevel[47]

"A conflict of interest is like dirt in a sensitive gauge," one that can not only soil one person's career but also taint an entire profession.[48] Thus, as professionals, engineers must be ever alert to signs of conflict of interest. The case of the *American Society of Mechanical Engineers (ASME) v. Hydrolevel Corporation* shows how easily individuals, companies, and professional societies can find themselves embroiled in expensive legal battles that tarnish the reputation of the engineering profession as a whole.

In 1971, Eugene Mitchell, vice president for sales at McDonnell and Miller, Inc., located in Chicago, was concerned about his company's continued dominance in the market for heating boiler low-water fuel cutoff valves that ensure that boilers cannot be fired without sufficient water in them because deficient water could cause an explosion.

Hydrolevel Corporation entered the low-water cutoff valve market with an electronic low-water fuel supply cutoff that included a time delay on some of its models. Hydrolevel's valve had won important approval for use from Brooklyn Gas Company, one of the largest installers of heating boilers. Some Hydrolevel units added the time-delay devices so the normal turbulence of the water level at the electronic probe would not cause inappropriate and repeated fuel supply turn-on and turn-off. Mitchell believed that McDonnell and Miller's sales could be protected if he could secure an interpretation stating that the Hydrolevel time delay on the cutoff violated the ASME B-PV code. He referred to this section of the ASME code: "Each automatically fired steam or vapor system boiler shall have an automatic low-water fuel cutoff, so located as to automatically cut off the fuel supply when the surface of the water falls to the lowest visible part of the water-gauge glass."[49] Thus, Mitchell asked for an ASME interpretation of the mechanism for operation of the Hydrolevel device as it pertained to the previously mentioned section of the code. He did not, however, specifically mention the Hydrolevel device in his request.

Mitchell discussed his idea several times with John James, McDonnell and Miller's vice president for research. In addition to his role at McDonnell and Miller, James was on the ASME subcommittee responsible for heating boilers and had played a leading role in writing the part of the boiler code that Mitchell was asking about.

James recommended that he and Mitchell approach the chairman of the ASME Heating Boiler Subcommittee, T. R. Hardin. Hardin was also vice president of the Hartford Steam Boiler Inspection and Insurance Company. When Hardin arrived in Chicago in early April on other business, the three men went to dinner at the Drake Hotel. During dinner, Hardin agreed with Mitchell and James that their interpretation of the code was correct.

Soon after the meeting with Hardin, James sent ASME a draft letter of inquiry and sent Hardin a copy. Hardin made some suggestions, and James incorporated Hardin's suggestions in a final draft letter. James' finalized draft letter of inquiry was then addressed to W. Bradford Hoyt, secretary of the B-PV Boiler and Pressure Vessel Committee.

Hoyt received thousands of similar inquiries every year. Since Hoyt could not answer James' inquiry with a routine, prefabricated response, he directed the letter to the appropriate subcommittee chairman, T. R. Hardin. Hardin drafted a response without consulting the whole subcommittee, a task he had authorization for if the response was treated as an "unofficial communication."

Hardin's response, dated April 29, 1971, stated that a low-water fuel cutoff must operate immediately. Although this response did not say that Hydrolevel's time-delayed cutoff was dangerous, McDonnell and Miller's salesmen used Hardin's conclusion to argue against using the Hydrolevel product. This was done at Mitchell's direction.

In early 1972, Hydrolevel learned of the ASME letter through one of its former customers who had a copy of the letter. Hydrolevel then requested an official copy of the letter from ASME. On March 23, 1972, Hydrolevel requested an ASME review and ruling correction.

ASME's Heating and Boiler Subcommittee had a full meeting to discuss Hydrolevel's request, and it confirmed part of the original Hardin interpretation.

James, who had replaced Hardin as chairman of the subcommittee, refrained from participating in the discussion but subsequently helped draft a critical part of the subcommittee's response to Hydrolevel. The ASME response was dated June 9, 1972.

In 1975, Hydrolevel filed suit against McDonnell and Miller, Inc., ASME, and the Hartford Steam Boiler Inspection and Insurance Company, charging them with conspiracy to restrain trade under the Sherman Antitrust Act.

Hydrolevel reached an out-of-court settlement with McDonnell and Miller and Hartford for $750,000 and $75,000, respectively. ASME took the case to trial. ASME officials believed that, as a society, ASME had done nothing wrong and should not be liable for the misguided actions of individual volunteer members acting on their own behalf. After all, ASME gained nothing from such practices. ASME officials also believed that a pretrial settlement would set a dangerous precedent that would encourage other nuisance suits.

Despite ASME arguments, however, the jury decided against ASME, awarding Hydrolevel $3.3 million in damages. The trial judge deducted $800,000 in prior settlements and tripled the remainder in accordance with the Clayton Act. This resulted in a decision of $7,500,000 for Hydrolevel.

On May 17, 1982, ASME's liability was upheld by the second circuit. The Supreme Court, in a controversial 6-3 vote, found ASME guilty of antitrust violations. The majority opinion, delivered by Justice Blackmun, read as follows:

> ASME wields great power in the nation's economy. Its codes and standards influence the policies of numerous states and cities, and has been said about "so-called voluntary standards" generally, its interpretation of guidelines "may result in economic prosperity or economic failure, for a number of businesses of all sizes throughout the country," as well as entire segments of an industry. … ASME can be said to be "in reality an extragovernmental agency, which prescribes rules for the regulation and restraint of interstate commerce." When it cloaks its subcommittee officials with the authority of its reputation, ASME permits those agents to affect the destinies of businesses and thus gives them power to frustrate competition in the marketplace.[50]

The issue of damages was retried in a trial lasting approximately one month. In June, the jury returned a verdict of $1.1 million, which was tripled to $3.3 million. Parties involved were claiming attorney's fees in excess of $4 million, and a final settlement of $4,750,000 was decreed.

Following the decision, ASME revised its procedures as follows: In the wake of the Hydrolevel ruling, the Society has changed the way it handles codes and standards interpretations, beefed up its enforcement and conflict-of-interest rules, and adopted new "sunset" review procedures for its working bodies.

The most striking changes affect the Society's handling of codes and standards interpretations. All such interpretations must now be reviewed by at least five persons before release; before, the review of two people was necessary. Interpretations are available to the public, with replies to nonstandard inquiries published each month in the Codes and Standards section of ME or other ASME publications. Previously, such responses were kept between the inquirer and the involved committee or subcommittee. Lastly, ASME incorporates printed disclaimers on the letterhead used for code interpretations spelling out their limitations: that they are subject to change should additional information become available and that individuals have the right to appeal interpretations they consider unfair.

Regarding conflict of interest, ASME now requires all staff and volunteer committee members to sign statements pledging their adherence to a comprehensive and well-defined set of guidelines regarding potential conflicts. Additionally, the Society now provides all staff and volunteers with copies of the engineering code of ethics along with a publication outlining the legal implications of standards activities.

Finally, the Society now requires each of its councils, committees, and subcommittees to conduct a "sunset" review of their operations every two years. The criteria include whether their activities have served the public interest and whether they have acted cost-effectively, in accordance with Society procedures.[51]

Conflict-of-interest cases quickly become complicated, as the following questions illustrate:

- How could McDonnell and Miller have avoided the appearance of a conflict of interest? This applies to both Mitchell and James.
- What was T. R. Hardin's responsibility as chair of the B-PV Code Heating Boiler Subcommittee? How could have he handled things differently to protect the interests of ASME?
- What can engineering societies do to protect their interests once a conflict of interest is revealed?
- Was the final judgment against ASME fair? Why or why not?
- Have ASME's revised conflict-of-interest procedures addressed the problems fully? Why or why not?

CASE 13

Incident at Morales

Incident at Morales is a multistage video case study developed by the National Institute for Engineering Ethics (NIEE). It involves a variety of ethical issues faced by the consulting engineer of a company that is in a hurry to build a plant so that it can develop a new chemical product that it hopes will give it an edge on the competition. Issues include environmental, financial, and safety problems in an international setting. Interspersed between episodes are commentaries by several engineers and ethicists involved in the production of the video. Information about ordering the video is available from the NIEE or the Murdough Center for Engineering Professionalism (http://www.depts.ttu.edu/murdoughcenter/). The full transcript of the video and a complete study guide are available online from the Murdough Center.

CASE 14

Innocent Comment?

Jack Strong is seated between Tom Evans and Judy Hanson at a dinner meeting of a local industrial engineering society. Jack and Judy have an extended discussion of a variety of concerns, many of which are related to their common engineering interests. At the conclusion of the dinner, Jack turns to Tom, smiles, and says, "I'm sorry not to have talked with you more tonight, Tom, but Judy's better looking than you."

Judy is taken aback by Jack's comment. A recent graduate from a school in which more than 20 percent of her classmates were women, she had been led to believe that finally the stereotypical view that women are not as well suited for engineering as men was finally going away. However, her first job has raised some doubts about this. She was hired into a division in which she is the only woman engineer. Now, even after nearly one year on the job, she has to struggle to get others to take her ideas seriously. She wants to be recognized first and foremost as a good engineer. So, she had enjoyed "talking shop" with Jack. But she was stunned by his remark to Tom, however innocently it might have been intended. Suddenly, she saw the conversation in a very different light. Once again, she sensed that she was not being taken seriously enough as an engineer.

How should Judy respond to Jack's remark? Should she say anything? Assuming Tom understands her perspective, what, if anything, should he say or do?

CASE 15

Member Support by IEEE

In the mid-1970s, the New York City Police Department operated an online computerized police car dispatching system called SPRINT. Upon receiving a telephoned request for police assistance, a dispatcher would enter an address into a computer and the computer would respond within seconds by displaying the location of the nearest patrol car. By reducing the response time for emergency calls, the SPRINT system probably saved lives.

In 1977, another system, PROMIS, was being considered by New York City prosecutors using the same host computer as that for SPRINT. The PROMIS system would provide names and addresses of witnesses, hearing dates, the probation statuses of defendants, and other information that would assist prosecutors or arresting officers who wanted to check the current status of apprehended perpetrators. This project was being managed by the Criminal Justice Coordinating Council, or Circle Project, a committee of high-level city officials that included the deputy mayor for criminal justice, the police commissioner, and Manhattan District Attorney Robert Morgenthau as chairman.

The committee employed a computer specialist as project director, who in turn hired Virginia Edgerton, an experienced system analyst, as senior information scientist to work under his supervision. Soon after being employed, Edgerton expressed concern to the project director about the possible effect on SPRINT's response time from loading the computer with an additional task, but he instructed her to drop the matter. Edgerton then sought advice from her professional society, the Institute of Electrical and Electronics Engineers (IEEE).

After an electrical engineering professor at Columbia University agreed that her concerns merited further study, she sent a memorandum to the project director requesting a study of the overload problem. He rejected the memorandum out of hand, and Edgerton soon thereafter sent copies of the memorandum with a cover letter to the members of the Circle Project's committee. Immediately following this, Edgerton was discharged by the project director on the grounds that she had, by communicating directly with the committee members, violated his orders. He also stated that the issues she had raised were already under continuing discussion with the police department's computer staff, although he gave no documentation to support this claim.

The case was then investigated by the Working Group on Ethics and Employment Practices of the Committee on the Social Implications of Technology (CSIT) of the IEEE, and subsequently by the newly formed IEEE Member Conduct Committee. Both groups agreed that Edgerton's actions were fully justified. In 1979, she received the second IEEE–CSIT Award for Outstanding Service in the Public Interest. After her discharge, Edgerton formed a small company selling data-processing services.[52]

Discuss the supporting role played by IEEE in this case. Does this provide electrical and electronic engineers an ethical basis for joining or supporting IEEE?

CASE 16

Oil Spill?[53]

Peter has been working with the Bigness Oil Company's local affiliate for several years, and he has established a strong, trusting relationship with Jesse, manager of the local facility. The facility, on Peter's recommendations, has followed all of the environmental regulations to the letter, and it has a solid reputation with the state regulatory agency. The local facility receives various petrochemical products via pipelines and tank trucks, and it blends them for resale to the private sector.

Jesse has been so pleased with Peter's work that he has recommended that Peter be retained as the corporate consulting engineer. This would be a significant advancement for Peter and his consulting firm, cementing Peter's steady and impressive rise in the firm. There is talk of a vice presidency in a few years.

One day, over coffee, Jesse tells Peter a story about a mysterious loss in one of the raw petrochemicals he receives by pipeline. Sometime during the 1950s, when operations were more lax, a loss of one of the process chemicals was discovered when the books were audited. There were apparently 10,000 gallons of the chemical missing. After running pressure tests on the pipelines, the plant manager found that one of the pipes had corroded and had been leaking the chemical into the ground. After stopping the leak, the company sank observation and sampling wells and found that the product was sitting in a vertical plume, slowly diffusing into a deep aquifer. Because there was no surface or groundwater pollution off the plant property, the plant manager decided to do nothing. Jesse thought that somewhere under the plant there still sits this plume, although the last tests from the sampling wells showed that the concentration of the chemical in the groundwater within 400 feet of the surface was essentially zero. The wells were capped, and the story never appeared in the press.

Peter is taken aback by this apparently innocent revelation. He recognizes that state law requires him to report all spills, but what about spills that occurred years ago, where the effects of the spill seem to have dissipated? He frowns and says to Jesse, "We have to report this spill to the state, you know."

Jesse is incredulous. "But there *is* no spill. If the state made us look for it, we probably could not find it; and even if we did, it makes no sense whatever to pump it out or contain it in any way."

"But the law says that we have to report…," replies Peter.

"Hey, look. I told you this in confidence. Your own engineering code of ethics requires client confidentiality. And what would be the good of going to the state? There is nothing to be done. The only thing that would happen is that the company would get into trouble and have to spend useless dollars to correct a situation that cannot be corrected and does not need remediation."

"But. …"

"Peter, let me be frank. If you go to the state with this, you will not be doing anyone any good—not the company, not the environment, and certainly not your own career. I cannot have a consulting engineer who does not value client loyalty."

What are the ethical issues in this case? What factual and conceptual questions need to be addressed? How do you think Peter should deal with this situation?

CASE 17

Pinto[54]

In the late 1960s, Ford designed a subcompact, the Pinto, which weighed less than 2,000 pounds and sold for less than $2,000. Anxious to compete with foreign-made subcompacts, Ford brought the car into production in slightly more than 2 years (compared with the usual 3½ years). Given this shorter time frame, styling preceded much of the engineering, thus restricting engineering design more than usual. As a result, it was decided that the best place for the gas tank was between the rear axle and the bumper. The differential housing had exposed bolt heads that could puncture the gas tank if the tank were driven forward against them upon rear impact.

In court, the crash tests were described as follows:[55]

> These prototypes as well as two production Pintos were crash tested by Ford to determine, among other things, the integrity of the fuel system in rear-end accidents. … Prototypes struck from the rear with a moving barrier at 21-miles-per-hour caused the fuel tank to be driven forward and to be punctured, causing fuel leakage. … A production Pinto crash tested at 21-miles-per-hour into a fixed barrier caused the fuel tank to be torn from the gas tank and the tank to be punctured by a bolt head on the differential housing. In at least one test, spilled fuel entered the driver's compartment.

Ford also tested rear impact when rubber bladders were installed in the tank, as well as when the tank was located above rather than behind the rear axle. Both passed the 20-mile-per-hour rear impact tests.

Although the federal government was pressing to stiffen regulations on gas tank designs, Ford contented that the Pinto met all applicable federal safety standards at the time. J. C. Echold, director of automotive safety for Ford, issued a study titled "Fatalities Associated with Crash Induced Fuel Leakage and Fires."[56] This study claimed that the costs of improving the design ($11 per vehicle) outweighed its social benefits. A memorandum attached to the report described the costs and benefits as follows:

Benefits	
Savings	180 burn deaths, 180 serious burn injuries, 2,100 burned vehicles
Unit cost	$200,000 per death, $67,000 per injury, $700 per vehicle
Total benefits	180 × $200,000 plus 180 × $67,000 plus 2100 × $700 = $49.15 million
Costs	
Sales	11 million cars, 1.5 million light trucks
Unit cost	$11 per car, $11 per truck
Total costs	11,000,000 × $11 plus 1,500,000 × $11 = $137 million

The estimate of the number of deaths, injuries, and damage to vehicles was based on statistical studies. The $200,000 for the loss of a human life was based on an NHTSA study, which estimated social costs of a death as follows:[57]

Component	**1971 Costs**
Future productivity losses	
Direct	$132,000
Indirect	41,300
Medical costs	
Hospital	700
Other	425
Property damage	1,500
Insurance administration	4,700
Legal and court	3,000
Employer losses	1,000
Victim's pain and suffering	10,000
Funeral	900
Assets (lost consumption)	5,000
Miscellaneous accident cost	200
Total per fatality	$200,725

Discuss the appropriateness of using data such as these in Ford's decision regarding whether or not to make a safety improvement in its engineering design. If you believe this is not appropriate, what would you suggest as an alternative? What responsibilities do you think engineers have in situations like this?

CASE 18

Profits and Professors

A *Wall Street Journal* article reports:

> High-tech launches from universities frequently can't get off the ground without a steady supply of students, who are often the most talented and the most willing to toil around the clock. But intense schedules on the job can keep students from doing their best academic work. And when both student and teacher share a huge financial incentive to make a company a success, some professors might be tempted to look the other way when studies slip or homework gets in the way.[58]

In some instances, the article claims, students seriously consider leaving school before completing their degrees in order to devote themselves more fully to work that is financially very attractive.

In 1999, Akamai won the MIT Sloan eCommerce Award for Rookie of the Year, an award to the start-up company that seems most likely to dominate its field. The article comments,

> No company has been more closely tied to MIT. The firm has its roots in a research project directed by Mr. Leighton [Computer Systems Engineering professor at MIT] about 3 years ago. Daniel Lewin, one of Mr. Leighton's graduate students, came up with a key idea for how to apply algorithms, or numerical instructions for computers, to Internet congestion problems.[59]

Soon, Mr. Leighton and Mr. Lewin teamed up to form Akamai, hiring 15 undergraduates to help code the algorithms.

They tried to separate their MIT and Akamai responsibilities. Mr. Leighton advised Mr. Lewin to get a second professor to cosign his master's thesis "because he worried about the appearance of conflict in his supervising Mr. Lewin's academic work while also pursuing a business venture with him." It turns out that the cosigner was someone involved in Mr. Lewin's original research project, who sometime after the completion of Mr. Lewin's thesis became a part-time research scientist at Akamai.

Akamai continues to rely heavily on MIT students as employees. However, it does not hire students full-time before they have completed their undergraduate degree. Still, the opportunities seem very attractive. According to the article, Luke Matkins took a summer job with Akamai in the summer after his sophomore year. By age 21, prior to completing his degree, he was making $75,000 a year and was given 60,000 shares of stock estimated to be worth more than $1 million.

Mr. Matkins' grades suffered because his work left him too little time to complete all of his homework assignments. However, he apparently has no regrets: "Mr. Matkins says the prospect of being a millionaire by his senior year is 'very cool.' He loves MIT, but in many ways, he says, Akamai has become his real university. 'There are different ways to learn stuff,' he says. 'I've learned more at Akamai than I would in a classroom.'"[60]

The article notes that Mr. Lewin's doctoral dissertation will be based on his work at Akamai, although he'll probably need permission from the Akamai board of directors to use some of the material. The article concludes, "He will also probably need approval from Akamai's chief scientist, Mr. Leighton, who, it turns out, is his PhD adviser."[61]

Identify and discuss the ethical issues that the previous account raises.

CASE 19

Pulverizer

Fred is a mechanical engineer who works for Super Mulcher Corporation. It manufactures the Model 1 Pulverizer, a 10-hp chipper/shredder that grinds yard waste into small particles that can be composted and blended into the soil. The device is particularly popular with homeowners who are interested in reducing the amount of garden waste deposited in landfills.

The chipper/shredder has a powerful engine and a rapidly rotating blade that can easily injure operators if they are not careful. During the five years the Model 1 Pulverizer has been sold, there have been 300 reported accidents with operators. The most common accident occurs when the discharge chute gets plugged with shredded yard waste, prompting the operator to reach into the chute to unplug it. When operators reach in too far, the rotating blades can cut off or badly injure their fingers.

Charlie Burns, president of Super Mulcher, calls a meeting of the engineers and legal staff to discuss ways to reduce legal liability associated with the sale of the Model 1 Pulverizer. The legal staff suggest several ways of reducing legal liability:

- Put bright yellow warning signs on the Model 1 Pulverizer that say, "Danger! Rapidly rotating blades. Keep hands out when machine is running!"
- Include the following warning in the owner's manual: "Operators must keep hands away from the rotating blades when machine is in operation."
- State in the owner's manual that safe operation of the Model 1 Pulverizer requires a debris collection bag placed over the discharge chute. State that operators are not to remove the debris collection bag while the Model 1 Pulverizing is running. If the discharge chute plugs, the owner is instructed to turn off the Model 1 Pulverizer,

remove the debris collection bag, replace the debris collection bag, and restart the engine.

From operating the Model 1 Pulverizer, Fred knows the discharge chute has a tendency to plug. Because the machine is difficult to restart, there is a great temptation to run the unit without the debris collection bag—and to unplug the discharge chute while the unit is still running.

For each of the following scenarios, discuss the various ways Fred attempts to resolve the problem:

Scenario 1: Fred suggests to his engineering colleagues that the Model 1 Pulverizer should be redesigned so it does not plug. His colleagues reply that the company probably cannot afford the expense of reengineering the Model 1, and they conclude that the legal staff's recommendations should be sufficient. Dissatisfied, in his spare time Fred redesigns the Model 1 Pulverizer and solves the plugging problem in an affordable way.

Scenario 2: Fred says nothing to his colleagues about the impracticality of requiring the machine to be run with the debris collection bag. He accepts the legal staff's advice and adds the warning signs and owner's manual instructions. No changes are made in the design of the Model 1 Pulverizer.

Scenario 3: Fred suggests to his engineering colleagues that they try to convince management that the Model 1 Pulverizer should be redesigned so that it does not plug. They agree and prepare a redesign plan that will cost $50,000 to implement. Then they take their plan to management.

CASE 20

Reformed Hacker?

According to John Markoff's "Odyssey of a Hacker: From Outlaw to Consultant," John T. Draper is attempting to become a "white-hat" hacker as a way of repaying society for previous wrongdoing.[62] In the early 1970s, Draper became known as "Cap'n Crunch" after discovering how to use a toy whistle in the Cap'n Crunch cereal box to access the telephone network in order to get free telephone calls. While serving time in jail for his misdeeds, he came up with the early design for EasyWriter, IBM's first word-processing program for its first PC in 1981. However, says Markoff, in subsequent years Draper used his skills to hack into computer networks, became a millionaire, lost jobs, and experienced homelessness. Now, however, Draper has been enlisted to help operate an Internet security software and consulting firm that specializes in protecting the online property of corporations. Draper says, "I'm not a bad guy." However, realizing there are bound to be doubters, he adds, "But I'm being treated like a fox trying to guard the hen house." SRI International's computer security expert Peter Neumann summarizes the concern:

> Whether black hats can become white hats is not a black-and-white question. In general, there are quite a few black hats who have gone straight and become very effective. But the simplistic idea that hiring overtly black-hat folks will increase your security is clearly a myth.

Discuss the ethical issues this case raises. What might reasonably convince doubters that Draper has, indeed, reformed? Are customers of the consulting firm entitled to know about Draper's history and his role at the firm?

CASE 21

Resigning from a Project

In 1985, computer scientist David Parnas resigned from an advisory panel of the Strategic Defense Initiative Organization (SDIO).[63] He had concluded that SDI was both dangerous and a waste of money. His concern was that he saw no way that any software program could adequately meet the requirements of a good SDI system.[64] His rationale for resigning rested on three ethical premises.[65] First, he must accept responsibility for his own actions rather than rely on others to decide for him. Second, he must not ignore or turn away from ethical issues. In Parnas' case, this means asking whether what he is doing is of any benefit to society. Finally, he "must make sure that I am solving the real problem, not simply providing short-term satisfaction to my supervisor."

However, Parnas did more than resign from the panel. He also undertook public opposition to SDI. This was triggered by the failure of SDIO and his fellow panelists to engage in scientific discussion of the technical problems he cited. Instead, Parnas says, he received responses such as "The government has decided; we cannot change it," "The money will be spent; all you can do is make good use of it," "The system will be built; you cannot change that," and "Your resignation will not stop the program."[66] To this, Parnas replied,

> It is true, my decision not to toss trash on the ground will not eliminate litter. However, if we are to eliminate litter, I must decide not to toss trash on the ground. We all make a difference.

As for his part, Parnas regarded himself as having a responsibility to help the public understand why he was convinced that the SDI program could not succeed, thus enabling them to decide for themselves.[67]

Parnas' concerns did not stop with SDI. He also expressed concerns about research in colleges and universities:[68]

> Traditionally, universities provide tenure and academic freedom so that faculty members can speak out on issues such as these. Many have done just that. Unfortunately, at U.S. universities there are institutional pressures in favor of accepting research funds from any source. A researcher's ability to attract funds is taken as a measure of his ability.

Identify and discuss the ethical issues raised by David Parnas. Are there other ethical issues that should be discussed?

CASE 22

Responsible Charge[69]

Ed Turner graduated from Santa Monica College (a two-year school) with an associate degree in 1961. He worked for eight years for the City of Los Angeles in its engineering department and took the professional engineer in training exam in California. As a result, he received a civil engineering/professional engineering license in the state of Idaho. To get his license, he had to work under the direction of already licensed supervisors and be strongly recommended for licensure by all of them. Because he did not have a BS degree in engineering from an accredited school, his experience had to be exemplary.

In the late 1960s, Ed moved to the city of Idaho Falls and went to work for the Department of Public Works. As a licensed professional engineer in 1980, he had sign-off authority for all engineering work done in the city. His problems with the city started when he refused to approve some engineering designs for public works projects. One such project omitted the sidewalk, requiring students to walk in street traffic on their way to school. The public works director and mayor responded to his refusal by demoting him and moving him out of his office to a new and smaller work area. They appointed an unlicensed nonengineer as city engineering administrator to replace him and sign off on all engineering work. This was in violation of Idaho state law.

Ed stayed on that new job as long as he could to keep an eye on engineering work in the city and because he needed an income to support his family. Finally, he was dismissed, and he and his wife had to sort potatoes and do custodial work in order to survive and to finance a court appeal.

The Idaho Job Service Department approved his request for unemployment insurance coverage, but the city of Idaho Falls succeeded in getting that ruling reversed. The Idaho Industrial Commission eventually overturned the city's ruling, and Ed ultimately received his unemployment insurance.

Ed and the American Engineering Alliance (AEA) of New York managed to obtain the support of 22 states in his case against Idaho Falls for wrongful discharge and for not having responsible charge of engineering work. The Idaho State Board of Professional Engineers and the National Society of Professional Engineers (NSPE) also supported him, as did the ASME, the ASCE, the AEA, as well as several other important professional societies. Ed's wife, Debra, played a significant role throughout the four-year litigation. In addition to keeping the court files in order, she was on the witness stand and was cross-examined by the city's lawyers.

Many individuals cognizant of the issues involved, including one of the authors of this text, volunteered their services to Ed on a pro bono basis and submitted depositions. However, the depositions were not admitted by the Idaho Falls city court that was hearing the case, and the case was thrown out of the court because the papers submitted to the Idaho Falls judge were late and on the wrong forms.

Fortunately, the story does have a happy ending. On the advice of many, and with a new lawyer, Ed's former lawyer was sued for malpractice at a court in another city. In order for a malpractice suit to be successful, the jury must first vote that the original case was winnable, and then it must separately determine that there was malpractice involved. Ed won both those decisions, with the court admonishing the government of Idaho Falls that it had violated state law. Although the settlement was large, after legal fees and taxes were paid, it was clear that Ed was not, in his words, "made whole." But he resumed practicing as a licensed professional civil engineer and happy that he was able to contribute to his profession and to public safety. It is noteworthy that in response to the devastation caused by Hurricane Katrina in 2005, Ed and his wife Debra spent months doing volunteer work in Alabama to provide aid to its victims.

CASE 23

Service Learning[70]

Current ABET[71] requirements for accredited engineering programs in the United States include helping students acquire "an understanding of professional and ethical responsibility."[72] ABET also requires that engineering programs provide graduates "… the broad education necessary to understand the impact of engineering in a global, economic, environmental, and societal context" and "a knowledge of contemporary issues." The recent surge of interest in service learning in engineering education presents students with creative, hands-on possibilities to meet these ABET expectations.

Service learning involves combining community service and academic study in ways that invite reflection on what one learns in the process. Given ABET requirement that students be involved in a "major design experience, the idea of service learning in engineering may be especially promising. But this idea is important for another reason. Much of the engineering ethics literature dwells on the negative—wrongdoing, its prevention, and appropriate sanctioning of misconduct. These will always be fundamental concerns. However, there is more to engineering ethics. There is the more positive side that focuses on doing one's work responsibly and well—whether in the workplace or in community service.

Given the common association of engineering ethics with wrongdoing and its prevention, it might be asked whether community service should be regarded as a part of engineering ethics at all. However, it is not uncommon for other professions to include pro bono service as an important feature of their professional ethics. This is based in large part on the recognition that professions provide services that may be needed by anyone but which not everyone can afford or gain easy access to. Medical and legal services readily come to mind. But this is no less true of engineering.

Is this acknowledged in engineering codes of ethics? It is in at least two—those of the NSPE and the ASCE. Emphasizing the crucial impact that engineering has on the public, the Preamble of NSPE's Code of Ethics for Engineers states that engineering "requires adherence to the highest principles of ethical conduct on behalf of the public, clients, employers, and the profession." Following this, the code lists as its first Fundamental Canon that engineers are to hold paramount the safety, health, and welfare of the public in the performance of their professional duties. Under section III. Professional Obligations, provision 2 reads, “Engineers shall at all times strive to serve the public interest.” Subsection a under this obligation reads, “Engineers shall seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health, and well-being of their community.”

Noteworthy here is the assertion that engineers are to seek opportunities to be of service to the community. Furthermore, there is no qualifier, “in the performance of their professional duties.” This suggests that engineers’ obligations in regard to public well-being are not restricted to their responsibilities within their place of employment.

The first Fundamental Canon of ASCE’s code reads, “Engineers shall hold paramount the safety, health, and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.” Subsection e, directly under this, reads, “Engineers should seek opportunities to be of constructive service in civic affairs and work for the advancement of the safety, health, and well-being of their communities, and the protection of the environment through the practice of sustainable development.” Subsection f reads, “Engineers should be committed to improving the environment by adherence to the principles of sustainable development so as to enhance the quality of life of the general public.”

Although the NSPE and ASCE provisions are rather broadly stated, they do provide a rationale for concluding that, at least from the perspective of two major professional engineering societies, community service is an important feature of engineering ethics.

Many worry that students today are part of a “me-generation.” At the same time, however, there has been a marked increase in student interest in volunteer work. Until fairly recently, there has not been a strong correlation between students’ academic pursuits and the types of volunteer work they undertake. Noting this lack of correlation, organizations such as Campus Compact have made concerted efforts to encourage the development of academic programs that explicitly encourage students to seek volunteer work related to their course of academic study and to reflect quite self-consciously on the connections.[73]

Academic areas such as teacher education and the health care professions immediately suggest themselves as candidates for service learning programs. Students preparing to become teachers can offer tutorial or mentoring services to the schools, students in nursing programs can volunteer their services to nursing homes or other health care facilities, and so on. But engineering students, even early on in their programs, can volunteer tutorial services to the schools, particularly in areas of computer science, math, science, and technology that are relevant to engineering. For example, while at the University of South Alabama, Edmund Tsang’s Introduction to Mechanical Engineering course included a service learning project.[74] Engineering student teams worked with the Mobile school system and its Southeastern Consortium for Minorities in Engineering program. Students in this class designed equipment for teachers and middle-school students that illustrated basic principles of motion, energy, and force and mathematical modeling.

To illustrate the potential value of service learning projects for both students and those who benefit from their projects, it is helpful to discuss an example in some detail. This was a project undertaken some years ago by a group of electrical engineering students at Texas A&M in Tom Talley’s senior design course.[75] This course was intended to help prepare students for the challenges in project design and management that they will confront in industry. In this case, the students were also introduced to community service.

Team members were undecided about what project to undertake until Tom Talley shared with them a letter he had received from the Brazos Valley Rehabilitation Center. The letter identified a need for an auditory visual tracker (AVIT) to help in evaluating and training visual skills in very young children with disabilities. Most students, Talley said, end up only building a working prototype. However, in this case, he pointed out, “The students took on the project knowing that it was larger and potentially more expensive for them to produce than might be expected of a typical project.”

“We like that it was a project that was going to be genuinely used,” said team member Robert D. Siller, “It wasn’t going to just end up in a closet. It’s actually helping someone.” Myron Moodie added, “When we presented the AVIT to the center, we got to see some of the kids use it. It was worth it watching the way the children like it." However, completion of the project was anything but easy. One complication was that the team was interdisciplinary. It included a student from management, which meant that the team was introduced to the project management environment, giving the endeavor a more industry-like flavor than was typical of projects in Talley's design class. To further complicate matters, the management student was seriously injured in a car accident during the semester, but she was able to continue in the project. By the end of the semester, the project was not quite completed. However, the students were so committed to providing a usable AVIT for the rehabilitation center that they stayed on after the semester.

What seems obvious from student comments is that they found the service aspect of their experience very rewarding. Whether this encouraged them to continue to seek out community service opportunities once they were fully employed engineers can be, of course, only a matter for speculation. Another matter for speculation is that this experience speaks positively about the kinds of engineers these students could be expected to become in their places of employment. Tom Talley, at least, was quite optimistic. He said, "They clearly went above and beyond—that's Aggie spirit. Someone is going to get some fine young engineers." This comment can be taken to include what can be expected from these students both as engineers in the workplace and as civic-minded contributors to the public good.

This particular kind of project—one taken to completion and one involving direct interaction with those being helped—can enhance students' understanding and appreciation of responsibilities they have both on the job and in community service. In this case, the project went well beyond designing a prototype; everything worked out well. However, this required very careful attention to the specific needs of the center's staff and the children who were in need of assistance. This is a very important lesson in responsible engineering, whether volunteer or work related.

From a service learning perspective, two limitations of this example should be noted. First, although the students apparently did reflect on the significance of the service aspects of their experience, this was not a specific objective of the project. Service learning is distinguished by its deliberate combining of service and study: "One of the characteristics of service learning that distinguishes it from volunteerism is its balance between the act of community service by participants and reflection on that act, in order both to provide better service and to enhance the participants' own learning."[76] This project was not simply an instance of volunteerism; it was a class project. However, it was a project primarily in engineering design and, from the perspective of the class, only incidentally did it involve community service. Nevertheless, this is the sort of project that could be undertaken with the full service learning objectives in mind; many of those objectives were, in fact, fulfilled even though this was not part of the official class agenda.

Second, a point related to the first, the AVIT project stood virtually alone. There may have been other projects that lent themselves to service learning objectives that were undertaken by students in Tom Talley's design class or in other design classes at Texas A&M. But service learning in engineering as a planned, coordinated activity requires a much more sustained effort. A second example illustrates this point.

An early service learning program in engineering, the student-initiated Case Engineering Support Group (CESG) at Case Western Reserve University, was founded in 1990 as a nonprofit engineering service organization composed of engineering students who "design and build custom equipment to assist the disabled in therapy or normal daily activities."[77] According to the CESG brochure, the equipment is given to individuals at therapy centers at no cost. CESG has received donations of equipment from industry, financial support from the National Science Foundation and the Case Alumni Association, legal services from Case's Law School Clinic, and cooperation and support from the medical and health care community in Cleveland.

In CESG's first year, 18 students completed 6 projects. During the 1995–1996 academic year, 120 students completed 60 projects, as well as follow-up work on previous projects. At that time, CESG supported four major programs:[78]

- Custom Product Development Program: working with faculty members designing, manufacturing, and providing at no cost to individuals' adaptive devices and equipment to help them gain a higher level of independent living skills; working with physicians and physical, occupational, and speech therapists in adapting, modifying, and providing devices and equipment.

- Technology Lender Program: repairing and adapting donated computer equipment and designing specialized software for those with special communication, vocational, or educational needs.
- Toy Modification Program: providing specially adapted toys to families of children with disabilities and to hospitals, and presenting related workshops to junior and senior high-school students to stimulate interest in engineering as a career.
- Smart Wheelchair Project: working with the Cleveland Clinic Foundation's Seating/Wheeled Mobility Clinic, Invacare Corporation, and engineers at the NASA Lewis Research Center to design, modify, and improve the "smart wheelchair," which is fit with special sensors and artificial intelligence routines.

Recent years have seen the rapid growth of service learning programs in engineering. The *International Journal for Service Learning in Engineering* was launched in 2006. This periodical provides detailed accounts of service learning projects written by faculty and students. Learn and Serve America's National Service-Learning Clearinghouse provides a comprehensive list of web resources on service learning in engineering, as well as a list of print resources (https://gsn.nylc.org/). Three web references warrant special mention here:

Engineers Without Borders (www.ewb-usa.org). Established in 2000, this is a national, nonprofit organization that offers help developing areas throughout the world with their engineering needs. It has the goal of "involving and training a new kind of internationally responsible engineering student." This website lists all the EWB-USA registered student chapters, along with their websites. EWB-USA also has a *Wikipedia* entry (http://en.wikipedia.org). It is identified as a member of the "Engineers Without Borders" international network. EWB-USA's projects typically involve the design and construction of water, sanitation, energy, and shelter systems in projects initiated by and completed with the host communities. According to the *Wikipedia* entry, "These projects are initiated by, and completed with, contributions from the host community, which is trained to operate the systems without external assistance. In this way, EWB-USA ensures that its projects are appropriate and self-sustaining."

Engineering Projects in Community Service (EPICS) National Program (https://engineering.purdue.edu/EPICS/university). EPICS is described as integrating "highly mentored, long-term, large-scale, team-based, multidisciplinary design projects into the undergraduate engineering curriculum. … Teams work closely with a not-for-profit organization in the community to define, design, build, test, deploy, and support projects that significantly improve the organization's ability to serve the community."

Service-Learning in Engineering: A Resource Guidebook (www.compact.org/publications). Developed by William Oaks and published by Campus Compact, this guidebook introduces the idea of service learning in engineering and provides models from the EPICS program, course descriptions and syllabi, and evaluation tools. It can be downloaded from the Campus Compact website.

CASE 24

Software for a Library[79]

A small library seeks a software system to catalogue its collection and keep records of materials checked out of the library. Currently, the records of who has checked out what, when materials are due, and the like are kept in a file drawer behind the check-out desk. These records are confidential. Patrons are assured that these records are not accessible to anyone other than library personnel. But, of course, drawers can be opened when no one is looking. What assurance is there that the software systems under consideration will provide as much, if not greater, security? Assuming that no one in the library is a software specialist, the library has no alternative but to place its trust in someone who presumably has the requisite expertise. How concerned should that expert be (again, bearing in mind that even the best system is not completely sleuthproof)? Furthermore, what assurance has the library that it is not being oversold or undersold in general? To what extent should software specialists be concerned with determining precisely what the various needs of the library are—and to try to meet those needs rather than offer more than is necessary in order to secure greater profit or less than is needed in order to come in with a lower bid?

CASE 25

Sustainability

Scientists, engineers, and the government are publicly expressing urgent concern about the need to address the challenges of sustainable scientific and technological development. Global warming, for example, raises concern about glacial meltdown and consequent rising ocean levels threatening coastal cities. A related concern is the lowering of levels of freshwater in the American West as a result of lowered levels of accumulated mountain snow. In Joe Gertner's "The Future Is Drying Up," Nobel laureate Steven Chu, director of the Lawrence Berkeley National Laboratory, is cited as saying that even optimistic projections for the second half of the twenty-first century indicate a 30 to 70 percent drop in the snowpack level of the Sierra Nevada, provider of most of northern California's water.[80] Gertner goes on to discuss other likely freshwater problems that will have to be faced by Western states as a result of both global warming and the consumption needs and demands of an increasing population. He also outlines some of the efforts of engineers to address these problems aggressively now rather than wait until it is too late to prevent disaster.[81]

We noted in Chapter 7 that most engineering society codes of ethics do not make direct statements about the environmental responsibilities of engineers. However, in 2007, the NSPE joined the ranks of engineering societies that do. Under section III. Professional Obligations, provision 2 reads, "Engineers shall at all times strive to serve the public interest." Under this heading, there is a new entry, d: "Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations." Footnote 1 addresses the conceptual question of what is meant by "sustainable development":

> "Sustainable development" is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development.

Although this definition of sustainable development leaves many fundamental conceptual and value questions in need of further analysis (e.g., What are human needs? What is meant by "environmental quality"?), it provides a general framework for inquiry. It also identifies a variety of fundamental areas of concern (e.g., food, transportation, and waste management). Of course, responsibilities in these areas do not fall only on engineers. Government officials, economists, business leaders, and the general citizenry need to be involved as well. Thus, a basic question relates to how those who need to work together might best do so and what role engineers might play. We offer three illustrations for discussion. The first is an early effort to involve students from different disciplines in a project that supports sustainable development. The second is the recent proliferation of centers and institutes for sustainability on college campuses throughout the country. The third is service learning opportunities in support of sustainable design and development.

Renewable Energy[82]

Dwayne Breger, a civil and environmental engineer at Lafayette College, invited junior and senior engineering, biology, and environmental science students to apply to be on an interdisciplinary team to design a project that would make use of farmland owned by Lafayette College in a way that supports the college mission. Twelve students were selected for the project: two each from civil and environmental engineering, mechanical engineering, chemical engineering, and bachelor of arts in engineering, plus three biology majors and one in geology and environmental geosciences. These students had minors in areas such as economics and business, environmental science, chemistry, government, and law. The result of the project was a promising design for a biomass farm that could provide an alternative, renewable resource for the campus steam plant.[83]

Professor Breger regards projects such as this as providing important opportunities for students to involve themselves in work that contributes to restructuring our energy use toward sustainable resources. ABET's *Engineering Criteria 2000* for evaluating engineering programs includes the requirement that engineering programs demonstrate that their graduates have "an understanding of professional and ethical responsibility," "the broad education necessary to understand the impact of engineering solutions in a global and societal context," and "a knowledge of contemporary issues." Criterion 4 requires that students have "a major design experience" that includes consideration of the impact on design of factors such as economics, sustainability, manufacturability, ethics, health, safety, and social and political issues.[84] Discuss how the Lafayette College project might satisfy criterion 4, especially the ethical considerations.

Academic Centers for Sustainability

Historically, joint research in colleges and universities is done within separate disciplines rather than in collaboration with other disciplines. Thus, biologists collaborate with other biologists, chemists with other chemists, economists with other economists, and political scientists with other political scientists. The recent emergence of centers and institutes for sustainability represents a significant and important break from that tradition.

In September 2007, the Rochester Institute of Technology initiated the Golisano Institute for Sustainability.[85] Noting that it is customary for new programs to be run by just one discipline, Nabil Nasr, the institute director, comments, "But the problem of sustainability cuts across economics, social elements, engineering, everything. It simply cannot be solved by one discipline, or even by coupling two disciplines."[86]

Dow Chemical has recently given the University of California at Berkeley $10 million to establish a sustainability center. Dow's Neil Hawkins says, "Berkeley has one of the strongest chemical engineering schools in the world, but it will be the MBA's who understand areas like microfinance solutions to drinking water problems."[87] The center is in Berkeley's Center for Responsible Business, directed by Kellie A. McElhaney. Commercialization of research undertaken by students and professors is expected. However, McElhaney notes, "Commercialization takes forever if the chemical engineers and the business types do not coordinate. So think how much easier it will be for chemistry graduates to work inside a company if they already know how to interact with the business side."[88]

Discuss how considerations of ethics might enter into the collaborative efforts of centers and institutes for sustainability.

Service Learning Opportunities

The first two issues of the recently launched *International Journal for Service Learning* feature three articles promoting the notion that service learning projects can provide hands-on opportunities to undertake sustainable design and development. In "Service Learning in Engineering and Science for Sustainable Development," Clarion University of Pennsylvania physicist Joshua M. Pearce urges that undergraduates should have opportunities to become involved in projects that apply appropriate technologies for sustainable development.[89] Especially concerned with alleviating poverty in the developing world, Pearce argues,

> The need for development is as great as it has ever been, but future development cannot simply follow past models of economic activity, which tended to waste resources and produce prodigious pollution. The entire world is now paying to clean up the mess and enormous quantities of valuable resources have been lost for future generations because of the Western model of development. For the future, the entire world population needs

ways to achieve economic, social, and environmental objectives *simultaneously*.

He cites successful projects in Haiti and Guatemala that make use of readily available materials in the locales in which they have been undertaken.

In "Learning Sustainable Design through Service," Stanford University PhD students Karim Al-Khafaji and Margaret Catherine Morse present a service learning model based on the Stanford chapter of Engineers for a Sustainable World to teach sustainable design.[90] They illustrate this model in discussing a Stanford project in the Andaman Islands that focused on rebuilding after the December 26, 2004, earthquake and tsunami. Behind such projects is a student-led course, "Design for a Sustainable World," that seeks to

- Develop students' iterative design skills, project management and partnership-building abilities, sustainability awareness, cultural sensitivity, empathy, and desire to use technical skills to promote peace and human development.
- Help developing communities ensure individuals' human rights via sustainable, culturally appropriate, technology-based solutions.
- Increase Stanford University's stewardship of global sustainability.[91]

In "Sustainable Building Materials in French Polynesia," John Erik Anderson, Helena Meryman, and Kimberly Porsche, graduate students at the University of California at Berkeley's Department of Civil and Environmental Engineering, provide a detailed, technical description of a service learning project designed to assist French Polynesians in developing a system for the local manufacturing of sustainable building materials.[92]

CASE 26

TV Antenna[93]

Several years ago, a TV station in Houston decided to strengthen its signal by erecting a new, taller (1,000-foot) transmission antenna in Missouri City, Texas. The station contracted with a TV antenna design firm to design the tower. The resulting design employed twenty 50-foot segments that would have to be lifted into place sequentially by a jib crane that moved up with the tower. Each segment required a lifting lug to permit that segment to be hoisted off the flatbed delivery truck and then lifted into place by the crane. The actual construction of the tower was done by a separate rigging firm that specialized in such tasks.

When the rigging company received the 20th and last tower segment, it faced a new problem. Although the lifting lug was satisfactory for lifting the segment horizontally off the delivery truck, it would not enable the segment to be lifted vertically. The jib crane cable interfered with the antenna baskets at the top of the segment. The riggers asked permission from the design company to temporarily remove the antenna baskets and were refused. Officials at the design firm said that the last time they gave permission to make similar changes, they had to pay tens of thousands of dollars to repair the antenna baskets (which had been damaged on removal) and to remount and realign them correctly.

The riggers devised a solution that was seriously flawed. They bolted an extension arm to the tower section and calculated the size of the required bolts based on a mistaken model. A sophomore-level engineering student who had taken a course in statics could have detected the flaw, but the riggers had no engineers on their staff. The riggers, knowing they lacked engineering expertise, asked the antenna design company engineers to review their proposed solution. The engineers again refused, having been ordered by company management not only not to look at the drawings but also not to visit the construction site during the lifting of the last segment. Management of the design firm feared that they would be held liable if there were an accident. The designers also failed to suggest to the riggers that they should hire an engineering consultant to examine their lifting plans.

When the riggers attempted to lift the top section of the tower with the microwave baskets, the tower fell, killing seven men. The TV company was taping the lift of the last segment for future TV promotions, and the videotape shows the riggers falling to their death.

Consider how you would react to watching that tape if you were the design engineer who refused to look at the lifting plans or if you were the company executive who ordered the design engineer not to examine the plans.

To take an analogy, consider a physician who examines a patient and finds something suspicious in an area outside her specialty. When asking advice from a specialist, the physician is rebuffed on the grounds that the specialist might incur a liability. Furthermore, the specialist does not suggest that the patient should see a specialist.

What conceptions of responsibility seemed most prevalent in this case? Can you suggest other conceptions that might have helped avoid this tragedy?

CASE 27

Scientists and Responsible Citizenry

As a young man, Harrison Brown (1917–1986) played a prominent role in the Manhattan Project at the University of Chicago and Oak Ridge. In 1943, he became assistant director of chemistry for the Oak Ridge Plutonium Project. During the very few years it took to develop the atomic bomb, Brown and many of his fellow research scientists had serious and deep discussions of their responsibilities as scientists. After the bomb was used in 1945, Brown immediately wrote a book, *Must Destruction Be Our Destiny?* (Simon & Schuster, 1946), in which he articulated his concerns and those of his colleagues. An ardent advocate for the establishment of an international body that could peaceably control the spread and possible use of atomic weapons, in the space of 3 months in 1946, he gave more than 100 speeches throughout the country presenting the basic arguments of his book.

It is noteworthy that on the jacket of this book, Albert Einstein is quoted as saying the following:

> One feels that this book is written by a man who is used to responsible work. It gives a clear, honest, and vivid description of the atom bomb as a weapon of war, objective and without any exaggeration. It gives a clear discussion, free of rhetoric, of the special international problems and the possibilities for their solution. Everyone who reads this book carefully will be enabled—and one hopes stimulated—to contribute to a sensible solution of the present dangerous situation.

It is also noteworthy that the subtitle of *Must Destruction Be Our Destiny?* is *A Scientist Speaks as a Citizen.* This subtitle reflects the modesty, yet firmness of conviction, with which Brown undertook his effort to communicate his concerns to the public. He was very sensitive to the claim that scientists should restrict themselves to questions of science. Without crediting scientists with special expertise regarding the social or political implications of science and technology, he responded by pointing out that scientists working on the atomic bomb had the advantage of knowing about the potential uses and consequences of this weapon some time before the general public did, and they had given this much careful thought. Convinced that the "man in the street" needs to be well informed before presenting social and political opinions about matters of great importance, Brown held that scientists have a responsibility to acquire and communicate needed information to lay audiences so that they are able to exercise better judgment.

As for himself, Brown said in his preface, "I have written as a man in the street, as an ordinary citizen, possessing primarily the fundamental desires to live freely, comfortably, and unafraid." Implicit here is the notion that *this* ordinary citizen also possessed information needed by all other ordinary citizens—information that, he was convinced, would enable them to join hands with those scientists who "have had the advantage of months and years to become acquainted with the problems and to think of them as would any reasonably literate and sensitive persons." He added, "As scientists we have indicated the problems—as citizens we have sought the answers."

Of course, Harrison Brown the scientist and Harrison Brown the ordinary citizen were one and the same person. He also chose to pursue a career at the California Institute of Technology, holding joint appointments in the geology and humanities divisions. In other words, he deliberately chose an interdisciplinary path in higher education. This is further reflected in his joining the Emergency Committee of Atomic Scientists as vice chair (with Albert Einstein serving as chair) in 1947, his role as editor-in-chief of *The Bulletin of Atomic Scientists*, his service as foreign secretary of the National Academy of Sciences (1962–1974), and his service as science advisor to the presidential campaigns of Adlai Stevenson and Robert Kennedy.

Apparently, Harrison Brown's commitments as citizen–scientist did not interfere with his commitments to "pure science." He continued his scientific studies on meteorites, along with work in mass spectroscopy, thermal diffusion, fluorine and plutonium chemistry, geochemistry, and planetary structure. In 1947, at age 30, he became the youngest scientist ever to receive the annual award for making "the most notable contribution to science," based on his report, "Elements in Meteorites and the Earth's Origins." In 1952, he received the American Chemical Society's Award in Pure Chemistry.

In his second book, *The Challenge of Man's Future* (Viking Press, 1954), and in subsequent writings throughout the next three decades, Harrison Brown argued that technological advancement, population growth, the desire for increased living standards throughout the world, and limited food, mineral, and energy resources call for urgent consideration by scientists and ordinary citizens alike. Convinced that we have the power, intelligence, and imagination to deal with the challenges posed by these developments, he insisted, however, that this "necessitates an understanding of the relationships between man, his natural environment, and his technology."

The comments of three Nobel Prize winners were quoted on the jacket of this second book. One of them, Albert Einstein, said,

> We may well be grateful to Harrison Brown for this book on the condition of mankind as it appears to an erudite, clear-sighted, critically appraising scientist. … The latest phase of technical–scientific progress, with its fantastic increase of population, has created a situation fraught with problems of hitherto unknown dimensions. … This objective book has high value.

Harrison Brown died in 1986. Twenty years later, Harvard University's John Holdren, Teresa and John Heinz professor of environmental policy and director of the program on science, technology, and public policy in the John F. Kennedy School of Government, recalled reading *The Challenge of Man's Future* years before as a high-school student. In a speech titled, "Science, Technology, and the State of the Word: Some Reflections after September 11," he said that prior to reading that book and C. P. Snow's *The Two Cultures*, his ambition was to become the chief design engineer at Boeing. Moved by these books, he decided that, instead, he wanted to "work on the great problems of the human condition that sit at the intersection of disciplines, the intersection of the natural sciences and the social sciences where science, technology, and the public policy come together."[94]

At the outset of his speech, Holdren said that he would be sharing his reflections in the way he thought Harrison Brown would if he were still alive—focusing on what we can now (and should have been able to earlier) clearly understand about the relationships among science, technology, and the state of the world prior to September 11, 2001. Most important, he indicated that he would be talking "in terms of what socially responsible scientists and technologists should be striving to contribute to these issues, not just the issues in the aftermath of September 11th but the still wider ones at this immensely important intersection of science and technology and the human condition."

CASE 28

Where Are the Women?[95]

Although women have become more prevalent in engineering schools during the past few decades, they still make up only approximately 20 percent of engineering school undergraduates in the United States. Even this percentage is somewhat misleading. Women are more prevalent in some engineering fields than others. For example, more than 30 percent of the undergraduates in chemical engineering departments are women, but only 13 percent of the undergraduates in mechanical engineering and electrical engineering are women.[96] Eighteen percent of all engineering PhDs are awarded to women. There are even fewer women faculty in engineering schools. The higher the faculty rank, the fewer women there are. At the top rank of full professor, less than 5 percent are women.[97] This means that engineering students in the United States are taught and mentored almost exclusively by males, that there are few women faculty serving as role models for female students, and that engineering more generally remains dominated by men.

As interesting comparisons, women receive 57 percent of all baccalaureate degrees in the United States and 55 percent of all social science PhDs, women make up at least 50 percent of the students in medical and law schools, and 28 percent of full professors in the social sciences are women.[98] Therefore, what is happening in engineering schools? No doubt, there are a number of contributing factors to the fact that there are so few women in engineering. But many common beliefs about women and academic advancement in engineering prove to be without merit when the evidence is examined.

Belief	**Evidence**
1. Women are not as good in mathematics as men.	Female performance in high-school mathematics now matches that of males.
2. It is only a matter of time before the issue of "underrepresentation" on faculties is resolved; it is a function of how many women are qualified to enter these positions.	Women's representation decreases with each step up the tenure track and academic leadership hierarchy, even in fields that have had a large proportion of women doctorates for 30 years.
3. Women are not as competitive as men. Women do not want jobs in academe.	Similar proportions of men and women with science and engineering doctorates plan to enter postdoctoral study or academic employment.
4. Women and minorities are recipients of favoritism through affirmative action programs.	Affirmative action is meant to broaden searches to include more women and minority group members but not to select candidates on the basis of race or sex, which is illegal.
5. Academe is a meritocracy.	Although scientists like to believe that they "choose the best" based on objective criteria, decisions are influenced by factors—including biases about race, sex, geographic location of a university, and age—that have nothing to do with the quality of the person or work being evaluated.
6. Changing the rules means that standards of excellence will be deleteriously affected.	Throughout a scientific career, advancement depends on judgments of one's performance by more senior scientists and engineers. This process does not optimally select and advance the best scientists and engineers because of implicit bias and disproportionate weighting of qualities that are stereotypically male. Reducing these sources of bias will foster excellence in science and engineering fields.
7. Women faculty are less productive than men.	The publication productivity of women science and engineering faculty has increased during the past 30 years and is now comparable to that of men. The critical factor affecting publication productivity is access to institutional resources; marriage, children, and elder care responsibilities have minimal effects.

(*Continued*)

Belief	Evidence
8. Women are more interested in family than in careers.	Many women scientists and engineers persist in their pursuit of academic careers despite severe conflicts between their roles as parents and as scientists and engineers. These efforts, however, are often not recognized as representing the high level of dedication to their careers they represent.
9. Women take more time off due to childbearing, so they are a bad investment.	On average, women take more time off during their early careers to meet caregiving responsibilities, which fall disproportionately to women. However, by middle age, a man is likely to take more sick leave than a woman.
10. The system as currently configured has worked well in producing great science; why change it?	The global competitive balance has changed in ways that undermine America's traditional science and engineering advantages. Career impediments based on gender, racial, or ethnic bias deprive the nation of talented and accomplished researchers.[99]

Recently, a number of academic researchers have attempted to separate the myths from the facts about why so few women hold senior-level and leadership engineering positions. One plausible explanation is that slight disparities accumulate over time to disadvantage women and advantage men. Subconscious expectations tied to gender (gender schemas) are an important source of these disparities. We expect, for example, men to be the primary earners and women to be the primary providers of child care. A full range of studies on the influence of gender schemas in assessments of professional competence shows quite convincingly that over time, gender schemas contribute significantly to female engineering faculty being consistently underrated and male engineering faculty being consistently overrated.[100] Gender schemas are held unconsciously by both men and women and subtly influence perceptions and judgments made about one another.[101] Experimental data show, for example, that letters of reference for professional women tend to be shorter and to contain twice as many doubt-raisers (e.g., "she has a somewhat challenging personality"), more grindstone adjectives (e.g., "hardworking" or "conscientious"), and fewer standout adjectives (e.g., "brilliant") as letters for men.[102] Other studies show that women tend to feel less entitled to high salaries and less confident in their mathematical abilities even when their actual performance levels equal those of male peers. Men are expected to be strong and assertive (leaders) and women to be nurturing listeners. As a result, women holding positions of leadership often must work harder to demonstrate actual leadership.

Because most of the faculty and administrators at engineering schools, both male and female, genuinely wish to advance and promote more women, focusing on gender schemas is especially relevant to advancing women in engineering fields. Virginia Valian, a researcher on gender schemas, makes this point. She writes, "The moral of the data on gender schemas is that good intentions are not enough; they will not guarantee the impartial and fair evaluation that we all hold as an ideal."[103] As engineering schools attempt to recruit and advance more women, it is important to assess the ways in which and the degree to which harmful gender schemas serve as barriers to women's advancement. At some institutions, such as the University of Michigan, such efforts have involved conducting gender schema workshops, forming focus groups, conducting interviews, and collecting survey data to assess the prevalence of gender schemas contributing to underrating women faculty in science, technology, engineering, and mathematics fields.[104]

One hypothesis is that once the harmful implicit schemas are made explicit, we can begin to address them at individual, departmental, and institutional levels and, at the very least, decrease their harmful impact. Identify and discuss some of the subtle expectations both men and women have about gender. How do these gender schemas influence the advancement and promotion of women in engineering? Can you think of any examples from your own experience of men being advantaged and women being disadvantaged as a result of gender schemas?

CASE 29

The 2010 Macondo Well Blowout and Loss of the Deepwater Horizon

The Deepwater Horizon was a $340 million semisubmersible deep water drilling rig owned and operated by Transocean. Transocean was contracted by British Petroleum (BP) to drill the 18,360 ft Macondo well in about 5,000 feet of water in the Gulf of Mexico about 40 miles off the coast of Louisiana. Deepwater Horizon drilling operations, planned for 51 days at a cost of about $1 million per day, began at the Macondo well site in February 2010, resuming drilling operations that had been initiated in October 2009 by another rig. The well was being shut in and abandoned (for later production) on April 20, 2010, when an explosion and fire resulted in the loss of 11 lives (out of 126 workers on the rig at the time), the sinking of the rig, and a prolonged uncontrolled release of oil and gas from the wellhead on the seafloor. Efforts to control the well were unsuccessful for months, resulting in the largest oil spill in U.S. history. As of July 2016, well owner BP has spent nearly $62 billion for clean-up and compensations for damages resulting from the Macondo blowout.

House Committee on Energy and Commerce hearings in the weeks following the disaster focused attention on several aspects of the drilling and completion operations that suggest owner BP repeatedly cut corners to reduce costs with several risky design decisions. What follows is from testimony to the committee as summarized in a June 14, 2010 letter from the Committee Chairman Henry Waxman to BP CEO Tony Hayward that outlines five areas where questionable decisions were made by BP managers and engineers seemingly favoring economy over safety.[105] These areas were well design, the number of centralizers used in cementing the final string of casing, a decision not to require a cement bond log, abbreviated mud circulation prior to cementing the final string of casing, and a decision not to use a lockdown sleeve.

- *Well Design*: A critical decision in the design of the Macondo well was to use a full string casing in the final 1192 feet of the wellbore rather than the more conservative liner/tieback casing design. Full string casing is faster and therefore less expensive than the liner/tieback casing design, but does not offer as much redundancy in the control of gas in the annular space surrounding the casing, and it may have failed to meet Minerals Management Service (MMS) regulations. This conscious decision by BP in the final days before the blowout reduced the cost of the well completion by several million dollars, but with a reduction in safety against blowout.
- *Centralizers*: Centralizers are annular spacers that center the casing in the borehole prior to cementing to improve displacement of mud by the cement slurry. When casing is not centered in the wellbore, American Petroleum Institute (API) Recommended Practice 65 says that mud will not effectively be displaced by the slurry, which can result in weak or porous cement seals, leading to gas leakage and the risk of blowout. BP chose to use six centralizers on the final 1192 feet of casing despite predictions by the contractor Halliburton that 21 centralizers were required to reduce the risk of a gas flow problem from "severe" to "minor." An additional 15 centralizers were located, but evidently the time required to get them to the rig, 10 hours, represented an unacceptable delay, so the decision was made to use only the six available centralizers.
- *Cement Bond Log*: This standard nondestructive test is designed to detect if any mud inclusions or other problems have caused voids or channels in the cement seal, reducing the integrity of the cement seal. MMS regulations may have required such a test on the Macondo well. BP flew a Schlumberger crew to the rig on April 18 to stand by to perform such a test, but dismissed them on April 20. A cement bond test on the Macondo well would have taken about 9–12 hours, and the

discovery of any voids in the cement would have led to further delay.

- *Mud Circulation*: Before the cement slurry is placed in the annular region, displacing the mud to form the annular seals, it is good practice to circulate the mud to remove cuttings, gas bubbles, and decrease the viscosity of the mud to allow better cement flow and mud displacement. API guidelines recommend circulating the greater of 1.5 annular volumes of mud or 1.0 casing volume, at a minimum. Circulating this much mud takes time, perhaps as much as 12 hours on the Macondo well, and BP chose to circulate a much smaller amount, 261 barrels of mud.
- *Casing Hanger Lockdown Sleeve*: BP had not installed a casing hanger lockdown sleeve (LDS) designed to lock the wellhead and casing in the seal assembly at the seafloor. This may have just been a delay while waiting for MMS approval of a design change, but the end result was that an LDS not installed at the time of the April 20 blowout. LDS devices represent another safety feature against blowouts by preventing the casing from rising up and damaging the wellhead seal.

In at least the first four of these questions raised by the committee, it appears that BP engineers' and managers' design decisions represented the faster (cheaper) and less conservative (riskier) alternatives. Well team leader John Guide reportedly reversed drilling engineering team leader John Walz's decision to order the additional 15 centralizers because of the 10-hour delay for delivery. In making this decision, Guide reportedly made use of a "risk/reward equation," but the details of that decision are not public knowledge. The "risk/reward" approach is a management tool commonly used in making investment and stock-trading decisions, and is not common engineering terminology, suggesting that this critical engineering decision may have been based on logic foreign to engineering, perhaps without an appropriate engineering consideration of public health, safety, and welfare.

A summary report[106] by a blue-ribbon panel of the National Academy of Engineering (NAE) identified several findings that contributed to the disaster. Briefly, these findings confirm that there were engineering failures in designing, constructing, and testing the cement seals intended to contain the pressurized hydrocarbons in the Macondo well during subsequent abandonment, and a failure to recognize clear symptoms that the seals were leaking during negative pressure tests. Furthermore, the failure of the blowout preventer (BOP) was attributed to engineering failures in designing, testing, operating, and maintaining the BOP. The report faults a lack of a strong safety culture because of a deficient overall systems approach to safety for the "multiple flawed decisions that led to the blowout."

The personnel in the BP chain of command responsible for these questionable decisions did not include many, if any, registered professional engineers, which raises another very important question about BP's operation and culture. The rules of the Texas Board of Professional Engineers (and probably those boards in other gulf states) do not require licensure of Houston-based individuals holding these jobs, because an exemption in Texas law allows individuals employed by industrial employers who do not offer services to the public to perform engineering work without being licensed. But the apparent absence or scarcity of licensed engineers in this chain of command raises serious questions about the level of professionalism behind several critical engineering decisions. The team responsible for design and drilling of the well included numerous experienced but unlicensed individuals, but the only licensed engineer the authors have identified having any authority over operations at the Macondo well was David Sims, an experienced and licensed (Texas) professional engineer who was assigned to be John Guide's supervisor only 18 days before the blowout, perhaps in response to reported difficulties in drilling the "well from hell." Whether his earlier assignment to this project might have resulted in better engineering decision-making in response to the critical events during the drilling and abandonment process can only be speculated, but it is the author's belief that unprofessional decision-making, likely influenced by the pressures of time and cost, was the most significant factor contributing to this disaster.

One comment in the House Committee letter, attributed to BP drilling engineer Brian Morel, suggests that BP discounted or ignored, without technical justification, a contractor's quantitative simulations that indicated the use of only six centralizers would not ensure a safe cement job—the kind of decision a professional engineer would surely not make. Morel's e-mail to the contractor said, "We have 6 centralizers, we can run them in a row, spread out, or any combination of the two. It's a vertical hole, so *hopefully* the pipe stays centralized due to gravity … it's too late to get any more product on the rig. Our only option is to rearrange placement of these centralizers" (emphasis added). The essence of engineering is the reliance on accurate quantitative simulations to develop safe designs, yet Morel's comment suggests that the decision may have relied on "hope" rather than calculated safety. One would expect an experienced professional engineer would have not made or accepted a decision based on *hope*. The authors believe that the industry exemption to engineering registration requirements, or the overreliance on that exemption by some employers involved in this incident, deserves much of the blame for this disaster.

Finally, the oversight by the MMS has been questioned. Many aspects of the design process appear to have been approved without challenge by the MMS or justification by BP. The choice of a single string of casing instead of the potentially safer liner/tieback casing was approved the same day it was requested. While excessive regulatory oversight can stifle economic growth, safety in some industries necessarily relies on responsible and competent regulatory oversight, and that appears to have been lacking in this case.

A question for discussion: The apparent link between critical engineering decision-making by unlicensed engineers and the Macondo blowout suggests a serious problem with the so-called "industry exemption" that allows unlicensed individuals to perform engineering services for employers so long as their services are not offered to the public—the safety, health, and welfare of the public (and the natural environment) seems to be at higher risk. Yet, industrial employers argue that if this practice were not permitted, if anyone performing any engineering service was required to be a licensed engineer, the cost of industry operations would increase because of a shortage of licensed engineers, harming the economy (and public welfare). Is there some creative middle-way public policy that might satisfy both of these competing ethical obligations?

CASE 30

Units, Communications, and Attention to Detail—the Loss of the Mars Climate Orbiter

The Mars Climate Orbiter was a 629 kg Mars satellite launched by NASA on December 11, 1998, with a mission to map the Martian surface and atmosphere for about two years and serve as a communications relay station for future Mars landers for about three additional years. The Orbiter was lost during entry into Martian orbit; it is presumed to have burned up during atmospheric entry or overheated and skipped into space.

The following, taken from the official report of the investigation into the loss of the Climate Orbiter, indicates the probe was inserted into Mars orbit much lower in the atmosphere than designed because of cumulative navigation errors resulting from the use of data in English units provided by a contractor in onboard calculations requiring metric units.[107]

> At the time of Mars insertion, the spacecraft trajectory was approximately 170 kilometers lower than planned. As a result, MCO either was destroyed in the atmosphere or re-entered heliocentric space after leaving Mars' atmosphere. The Board recognizes that mistakes occur on spacecraft projects. However, sufficient processes are usually in place on projects to catch these mistakes before they become critical to mission success. Unfortunately for MCO, the root cause was not caught by the processes in-place in the MCO project.
>
> A summary of the findings, contributing causes and MPL recommendations are listed below. These are described in more detail in the body of this report along with the MCO and MPL observations and recommendations.
>
> Root Cause: Failure to use metric units in the coding of a ground software file, "Small Forces," used in trajectory models.

In addition, the report lists eight contributing causes, including inadequate communications between project elements, inadequate staffing, and inadequate training.

Consider the responsibility of engineers in organizations to satisfy the "standard of care," that is, to make sure that their errors and omissions are no more in number or in significance that would be made by other competent engineers working in the same field. Discuss how engineers working in multiple large organizations on large projects can be sure that the standard of care expected by the public is satisfied.

CASE 31

Expensive Software Bug—the Loss of the Mars Polar Lander

On December 3, 1999, 11 months after its launch, the Mars Polar Lander communications with NASA halted abruptly during descent to the Martian surface. Subsequent investigations identified several possible failure mechanisms but focused on a coding error in one line of software. It is theorized that the programming error allowed the system to misinterpret vibrations of the craft's extended landing gear as touchdown on the Martian surface, triggering a premature shutdown of the braking rockets and a subsequent free fall of about 130 feet, which destroyed the lander.

Some interpret this failure as an outcome of increasingly complex computer programs and believe that NASA's testing of large and complex codes cannot always identify and prevent all possible errors. It has been suggested that too often testing is done to demonstrate that the codes work as intended when all input is within an expected range of "normal" operations, but not enough testing is done to ascertain possible outcomes whenever operational parameters vary into abnormal territory.

Leveson[108] cites several aspects of software design, testing, and operations that have contributed to recent aerospace failures or incidents, including:

- Overconfidence and overreliance on digital automation
- Not understanding the risks associated with the software
- Confusing reliability and safety a tendency of computer scientists in general
- Overrelying on redundancy (redundancy influences reliability more than safety)
- Assuming risk decreases over time (Therac-25)
- Ignoring warning signs in software incidents (related to what has been called "normalization of deviance")
- Inadequate cognitive engineering
- Inadequate specifications—specifications sometimes include what the software was supposed to do, but no mention of what it *must not* do (Mars Polar Lander)
- Flawed review process (Mars Polar Lander)
- Inadequate system safety engineering
- Violation of basic safety engineering practices in the digital parts of the system—software engineers are almost never taught these principles (Mars Polar Lander)
- Software reuse without appropriate safety analysis
- Unnecessary complexity and software functions—Creeping featurism (Keep it simple, stupid!)
- Operational personnel not understanding the automation
- Test and simulation environments that do not match the operational environment (Fly what you test and test what you fly!)
- Deficiencies in safety-related information collection and use

CASE 32

A Construction Inspector's Responsibility in Collapsed Cantilevered Balcony

No engineer was involved in the project, which is common for residential structures like this one, but the same ideas about ethical responsibility in design and construction oversight apply to engineers with these responsibilities.

In 2004, two visitors to a recently constructed Central Texas lakeside residence walked out onto a third-floor balcony to enjoy the new view of Inks Lake, but the balcony collapsed and both fell more than 20 feet, which caused serious injuries.[109] The cantilevered balcony had been attached to a ledger board that was nailed to the structure by the framing subcontractor instead of bolted as specified by the architect. The ledger board separated from the structure under dead load plus a very light live load (the two visitors). The architect designed the structure, including the balconies, and oversaw the construction but did not inspect the finished balcony closely enough to detect the deviation from his plans and specifications.

The architect's contract required that he sign off on the contractor's pay applications as assurance that "the quality of workmanship and materials used conforms with the contract documents." But the contract also said that, "The architect shall not be required to make exhaustive or continuous on-site inspections to check the quality or quantity of the work."

The legal argument centered on whether the architect should have done more to inspect the structure, with the plaintiffs arguing that he was contracted to "observe construction" and "endeavor to guard the owner against defects and deficiencies" in addition to providing his design services. The defendant architect argued that his inspection could not be detailed for that fee and that he had properly discharged his responsibility for construction observation.

A general counsel for the Texas Society of Architects wrote, "unless the project's owner retains the architect to provide more extensive services, the architect's on-site duties are limited and do not include exhaustive or continuous on-site inspections to check the quality of the construction work performed by the contractor. … The architect cannot be expected to guarantee the quality of the contractor's work, however, unless the architect has agreed to provide the additional services that would be necessary to enable the architect to provide that assurance."

In our assessment, the construction error that occurred was egregious, and because of the criticality of the cantilevered balcony components, this construction error should not have gone undetected by any reasonable inspection by a professional architect or engineer with ANY responsibility for oversight of structural construction.

The original design has not been questioned, but it called for joist hangers that were not used by the framing subcontractor to secure the joists to the ledger board and bolts to secure the ledger board to the structure. Instead, nails were used. But even the original design was likely inadequate. Joist hangers are not designed to carry a moment as in this cantilevered application. Had the joist hangers been used and had the ledger board been more securely fastened to the structure with the bolts originally specified, the failure would likely have occurred between joist and ledger, rather than between ledger and structure, and perhaps with more than two people on the structure. A more reasonable design would involve joists that penetrate into the structure and are secured to parallel floor/ceiling joists that allow them to develop the required moment capacity at the wall, and it is not clear whether this design was an alternative that was also rejected by the general or framing contractor.

The lesson here is that the professional engineer (or architect) has a moral responsibility, even where there is no clear legal responsibility, to prevent problems like this from developing in projects in which he or she has a significant role. In engineered projects, there must be a contractual arrangement allowing appropriate construction inspection engineering efforts, and the most critical design details such as the one in question here should have the highest priority for the construction inspector.

CASE 33

Computer Programs and Moral Responsibility—the Therac-25 Case

Medical linear accelerators (linacs) create high-energy beams that can destroy tumors with minimal damage to surrounding healthy tissue. For relatively shallow tissue, accelerated electrons are used; for deeper tissue, the electron beam is converted into X-ray photons.[110] In the mid-1970s, Atomic Energy of Canada Limited (AECL) developed a radical new "double-pass" accelerator that needs much less space to develop the required energy levels because it folds the long physical mechanism required to accelerate electrons. Using this double-pass mechanism, AECL designed the Therac-25, which also had the economic advantage over the Therac-20 and other predecessor machines of combining electron and photon acceleration in one machine. The Therac-25 was also different in another way: The software had more responsibility for insuring patient safety than in previous machines. The earlier Therac-20, for example, had independent protective circuits for monitoring electron-beam scanning, plus mechanical interlocks for ensuring safe operation.

Eleven Therac-25 machines were installed in the United States and Canada between 1985 and 1987, and six accidents involving massive overdoses occurred. The first overdose occurred at the Kennestone Regional Oncology Center in 1985. When the machine turned on, the patient felt a “tremendous force of heat … this red-hot sensation.” When the technician came in, the patient said, “You burned me.” The technician said this was not possible. Later, the patient’s shoulder (the area of treatment) “froze,” and she experienced spasms. The doctors could provide no satisfactory explanation for an obvious radiation burn. Eventually, the patient’s breast had to be removed because of radiation burns, and she was in constant pain. The manufacturer and operators of the machine refused to believe that it could have been caused by the Therac-25. A lawsuit was settled out of court, and other Therac-25 users were not informed that anything untoward had happened.

The second accident occurred at the Ontario Cancer Foundation in Hamilton, Ontario. When the machine shut down on the command to deliver the dose, the operator was not concerned, having become accustomed to frequent malfunctions with no harmful consequences. After the treatment was finally administered, however, the patient described a burning sensation in the treatment area. The patient died four months later of an extremely virulent cancer, but an autopsy revealed that a total hip replacement would have been necessary because of the radiation overexposure. AECL could not reproduce the malfunction that occurred at the Hamilton facility, but it altered the software, claiming an improvement over the old system by five orders of magnitude—a claim that was probably exaggerated.

The third accident occurred at Yakima Valley Memorial Hospital in 1985 in Yakima, Washington. After treatment, the patient developed an excessive reddening of the skin, which the hospital staff eventually attributed to “cause unknown.” The patient was in constant pain, which was relieved by surgery, and did not die from the radiation. The fact that three similar incidents had occurred with this equipment did not trigger investigation by the manufacturer or government agencies.

The fourth accident occurred in 1986 at the East Texas Cancer Center (ETCC) in Tyler, Texas. Upon attempting to administer the dose, the machine shut down with a “Malfunction 54” error message. The patient said he felt like he had received an electric shock or that someone had poured hot coffee on his back. He began to get up from the treatment table to ask for help, but at that moment the operator hit the “P” key to proceed with treatment. The patient said he felt like his arm was being shocked by electricity and that his hand was leaving his body. He went to the treatment room door and pounded on it. The operator was shocked and immediately opened the door for the patient, who appeared shaken and upset. Unknown to anyone at the time, the patient had received a massive overdose. He died from complications of the overdose five months after the accident.

One local AECL engineer and one from the home office in Canada came to investigate. They were unable to reproduce Malfunction 54. One local AECL engineer explained that it was not possible to overdose a patient. AECL engineers also said that AECL knew of no accidents involving radiation overexposure by Therac-25, even though AECL must surely have been aware of the Hamilton and Yakima incidents. The AECL engineers suggested that an electrical problem might be to blame, but further investigation by ETCC ruled out this possibility.

The fifth incident also occurred at ETCC, this time on April 11, 1986. Upon being given the command to administer the dose, the Therac-25 again registered the Malfunction 54 message, made some loud noises, and shut down. The patient said he heard a sizzling sound, felt “fire” on the side of his face and saw a flash of light. Agitated, he asked, “What happened to me, what happened to me?” He died from the overdose on May 1, 1986.

If not for the efforts of Fritz Hager, the Tyler hospital physicist, the understanding of the software problems might have come much later. Mr. Hager was eventually able to elicit the Malfunction 54 message, determining that the speed of the data entry was the key factor in producing the error condition. After explaining this to AECL, the firm was finally able to produce the condition on its own. This seemed to suggest that the particular coding error was not as important as the fact that there was an unsafe design of the software and the lack of any backup hardware safety mechanisms.

The sixth accident also occurred at Yakima Valley Hospital in January 1987. The patient reported "feeling a burning sensation" in the chest and died in April from complications related to the overdose. After the second Yakima accident, the U.S. Food and Drug Administration concluded that the software alone could not be relied upon to ensure the safe operation of the machine. The initiatives for identifying the problems with the Therac-25 came from users, not the manufacturer, which was slow to respond. The medical staff on the user side were also slow to recognize the problem.

Blame-Responsibility: Corporate Responsibility

This tragic story illustrates irresponsible actions on both the corporate and individual levels. Yet, the investigators of the accidents did not wish "to criticize the manufacturer of the equipment or anyone else."[111] Philosopher Helen Nissenbaum believes that this reluctance to assign blame, either to organizations or groups, is not unusual. Rather, "accountability is systematically undetermined in our computerized society—which, given the value of accountability to society, is a disturbing loss."[112] She believes further that "if not addressed, this erosion of accountability will mean that computers are 'out of control' in an important and disturbing way."[113] Even if Nissenbaum's claims are extreme, it is probably true that the increased usage of computers have raised in an especially urgent way the problem of responsibility or accountability, and that the issue must be addressed.

Let us first consider the issue of blame-responsibility, on the corporate level. What is the blame-responsibility (if any) that can be assigned to such corporate entities as AECL, Yakima Valley Memorial Hospital, and the East Texas Cancer Center?

We saw in Chapter 4 that corporations can be causes of harm by way of specific corporate policies (or the absence of corporate policies), corporate decisions, management decisions, and a corporate culture. We noted that there are some relatively strong arguments that organizations such as corporations can be morally responsible agents like people. Whether or not they can be morally responsible agents, they can still be

1. criticized for harms,
2. asked to make reparations for harms, and
3. assessed as in need of reform.

Let us look at specific issues in the Therac-25 case that might lead to blame-responsibility on the corporate level.

1. One design flaw in the Therac-25 was the absence of hardware safety backups. Earlier versions of the machine had such backups, and if they had been present in the later version, some (or all) of the accidents might not have occurred. Although this design flaw may have been simply the fault of the individual engineers, it may have resulted from the fact that some of the engineers at AECL apparently did not have proper training in systems engineering. This, in turn, may have been the result of a failure of AECL management and company policy with respect to the training of AECL engineers.
2. AECL evidently did not have adequate testing and an adequate quality assurance program. This deficiency may also have been a major factor in producing the accidents, and these failures should probably be attributed to management and perhaps to corporate policies and a corporate culture that did not sufficiently value both testing and quality assurance.
3. AECL made exaggerated claims for the safety of the Therac-25. Technicians were led to believe that the machines could not possibly administer an overdose, and this was probably one reason the technicians were also insufficiently responsive to patient complaints. The exaggerated claims for safety may have also been partially responsible for

the fact that physicians were slow to recognize the radiation burns. These problems could well be attributable to a corporate culture that was excessively concerned for sales.

4. AECL was slow in responding to reports of accidents and in informing other users of the malfunctions of the Therac-25. Bad management decisions and, again, a corporate culture that was overly concerned with sales and insufficiently concerned with safety were probably at least partly to blame.
5. The monitoring equipment in at least one of the medical facilities (the East Texas Cancer Center) was not properly functioning, and this may have played a part in the injuries to patients. There may have been a deficiency with management and perhaps with a corporate culture that was not sufficiently oriented toward the highest standards of safety.

These examples strongly suggest that at least AECL deserves moral criticism for the injuries and deaths to patients. AECL could be asked to make reparations for harms (and may be legally liable for such reparations) and is in need of internal reform. The East Texas Cancer Center may also be open to criticisms, although on a far more limited basis.

Blame-Responsibility: Individual Responsibility

The Therac-25 accidents were not caused by any single individual. In Chapter 3, however, we saw that in situations involving collective action and inaction, there are principles that give direction for assigning blame-responsibility. The principle of responsibility for action in groups states: In a situation in which harm has been produced by collective action, the degree of responsibility of each member of the group depends on the extent to which the member caused the action by some action reasonably avoidable on his part. The principles of responsibility for inaction in a group states: In a situation in which harm has been produced by collective inaction, the degree or responsibility of each member of the group depends on the extent to which the member could reasonably be expected to have tried to prevent the action.

We have also seen that blame-responsibility can be the result of malicious intent, recklessness, or negligence. The following enumeration is probably best understood as a list of various types of negligence and therefore as types of inaction for which those who are involved bear some degree of blame-responsibility, depending on the causal importance of their inaction in the harms.

We also saw that negligence involves the following four factors:

1. the existence of a standard of conduct,
2. a failure of conformity to these standards,
3. a reasonably close causal connection between the conduct and resulting harm, and
4. a resulting actual loss or damage to the interests of another person.

One of the problems with attributing negligence in computer-related incidents is that the standards of conduct (or "due care") are sometimes insufficiently developed and made public. Nevertheless, we believe that there are implicit standards that warrant the attribution of blame-responsibility with respect to the following groups of individuals.

1. As we have noted, one of the design flaws in the Therac-25 was the absence of the hardware safety backups that the earlier machines had. If the backups had been present, some (or all) of the accidents might not have occurred. Although this design flaw may have been partly attributable to management and company policies that did not place enough emphasis on systems engineering, it may also be attributable to professional negligence that was the fault of the individual engineers involved. The accidents might not have occurred if the hardware backups had been present. Insofar as the professional negligence is the fault of the individual engineers, they bear considerable responsibility for the accidents. The negligence here was the failure of engineers to investigate more fully the dangers associated with a system with no hardware backups and the resulting failure to incorporate these backups into their design.
2. The manufacturing personnel who built the faulty microswitch that controlled the position of the

turntable on which the patients were placed were important causal agents in some of the accidents, especially the one at the Ontario Cancer Foundation. The standard account gives little information about the reasons for this fault, but perhaps we can best attribute it to negligence involved in the building of the faulty equipment. If the patients had been properly positioned, they might not have suffered radiation burns, but we shall see that there were other causal factors present. So we can say that the manufacturing personnel should be held partially responsible.

3. The programmers were also partially responsible for harm to patients. There were errors in programming and obscure error messages. There appeared to be considerable negligence on the part of the programmers, and their errors apparently were directly causally responsible in part for the harms. It should be said on behalf of the programmers, however, that there are usually "bugs" in programs, and the programmers may not have had sufficient training to be aware of the dangers of leaving all of the responsibility for safety to the computer programs.
4. Evidently, the user manuals were inadequately written. There was no explanation, for example, of the Malfunction 54 error message. The absence of proper instructions was clearly a factor in the accidents. Had the operators known how to respond to error messages, they might have been able to avoid some of the accidents. Here again, there appeared to be negligence that was causally related to the accidents. Manual writers can only write what they are given, however, and we do not know what information they were given. So we cannot, without further information, know just how much blame-responsibility the manual writers should bear.
5. In some of the accidents, technicians may not have been sufficiently aware of the possibility of radiation burns, and they sometimes seemed shockingly insensitive to patient distress. This again is a type of negligence that may have played some part in the harm done to patients. In defense of the technicians, however, two considerations are relevant. First, both of these faults can probably be attributed in part to the AECL claims that radiation burns were not possible and to the limited knowledge that was at the disposal of the technicians. Second, technician negligence probably was a minor factor in the actual harm done. Therefore, the causal relationship of technician negligence to actual harm done was probably minimal.
6. In several cases, physicians seemed slow to recognize that overexposure had occurred. This is also a type of professional negligence. Again, however, two considerations in defense of the physicians are relevant. First, whether lives would have been saved if treatments for radiation burns have been more prompt is not clear. Second, one reason for the physicians' tardiness might have been the excessive claims of AECL that overexposure was not possible. Still, physicians in radiation-treatment facilities should be alert to the possibility of radiation burns.

As this analysis shows, the major blame-responsibility for the injuries and deaths from the Therac-25 lies with AECL on both the individual and corporate levels. There was probably negligence on the part of both management and individuals at AECL. Furthermore, there was also probably a corporate culture that encouraged irresponsible action. Finally, the negligence had a strong causal relationship to the injuries and deaths.

It would be interesting to speculate on the impediments to responsibility that explain the problems at AECL. AECL was apparently plagued by a corporate culture in which managers focused excessively on profit and sales to the exclusion of other considerations such as safety. This may have been a type of microscopic vision. Managers may have also engaged in self-deception, convincing themselves that the reports of injuries and malfunctions of the Therac-25 were not significant, would not be repeated, and were not the result of any fundamental faults of the machine itself.

Individual negligence on the part of engineers and programmers may have been partly the result of self-interest because any insistence on greater attention to safety considerations might have resulted in disfavor by managers. We have already pointed out that engineers may have been affected by ignorance because of their insufficient training in systems engineering.

Finally, group-think may have played a part in the behavior of engineers and programmers. Perhaps, a "can-do" mentality and an emphasis on avoiding delays in getting the product on the market inhibited individuals from making objections based on safety considerations.

Maintain Accountability in a Computerized Society

Helen Nissenbaum has made several suggestions about ways to maintain accountability in a computerized society, two of which seem especially valuable.[114] One suggestion is that standards of care should be promoted in computer science and computer engineering. Guidelines for producing safer and more reliable computer systems should be widely promulgated and adhered to by computer professionals. Not only should such standards result in greater safety and reliability but also the existence of such standards should make it easier to identify those who should be held responsible and liable for failures. We have already mentioned one such standard, namely, that computer programs should not bear the sole responsibility for safety.

A second suggestion is that strict liability should be imposed for defective customer-oriented software and for software that has a considerable impact on society. Strict liability implies the manufacturer is responsible for any harm caused by a defective product, regardless of whether the fault can be assigned to the producer of the product. Strict liability would help to ensure that victims are properly compensated, and it would send a strong message to the producers of software that they should be vitally concerned with the safety of the public. As an example of the current situation in which the producers of software assume no responsibility for the safety of their product, according to Nissenbaum, Apple Computer makes the following statement:

> Apple makes no warranty or representation, either expressed or implied, with respect to software, its quality, performance, merchantability, or fitness for a particular purpose. As a result, this software is sold "as is," and you, the purchaser, are assuming the entire risk as to its quality and performance.

These evasions are problematic from an ethical standpoint. As the Therac-25 case illustrates, people can be harmed and even killed by computer mishaps.

Some people have objected to Nissenbaum's suggestions. One objection is that, although software engineering has standards for software-development processes, there are few standards for software products. Furthermore, setting product standards has turned out to be difficult. So Nissenbaum's first suggestion may be hard to implement. Nissenbaum's second suggestion is also somewhat impractical, according to some critics. Software may not be sufficiently mature to qualify for strict liability, they argue. Nevertheless, some computer scientists are sympathetic with Nissenbaum's suggestions, believing that they point the way to necessary reforms.

CASE 34

Roundabouts[115]

Roadway intersections present several engineering challenges. Consider, for instance, that in 2009, 20.8 percent of roadway fatalities in the United States occurred at intersections, or were in some way intersection related.[116] Signaled intersections are problematic for drivers, since a good deal of attention and thought may be required to traverse a busy intersection. Drivers must decide quickly when and how to proceed, especially when facing a changing light, or when navigating multiple traffic lanes. Consider as well that stop-and-go traffic, such as traffic at a busy intersection, increases automobile emissions significantly and results in traffic congestion. Both of these issues raise significant problems for engineers, since safety and efficiency are primary engineering concerns.

Roundabouts provide an elegant solution to many of these problems. Roundabouts are circular intersections designed to allow vehicles to traverse in any direction, often without ever coming to a complete halt. The process of traversing a roundabout is very straightforward, with drivers simply following the one-way circular roadway to their chosen exit without having to worry about changing lights or multiple turning lanes. In addition, because cars must travel in a fairly tight circle, drivers are forced to reduce their speed. These two factors together make accidents, both vehicular and pedestrian, less likely. The design of the roundabout also helps to prevent some of the most dangerous kinds of accidents, such as "T-bone" collisions, in which a vehicle passing through a standard intersection is struck by another vehicle moving perpendicular to it. It is therefore unsurprising that a study by the Insurance Institute for Highway Safety found that replacing standard intersections mediated by stop signs or signals with roundabout intersections resulted in a 37 percent overall reduction in intersection collisions, and a full 90 percent reduction in fatal collisions.[117]

In addition to safety improvements, roundabout intersections are also more efficient. Unlike at standard intersections, vehicles are not required to decelerate and accelerate repeatedly, but can usually proceed without stopping. This enhances fuel economy and also reduces traffic delays associated with standard intersection designs. Roundabouts can also typically handle traffic using fewer lanes than signaled intersections, typically making them smaller. Finally, roundabouts are *financially* efficient. Because no signals are employed, maintenance and electrical costs are significantly reduced. Given these benefits, the roundabout looks like an engineer's dream—a simple, low-cost design that provides holistic improvements in safety and efficiency. The story is complicated, however, by the needs of visually impaired pedestrians.

Navigating intersections is already a challenge for blind and visually impaired pedestrians, for obvious reasons. However, it is fairly easy to provide accessible crossing for them at signaled intersections. Many signaled intersections are equipped with crossing assistance systems that provide audible cues to help visually impaired individuals know when to cross. Even intersections mediated by stop signs can be effectively navigated by careful attention to the sounds of oncoming vehicles. Roundabouts, however, are much more challenging for the visually impaired. Audible crossing assistance is untenable at roundabouts, since there is typically no traffic signal with which to integrate such a system. Even worse, the fact that traffic in a roundabout is constant means that auditory cues of oncoming traffic are very easily lost in the din of vehicles moving around the circular roadway. These factors, in combination with the orientation challenges posed by the unusual geometry of roundabout crossings, make navigating a roundabout on foot much more dangerous for the visually impaired.[118]

However, someone might ask, "Why should the concerns of the visually impaired be of any great significance here? After all, visually impaired individuals represent a small minority of the overall population. Surely, the inconvenience of finding an alternative route for the disabled is a small price to pay for all the benefits roundabouts provide in terms of general safety and efficiency." One answer is the Americans with Disabilities Act (ADA). The ADA mandates that all transportation facilities be equally accessible to both able-bodied and disabled citizens. Failure to comply with the ADA can be quite costly, with legal damages between $55,000 and $110,000 being standard.[119]

But, even without considering the ADA, concerns of professional ethics exist that are relevant to these issues. Commitment to safety is a ubiquitous feature of professional engineering codes of conduct. While the visually impaired are, indeed, a minority in the United States, their safety is, nevertheless, threatened by standard roundabout design. Equality and accessibility are also strongly valued by American culture at large. Insofar as engineers are required to consider the values of the public who utilize what they design, such strong values should be respected.

These conflicting interests of safety, efficiency, financial risk, and equal access make roundabouts a difficult issue for engineers. Should we therefore abandon the idea, and rely only on standard sign and signal mediated intersections? Perhaps. However, one might also look at the issues surrounding access for the visually impaired as an opportunity for further innovation. And, indeed, much work has been done in developing roundabouts that retain the benefits described above while also providing easier access for the disabled. Many ideas have been explored, but two in particular serve to draw attention to the interplay of conflicting interests in this case.

Solution #1: Pedestrian-Actuated Signals

One potential solution to some of the issues discussed above is to introduce traffic signals at standard roundabouts that are typically inactive, and that can be activated by the presence of a pedestrian. This kind of system would provide safer passage for the visually impaired, while minimizing the congestion effects incurred by more traditional signaling systems. However, introducing such a system also incurs an increase in expense not associated with standard roundabout designs.

Solution #2: Raised Crosswalks

A particularly elegant solution to the problems raised by the odd geometry of roundabout crosswalks is to raise the crosswalk and provide tactile cues (such as ridges) to help keep visually impaired pedestrians on the right path. Raised crosswalks are a relatively inexpensive solution and have the added benefit of slowing traffic, resulting in an overall safer intersection.

QUESTIONS FOR FURTHER THOUGHT

1. What reasons other than legal concerns might motivate an engineer to attend to the needs of the visually impaired?
2. Studies indicate that drivers are much less likely to yield to pedestrians in crosswalks at intersections without traffic signals.[120] What does this mean for the second solution discussed above?
3. Should engineers be responsible for ensuring that their designs are accessible to individuals who are both visually *and* hearing impaired? Why or why not?
4. Fuel-efficient electric and gas/electric hybrid vehicles produce very little sound at normal driving speeds, and are thus difficult for the visually impaired to detect. Does this raise problems for engineers similar to those raised by roundabouts? In what ways are these problems similar? In what ways are they different?

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CASE 35

Interface[121]

Ray C. Anderson was, by his own account, the very picture of a successful American industrialist. He risked everything to found a company (Interface, a carpeting manufacturer), and as a result of hard work and his own intense competitiveness, the company flourished. But then something very unusual happened. In August of 1994, Anderson convened a task force whose role was to evaluate his company's environmental impact. The task he put before this group was a difficult one. Anderson summed it up in this way:

> We're going to push the envelope until we no longer take anything the earth can't easily renew. We're going to keep pushing until all our products are made from recycled or renewable materials. And we're not going to *stop* pushing until all our waste is biodegradable or recyclable, until nothing we make ends up as pollution. No gases up a smokestack, no dirty water out a pipe, no piles of carpet scraps to the dump. *Nothing*. (Anderson 2009, pp. 16–17)

These are, by most standards, radical goals, and certainly not those we typically associate with the world of bottom-line capitalism. Even more surprisingly, Anderson was not an environmentalist. He was driven to start his company by an intense competitiveness and a desire to succeed in business. So what happened? Why did Anderson's vision for the future of his company shift so suddenly, and so radically, from a vision unconcerned with the ethics of pollution and consumption of resources to a vision which deeply incorporates these issues? The answer to this question is illuminating, perhaps especially to employees attempting to affect change in managerial attitudes toward ethical concerns.

Before his "conversion," Anderson was, by his own admission, largely ignorant of his company's impact on the environment. This was fine by him. He writes:

> … after two decades of what can only be called spectacular success, it didn't bother me a bit that Interface consumed enough energy each year to light and heat a city. Or that we and our suppliers transformed more than a billion pounds of petroleum-derived raw materials into carpet tiles for offices and hospitals, airports and hotels, schools, universities, and stores all around the world. So what, if each day just one of my plants sent *six tons* of carpet trimmings to the local landfill? What happened to it there? I had no idea. Why should I? It was someone else's problem, not mine. That's what landfills were for. In fact, our belching smokestacks, our gushing effluent pipes, our mountains of waste (all completely legal), were tangible proof that business was good. They meant jobs. They meant orders coming in, products going out, and money in the bank. (Anderson 2009, p. 8)

This changed, though, when Jim Hartzfeld, an engineer from the Interface's research division, relayed a question from a sales associate, "Some customers want to know what Interface is doing for the environment. How should we answer?" It is unrealistic, although appealing, to imagine that this simple question could single-handedly spark such a monumental shift in the ethical trajectory of a company like Interface; Anderson was already aware that customers were concerned about the environmental practices at the company. But Hartzfeld's question was at least enough to get the proverbial ball rolling, and what's more, he kept at it. Anderson describes his own attitude toward the problem as nervous and unsure. He was content to pass the responsibility for handling the problem on to others. But Hartzfeld continued to press him, encouraging him not only to convene the task force responsible for identifying the company's environmental impact but also to carefully define the scope of its project in a speech to the committee's members.

It's important to note, too, that the question Hartzfeld asked was not obviously an ethical one. The "hook" for Anderson was not the notion that his company might be causing harm to the environment, but that this harm was of concern for his clients. He writes: "I wasn't about to ignore any customer's concerns or to turn my back on any piece of business. If we didn't answer the question Jim had relayed, I knew we stood to lose other sales." By making it clear that concrete, financially important factors were involved, Hartzfeld forced Anderson to genuinely consider the issue, rather than brush it off as being of no importance to his concerns as a businessman. This led Anderson to read *The Ecology of Commerce*, a book by environmentalist and entrepreneur Paul Hawken. It is there that Anderson seems to have found revelation.

Importantly, though, the content of the book that was most compelling to Anderson was not about the inherent goodness of stewardship of natural resources. He was already familiar with these worries and had dismissed them—believing, in his words, that "as technology improves, we'll get better and more efficient at supplying whatever the market demands." Anderson's credence in this "article of faith" seems to suggest, again, that his motivations and attitudes were typically capitalist. He had no special sympathies for the idea that, regardless of the demands of the market, corporations should be responsible consumers of resources. The mere fact that corporations were egregious polluters and consumers of finite resources was of little concern. Had that been the only message present in Hawken's book, Anderson would likely not have been swayed. If things needed to change, the market would make them change. But Hawken also presented a discussion of overconsumption, and it is here that Anderson's assumptions were fundamentally challenged. He had not before considered the fact that the resources demanded by market concerns might one day *just run out*. This prospect caused him to, in essence, broaden the scope of what he took to be the concerns of a business. Where there is a danger of overconsumption of resources, it is paramount to the success of any industrial enterprise to change the way it consumes those resources. This revelation, says Anderson, led him to radically question the practices of his company, leading to the wide-ranging environmental policies outlined above.

So what can we learn from Anderson's case? Taking him as being fairly representative of the financially minded leads to some optimistic conclusions. Anderson was not initially hostile to environmental issues, but merely ambivalent, despite being by his own description concerned primarily with financial interests. He characterizes his ambivalence as being largely due to ignorance of the relevant issues. Taking him as a representative case, then, indicates that inattention to ethical problems by management may typically be linked to a failure to understand or appreciate those problems, rather than a general disdain for ethical conduct, or the belief that ethical and financial interests are always at odds. This should be encouraging to the ethical engineer. Despite appearances, corporate management is not always hostile to ethical concerns.

Anderson's ignorance was not ignorance of the material facts of Interface's environmentally important conduct, but rather a failure to appreciate the impact of this conduct on the potential future of his company, and the world at large. Narrowness of vision of this sort may often play an important role in preventing managers from fully appreciating the ethical concerns of their employees. Part of the role of engineers, like all expert professionals, is to help inform the scope of their employer's vision. It appears that, at least in cases like Anderson's, such education can affect real change.

The initial push to evaluate Interface's environmental impact came from low-level employees through standard channels. This illustrates the importance of communication between employees, especially experts, and management. Again, what seems an intentional oversight on the part of management may, in fact, be the unintentional consequence of having not fully appreciated all relevant concerns. The fact that Hartzfeld was able to effectively transmit the concerns of a low-level sales associate to the highest level of the company was crucial to the overhaul of the company's environmental vision.

The impact of the employee input was heightened due to the fact that clients hung in the balance. This illustrates the effectiveness of generating concern for ethical interests when those interests are presented as financially relevant. This pressure (again, from employees of the company) forced Anderson to consider environmental issues, which led him to read Hawken's book, the source of his "revelation." This illustrates an important interplay between financial interests and "abstract" general ethical interests in motivating a change in managerial policy. Anderson's initial concern with the loss of potential clients led him to fully consider the ethical ramifications of his company's wasteful behavior.

Broadly, the upshot of this case seems to be that upper-level management can, in some cases, be expected to change its mind when supplied with the right information. As experts, it is the role of engineers to acquaint their employers with reality and it seems, at least in cases such as Anderson's, that such an acquaintance can go a long way toward encouraging managerial support of ethical conduct. Practically, this should encourage engineers to not only be vocal and straightforward with their ethical concerns, but also sensitive to any related financial matters, since addressing these interests can serve as an inroad with management, forcing them to more deeply consider the concerns of their employees.

It may also be important to note that Anderson seems to be an exceptional case, and that it is perhaps unrealistic to expect all managers to behave in precisely the same way. However, although it may well be the case that Anderson was not a typical businessman, this is not because he had any particular sympathies with environmentalism prior to his conversion. The difference between Anderson and more typical cases is not (or at least not obviously) a difference in motivation. That being the case, studying his account may lead to insight as to how typical management, with typically managerial motivations, might be convinced of the importance of ethical concerns.

QUESTIONS FOR FURTHER THOUGHT

1. Is Anderson really representative of industrialists in general? If not, what differentiates him from the norm? What is it about our standard conception of corporate management which makes behavior like Anderson's so surprising?
2. Imagine that you are an engineer employed by a manufacturing company, and you learn that some of the company's manufacturing processes could result in the contamination of local water supplies. What does the case of Ray Anderson tell you about the kinds of strategy to employ when bringing this issue to the attention of your managers?

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CASE 36

Drive by Wire and Unintended Acceleration[122]

Modern automobile designers have replaced mechanical throttle control with a digital computer-controlled throttle; an accelerator position sensor determines driver input and a computer (the electronic control module, or ECM) drives an electric motor and a throttle position sensor to position the throttle control according to the driver input. Aircraft have used this kind of technology advantageously for several decades, replacing the increasing long mechanical controls in increasingly larger aircraft with "fly-by-wire" controls, but it is comparatively newer in automobiles.

In recent years, a number of unintended acceleration (UA) events, in which an automobile is operated at open throttle, accelerating to unsafe speeds, while the driver reports attempts to brake or decelerate, have been reported in some models of Toyota automobiles. In some cases, it was later determined to be driver error (an elderly driver hits the accelerator instead of the brake). In other cases, some mechanical interference was blamed (a floor mat snags on the accelerator). But there were some crashes that were not easily explained.

The source code used to program the ECM is extremely complex and not readily accessible to investigators, which delayed independent investigations of the unexplained UA incidents. The fatal 2007 crash of a 2005 Camry in Oklahoma, during what the surviving driver Jean Bookout described as an unintended acceleration event, led to court-mandated access to the source code by plaintiff's experts. Those experts determined that the code was badly flawed and was the probable cause of the UA and subsequent crash. Additional evidence convincing the jury that this was not caused by driver error were long skid marks clearly supporting the driver's explanation of her attempts to stop or slow the vehicle using both service and parking brakes.

The plaintiff's experts identified numerous problems with the software, most importantly that it was far from compliance with generally accepted, but not mandatory, industry standards for such software. Motor Industry Software Reliability Association (MISRA) standards were introduced in 1995, but Toyota code developers chose not to follow those standards, preferring to develop their own standards instead. The experts examining the software testified that Toyota failed to follow their own standards and that deviations from MISRA standards numbered in the thousands to tens of thousands.

Some of the technical flaws described by the examining experts included:

> Allowing "single-point failures" where a single failure in some hardware or software system can result in an unsafe condition. Redundancy is an engineering design principle that increases safety in presence of failures.
>
> Using global variables, a variable with global scope which can be read and modified by logic anywhere in the code. Good programming practice is to avoid global variables, but the plaintiff's experts found that Toyota used more than 10,000 global variables.
>
> Failing to document programming problems (bugs) and fixes for bugs that were discovered.
>
> Writing poorly structured code. Examiners called it "spaghetti code," a common term for code that is difficult or impossible to debug because of its unstructured nature.
>
> Failing to insist on a peer review of the code used in the ECM when it was developed. Peer review could have highlighted some of the problems discovered later.

This case highlights the responsibility of the engineer and code developer whenever software for safety critical systems is being developed. Adopting and strictly adhering to accepted industry standards is always good practice to manage risk. Documenting the code development process and bug fixes is important. The code developer's professionalism, or lack thereof, can and will affect the quality of the end result. Coding can be developed by many individuals with varying levels of training, but much more is needed than simply knowledge of the programming language. The trend in some industries to assign software development to "technicians" rather than to engineers (or other professionals) is problematic. Design of such computer codes is no different in principle than design of some sort of product or infrastructure, and should only be assigned to an experienced professional with appropriate training and insight. Industries that don't practice this can probably expect the kinds of problems described in this case study.

CASE 37

Autopilot Mode and the Ethics of Autonomous Vehicles

Autonomous vehicles are squarely in our future. Developers ranging from traditional automobile manufactures to on-line retailers to social media companies are investing heavily in R&D in anticipation of a future in which autonomous vehicles will perform many of the tasks handled by human-operated vehicles today. Investors expect that costs and convenience of this new technology will allow it to displace the current technology of human-operated vehicles. In addition, proponents argue that highway transportation safety can be improved significantly, in particular that autonomous automobiles will reduce the rate and severity of automobile crashes we tolerate today.

But, nobody argues that automobile crashes, or accidents involving any other type of autonomous vehicle, can be eliminated. There will always be some crashes. Consider the May 7, 2016 Williston, Florida fatal crash of a 2015 Tesla Model S into a tractor-trailer. The National Highway Transportation Safety Board's Office of Defect Investigation investigated and reported that the Tesla was being operated in Tesla's "autopilot mode" and that the automatic emergency braking (AEB) system did not provide any warning or automated braking before the collision. The NHTSB report also found that the driver did not initiate any braking, steering, or other actions to avoid the collision.

The Tesla's autopilot and AEB systems are lane keeping and rear-end collisions avoidance technologies, and are not designed to prevent other types of collisions, such as the crossing path collision with the tractor trailer as it crossed the highway lane travelled by the Tesla. Current (2016) AEB technology can reduce rear-end collision rates by 40 percent, but is challenged by the limited time a crossing vehicle is in the field of view and is not designed to prevent crossing collisions. This technology is classified as an SAE Level 2 (partial automation) system. Both Level 2 and Level 1 (driver assistance) technologies require human monitoring and intervention. Accordingly, manufacturers of these systems instruct drivers to monitor the operation and be ready to take immediate control of the automobile. Tesla drivers are instructed to "always keep your hands on the wheel" and "be prepared to take over at any time." Data collected by the Tesla's computers indicated the driver did not recognize and react to a developing crash in the estimated seven seconds before impact during which it was perceptible that the crash was likely.

There was clearly a failure in this instance by the driver, who didn't operate the Tesla as instructed, and perhaps by the manufacturer, for not deploying a system capable of detecting the easily foreseeable situation of a human driver who was clearly not "prepared to take over at any time." Innovative new technology always requires more of the engineer, who must raise and address many questions that were not relevant with the displaced technology. Tesla has subsequently updated their driver engagement system and implemented a "strike-out" function that will notify an inattentive driver that the "autopilot" system is being disengaged because of repeated driver distraction.

So long as SAE level 1–2 (driver assistance or partial automation) systems are used in production vehicles, this problem will remain. The human driver is still responsible for part of the driving function (Level 1) or at least for monitoring the driving and taking over control when necessary (Level 2), and there must be a robust system for educating the human driver about the role he/she plays and monitoring the human driver's engagement in a way to ensure appropriate levels of driver engagement. Manufacturers have a responsibility to design with the inattentive driver in mind.

As technology involving SAE Level 3 (conditional automation), Level 4 (high automation), or Level 5 (full automation) is developed, other issues must be addressed. Patrick Lin[123] poses several questions about which rules of autonomous operation we should expect a programmer of the autonomous vehicle's logic to include—in particular, what happens when two of these rules conflict? After all, dealing with conflicting ethical obligations is what engineering ethics is all about.

Some of the potentially conflicting ethical obligations we might expect a developer to consider include obligations to:

(1) Protect the safety of the driver and occupants of the automobile
(2) Protect the safety of the others on or near the roadway
(3) Prevent or minimize damage to the automobile itself
(4) Prevent or minimize damage to property on or near the roadway
(5) Prevent or minimize injury to animals on or near the roadway
(6) Obey traffic laws.

Such ethical conflicts might be manifested in issues like the following:

(1) Should the safety of the driver and occupants, or of others on or near the roadway, depend on a violation of some traffic law by the autonomous vehicle, what logic should be applied?
(2) When some sort of crash is unavoidable, what logic should be used to decide which crash occurs?
(3) Should governmental regulation address issues like these?
(4) Should the owner and operator of the autonomous vehicle be able to control, or even know, the logic addressing issues like these?

And Lin explains that developers of autonomous vehicles might bear more responsibility than human drivers,

> Human drivers may be forgiven for making an instinctive but nonetheless bad split-second decision, such as swerving into incoming traffic rather than the other way into a field. But programmers and designers of automated cars don't have that luxury, since they *do* have the time to get it right and therefore bear more responsibility for bad outcomes.

CASE 38

Volkswagen Emissions Scandal

This is a somewhat unusual case in the study of engineering ethics, because it appears (at press time) that this scandal has resulted from an intentional decision to circumvent U.S. automobile emissions regulations. Not all facts are public at press time; it is not known how many engineers and managers were complicit or what pressures might have led to the decision to circumvent regulations. This case will probably still become an instructive case for future engineers, if for no other reason than to remind us how business pressures can affect engineering decisions, especially in large organizations, but also as an example of failure in crisis management.

In September 2015, the U.S. EPA charged German automaker Volkswagen (VW) with violations of the Clean Air Act[124], describing the action as "knowing endangerment," after it was discovered that emissions controls on certain diesel engines were programmed to operate only in a laboratory testing mode and not in normal highway driving. VW subsequently pled guilty to the criminal charges and agreed hefty penalties. The discovery came during a 2015 International Council on Clean Transportation (ICCT)-sponsored research study to measure emissions during actual real-world operations for comparison to measurements in laboratory testing, as it had long been a concern that real-world emissions might be greater than laboratory measurements. Researchers found that real-world NOx emissions for the Volkswagen Jetta were 14–35 times the EPA maximum allowable limit of 0.043 g/km, while dynamometer measurements in the laboratory indicated that the emissions were about half of the maximum allowable.

The Clean Air Act makes it a violation to "manufacture or sell, … or install, any part or component … of, any motor vehicle or motor vehicle engine, where a principal effect … is to bypass, defeat, or render inoperative any device or element of design. …" The EPA charged that VW had installed sensors and software in the electronic control module (ECM) that sensed various parameters including steering wheel position, vehicle speed, the duration of the engine's operation, and barometric pressure, concluding that these data were used to switch the emissions control systems between a dynamometer operations mode and a road operations mode, in such a way that the vehicle was only compliant with emissions regulations in the dynamometer operations mode, and when in the road operations mode the vehicle emitted 10–40 times the legal maximum of NOx. The EPA charged that VW did not disclose this system and knowingly sold several automobile models in model years 2009–2015 which were not in compliance with the CAA.

At the time of this writing, at least two high-level VW engineering managers have been arrested. James Robert Liang has pled guilty to charges, and Oliver Schmidt, the general manager in charge of VW's Environmental and Engineering Office (EEO) from 2012 to 2015, was arrested while travelling in the United States. Liang faces five-year imprisonment and a fine of $250,000. The criminal complaint against Schmidt[125] quotes VW's Certificate of Conformity application to EPA and California Air Resources Board (CARB) as certifying that:

> The Volkswagen Group states that any element of design, system, or emission control device installed on or incorporated in the Volkswagen Group's new motor vehicles or new motor vehicle engines for the purpose of complying with standards prescribed under section 202 of the Clean Air Act, will not, to the best of the Volkswagen Group's information and belief, cause the emission into the ambient air of pollutants in the operation of its motor vehicles or motor vehicle engines which cause or contribute to an unreasonable risk to public health or welfare except as specifically permitted by the standards prescribed under section 202 of the Clean Air Act.

What is not yet fully known is exactly how many individuals were complicit in the scheme or how the individuals involved came to a decision to violate the CAA by circumventing U.S. EPA air quality regulations. Top VW executives have claimed that they did not know about the problem until late August 2015,[126] but also admitted a subsequent attempt to cover up the scandal by deleting thousands of documents. One report[127] indicates software designed to turn off various engine functions was originally developed by Audi in 1999. The software, sometimes called an "acoustic function," was originally intended as a way to reduce clatter in luxury vehicles while idling, and perhaps intended only for testing, but was later incorporated in production vehicles as VW struggled to meet U.S. NOx emissions standards. Liang's admission includes a statement that VW engineers realized they could not meet U.S. emissions standards so they incorporated software that enabled the emissions control systems only when the vehicle was operating in test conditions, and not during normal driving.

It appears that the pressures of time and money—in this case, corporate pressures to make their products meet CAA standards while meeting production deadlines—caused engineers, who were probably in other situations very mindful of their legal and moral obligations, to resort to criminal behavior. It appears that the sense of professional responsibility is sometimes not strong enough to overcome the pressures engineers sometimes face. In this respect, the VW case is similar to the case of the Deepwater Horizon/Macondo, where high operational costs and/or competitive pressures appeared to be a deciding factor in several critical engineering decisions involving a balancing of public safety and operational costs. A key difference is that the engineers shutting in the Macondo well, when responding to those pressures acted unprofessionally and unethically, but not clearly illegally (Donald Vidrine pled guilty to manslaughter charges, but Robert Kaluza was acquitted and others were either acquitted or plea bargained for lesser charges), while the VW engineers have apparently knowingly and intentionally violated the law. How can engineers increase their sense of professional responsibility so that they remember the profession's paramount responsibility to protect the public health, safety, and welfare? Pursuing engineering licensure is one step engineers can and should take, because engineering licensure seems to increase an engineer's recognition of his or her professional responsibilities and accountability and perhaps can provide that extra bit of moral backbone needed to respond more appropriately when faced with conflicting obligations.

CASE 39

Water Crisis in Flint

Flint, Michigan, in 2011, was a financially challenged city of nearly 98,000 people, many of them living below the national poverty line, when the state of Michigan took control of the bankrupt city's purse strings. In 2014, the city, which had been purchasing treated water from Detroit, decided to reduce costs by taking water from Lake Huron and treating it in city-owned treatment plants. While the pipeline necessary to transport the Lake Huron water was being constructed, the city planned to temporarily draw raw water from the Flint River. In April 2014, the city began pumping water from the Flint River to its water treatment plant. Although the Flint River had been the source of its raw water many years earlier, subsequent development had resulted in significant degradation of the water source which now required a higher level of chlorination to safely disinfect the water.

The new water began to cause issues with the public and local industry. Fecal coliform bacteria were detected in the municipal supply, and the city increased the chlorination to levels considered risky for some members of the public. General Motors in Flint switched from the city water to a private source because of concerns that the water was corrosive. Residents began to complain about the discolored water at their taps. In February 2015, a resident contacted the U.S. EPA complaining about the discolored water and expressing her concern that it was making her children sick. Subsequent testing indicated that her water contained a high level of lead, from 7 times to more than 30 times the maximum allowable lead levels of 15 ppb.

The heavily chlorinated river water proved to be highly corrosive, and during the 18 months it was used, it removed the passivating film on the inside of water pipes and leached lead from service lines and fixtures, and carried the lead to the taps in the homes of Flint residents. Monitoring and adding phosphates to treated water is a standard method of water treatment to develop and maintain a corrosion-preventing passivating film in pipes and fixtures. Engineers charged with operating municipal water treatment facilities know to check phosphate levels in the water. The AP report[128] of a meeting between Mike Glasgow, who supervised the laboratory at the water treatment plant, with Michigan Department of Environmental Quality District engineer Mike Prysby and a consulting engineer gives a clue about the source of the problem. Glasgow, probably under pressure by the city to hold water treatment costs down, asks Prysby how often his staff would need to check on the phosphate levels in the water. Glasgow testified that Prysby responded, "You don't need to monitor phosphate because you're not required to add it." Glascow indicated that both he and the consulting engineer at the meeting were surprised by the response. They both undoubtedly recognized that their costs would be significantly less if they didn't monitor and maintain phosphate levels, yet neither of these two engineers questioned the surprising response of the MDEQ regulator. Glasgow said, "Then we went on to the next question."

As Flint allowed the highly corrosive water to flow through the aging municipal water supply system, pipes corroded, leaks began to increase, and most importantly, lead was leached from lead service lines (not used today), from soldered joints in copper service lines (lead-free solder is required today), and from brass fixtures (lead-free brass alloys are required today). High levels of lead have exposed the residents, particularly young children, to significant risk of harm. High levels of lead in the blood can severely affect both mental and physical development. Very high levels can be fatal. Repairs to the damaged system, which could have been prevented by proper maintenance of the passivating film inside the pipes and fixtures by monitoring and adjusting phosphate levels, will be very expensive.

The problem seems to stem from the meeting described. Three engineers discussed the problem of monitoring and maintaining phosphate levels in the water in the system. Each of the three, given their respective positions and responsibilities, should have understood this problem, which would be basic knowledge to an engineer experienced in water treatment and municipal water supply. Prysby's reply, "You don't need to monitor phosphate…" may have been technically correct—if there was not a MDEQ requirement to add or monitor phosphate,[129] but water treatment engineers know they must not allow corrosive conditions to develop. And both Glascow and the consulting engineer present, who were both surprised by this statement, quietly accepted it, perhaps because of the implied cost savings, rather than challenging it as questionable engineering practice. The impression is that the financial pressures of the bankrupt city drove these two engineers to make an irrational decision not to monitor and maintain phosphate levels based on the verbal statement of the regulator that monitoring was not required by regulation.

Both Prysby and Glasgow, along with one other, were later charged with criminal conduct because of their actions.

CASE 40

Artifacts, Engineering, and Ethics

An artifact is something that is intentionally created for certain purposes, rather than simply found or discovered. Engineers specialize in bringing artifacts into our world. Consider something as seemingly simple as a metal wastebasket. Its primary intended use is to provide a place to temporarily deposit waste materials, which can then easily be transferred to a more permanent location. But it can be used for other purposes, too. A few years ago one of the authors of this book used a wastebasket to prop open the door to his classroom. He did this because no regular doorstops were readily available. Without something to prop open the door, it would quickly close—leaving students who had yet to enter the room on the wrong side of an automatically locking door.

So, here was a makeshift solution to a problem created, in part, by another artifact—a mechanism designed to lock doors automatically. But, a better way of handling this sort of problem is available—a small doorstop.

So, the instructor went to a local hardware store and purchased a couple of rubber doorstops, sold as a pair and wrapped inside plastic and cardboard. At some time, somewhere, engineers had something to contribute to the design, manufacture, and packaging of little doorstops like the ones the instructor brought to class the next time it met. This was a class on engineering ethics. So, the instructor decided to see if his students could uncover any value questions about doorstops. What advantages, if any, do these little doorstops have over wastebaskets in propping open doors? Why make them out of rubber rather than, say, wood? Why are they sold in pairs? Why are they sold in plastic and cardboard wrappings? The instructor's hope was that, as they thought carefully about such questions, students would be helped to see how engineering and ethics can be joined.

Of course, artifacts are all around us. We can hold some of them in our hands, lift them up easily, move them from place to place, and so on. Other artifacts are too large and heavy to be easily lifted or moved. Buildings are like that. Automobiles are, too—unless started and driven. An automobile can even be driven to all kinds of places one likes to travel, with passengers coming along for the ride. Soon cars that can drive themselves may take over the roads. An automobile of any sort is an engineering marvel, as are so many other artifacts. Cell phones, Blackberrys, and iPhones are artifacts—and they can be taken with us when we drive or ride in automobiles. Automobiles are often described as "iPhone friendly." This promises benefits of some sort. But it can also pose serious problems for iPhone users and those around them, especially when people use them while driving their automobiles. It is claimed that this can make drivers more dangerous on the road than drunk drivers are.

Here is an interesting task for you, the reader. Select at least one artifact—an actual, particular object in our world (e.g., this golf club, tennis ball, automobile, airplane, building, roundabout, stoplight, or interstate highway). Explore, as best you can, the likely history of your artifact—making as clear as you can how you think that engineering might be part of the story of your artifact. Consider how the story of this artifact, or at least artifacts like yours, might include some ethical considerations. These considerations can be about either good features of your artifact and its history and likely future, or bad features of its history and likely future.

In other words, let your artifact introduce you to the interplay between engineering and ethics. In talking about your artifact with others, you might or might not find it useful to use words like "ethical," "moral," "immoral," "unethical." However, whatever words you use, do your best to make sure that you and others will recognize that, in part, your account is about both engineering and ethics—working together.

NOTES

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/shows/cuny/bio/chron.html. Also, Cuny is featured as a moral leader on the Online Ethics Center for Engineering.

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15. This account is based on "The Talk of the Town," *The New Yorker,* 69, no. 39, November 22, 1993, pp. 45–46.
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21. Shawcross, "A Hero of Our Time," p. 39.
22. "Talk of the Town," p. 46.
23. Sudetic, "Small Miracle in a Siege," p. A7.
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32. Ibid., p. 61.
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34. Ibid., p. 73.
35. Ibid., p. 79.
36. Ibid.
37. Ibid.
38. Ibid., p. 81.
39. Ibid., p. 82.
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55. Information for this case is based on a case study prepared by Manuel Velasquez, "The Ford Motor Car," in Manuel Velasquez, *Business Ethics: Concepts and Cases,* 3rd ed. (Englewood Cliffs, NJ: Prentice-Hall, 1992), pp. 110–113.
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71. ABET originally stood for Accreditation Board for Engineering and Technology, but ABET now accredits other programs, so the acronym was dropped and the organization today is simply known as ABET. See ABET. (n.d.). What does ABET stand for? Retrieved March 12, 2017, from ABET: http://www.abet.org/about-abet/what-does-abet-stand-for/
72. Accreditation Board for Engineering and Technology, *Criteria for Accrediting Engineering Programs, 2017-2018*, Outcome f.
73. Campus Compact supports the development of service learning programs throughout the

country. For an early statement of its efforts, see Timothy Stanton, *Integrating Public Service with Academic Study* (Providence, RI: Campus Compact, Brown University, 1989).

74. Edmund Tsang, "Why Service Learning? And How to Integrate It into a Course in Engineering," in Kathryn Ritter-Smith and John Salt-marsh, eds., *When Community Enters the Equation: Enhancing Science, Mathematics and Engineering Education through Service-Learning* (Providence, RI: Campus Compact, Brown University, 1998). Currently at Western Michigan University as associate dean in the College of Engineering & Applied Sciences, Tsang continues his work in service learning. He has also edited *Projects That Matter: Concepts and Models for Service-Learning in Engineering*, Vol. 14 (Washington, DC: American Association for Higher Education, 2000). Service learning is appropriate throughout both undergraduate and graduate programs in engineering. This is well illustrated by Kevin Passino, professor of Electrical and Computing Engineering at Ohio State University. In addition to founding the student-centered Engineers for Community Service at his university, he is developing international service learning projects for PhD students. See Kevin Passino, "Educating the Humanitarian Engineer," *Science Engineering Ethics,* 15, no. 4, 2009, pp. 577–600.
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APPENDIX

NSPE Code of Ethics

PREAMBLE

Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.

I. FUNDAMENTAL CANONS

Engineers, in the fulfillment of their professional duties, shall:

1. hold paramount the safety, health, and welfare of the public;
2. perform services only in areas of their competence;
3. issue public statements only in an objective and truthful manner;
4. act for each employer or client as faithful agents or trustees;
5. avoid deceptive acts; and
6. conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. RULES OF PRACTICE

1. **Engineers shall hold paramount the safety, health, and welfare of the public.**
   a. If engineers' judgment is overruled under circumstances that endanger life or property, they shall notify their employer or client and such other authority as may be appropriate.

Source: https://www.nspe.org/sites/default/files/resources/pdfs/Ethics/CodeofEthics/Code-2007-July.pdf

b. Engineers shall approve only those engineering documents that are in conformity with applicable standards.
c. Engineers shall not reveal facts, data, or information without the prior consent of the client or employer except as authorized or required by law or this Code.
d. Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe is engaged in fraudulent or dishonest enterprise.
e. Engineers shall not aid or abet the unlawful practice of engineering by a person or firm.
f. Engineers having knowledge of any alleged violation of this Code shall report thereon to appropriate professional bodies and, when relevant, also to public authorities, and cooperate with the proper authorities in furnishing such information or assistance as may be required.

2. Engineers shall perform services only in the areas of their competence.

a. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved.
b. Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.
c. Engineers may accept assignments and assume responsibility for coordination of an entire project and sign and seal the engineering documents for the entire project, provided that each technical segment is signed and sealed only by the qualified engineers who prepared the segment.

3. Engineers shall issue public statements only in an objective and truthful manner.

a. Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony, which should bear the date indicating when it was current.
b. Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.
c. Engineers shall issue no statements, criticisms, or arguments on technical matters that are inspired or paid for by interested parties, unless they have prefaced their comments by explicitly identifying the interested parties on whose behalf they are speaking, and by revealing the existence of any interest the engineers may have in the matters.

4. Engineers shall act for each employer or client as faithful agents or trustees.

a. Engineers shall disclose all known or potential conflicts of interest that could influence or appear to influence their judgment or the quality of their services.
b. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.

c. Engineers shall not solicit or accept financial or other valuable consideration, directly or indirectly, from outside agents in connection with the work for which they are responsible.
d. Engineers in public service as members, advisors, or employees of a governmental or quasi-governmental body or department shall not participate in decisions with respect to services solicited or provided by them or their organizations in private or public engineering practice.
e. Engineers shall not solicit or accept a contract from a governmental body on which a principal or officer of their organization serves as a member.

5. **Engineers shall avoid deceptive acts.**

a. Engineers shall not falsify their qualifications or permit misrepresentation of their or their associates' qualifications. They shall not misrepresent or exaggerate their responsibility in or for the subject matter of prior assignments. Brochures or other presentations incident to the solicitation of employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or past accomplishments.
b. Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any contribution to influence the award of a contract by public authority, or which may be reasonably construed by the public as having the effect or intent of influencing the awarding of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee in order to secure work, except to a bona fide employee or bona fide established commercial or marketing agencies retained by them.

III. PROFESSIONAL OBLIGATIONS

1. **Engineers shall be guided in all their relations by the highest standards of honesty and integrity.**

a. Engineers shall acknowledge their errors and shall not distort or alter the facts.
b. Engineers shall advise their clients or employers when they believe a project will not be successful.
c. Engineers shall not accept outside employment to the detriment of their regular work or interest. Before accepting any outside engineering employment, they will notify their employers.
d. Engineers shall not attempt to attract an engineer from another employer by false or misleading pretenses.
e. Engineers shall not promote their own interest at the expense of the dignity and integrity of the profession.

2. **Engineers shall at all times strive to serve the public interest.**

a. Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community.

b. Engineers shall not complete, sign, or seal plans and/or specifications that are not in conformity with applicable engineering standards. If the client or employer insists on such unprofessional conduct, they shall notify the proper authorities and withdraw from further service on the project.
c. Engineers are encouraged to extend public knowledge and appreciation of engineering and its achievements.
d. Engineers are encouraged to adhere to the principles of sustainable development* in order to protect the environment for future generations.

3. **Engineers shall avoid all conduct or practice that deceives the public.**

a. Engineers shall avoid the use of statements containing a material misrepresentation of fact or omitting a material fact.
b. Consistent with the foregoing, engineers may advertise for recruitment of personnel.
c. Consistent with the foregoing, engineers may prepare articles for the lay or technical press, but such articles shall not imply credit to the author for work performed by others.

4. **Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.**

a. Engineers shall not, without the consent of all interested parties, promote or arrange for new employment or practice in connection with a specific project for which the engineer has gained particular and specialized knowledge.
b. Engineers shall not, without the consent of all interested parties, participate in or represent an adversary interest in connection with a specific project or proceeding in which the engineer has gained particular specialized knowledge on behalf of a former client or employer.

5. **Engineers shall not be influenced in their professional duties by conflicting interests.**

a. Engineers shall not accept financial or other considerations, including free engineering designs, from material or equipment suppliers for specifying their product.
b. Engineers shall not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with clients or employers of the engineer in connection with work for which the engineer is responsible.

6. **Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable methods.**

a. Engineers shall not request, propose, or accept a commission on a contingent basis under circumstances in which their judgment may be compromised.

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*"Sustainable development" is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development.

b. Engineers in salaried positions shall accept part-time engineering work only to the extent consistent with policies of the employer and in accordance with ethical considerations.
c. Engineers shall not, without consent, use equipment, supplies, laboratory, or office facilities of an employer to carry on outside private practice.

7. **Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.**

    a. Engineers in private practice shall not review the work of another engineer for the same client, except with the knowledge of such engineer, or unless the connection of such engineer with the work has been terminated.
    b. Engineers in governmental, industrial, or educational employ are entitled to review and evaluate the work of other engineers when so required by their employment duties.
    c. Engineers in sales or industrial employ are entitled to make engineering comparisons of represented products with products of other suppliers.

8. **Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.**

    a. Engineers shall conform with state registration laws in the practice of engineering.
    b. Engineers shall not use association with a nonengineer, a corporation, or partnership as a "cloak" for unethical acts.

9. **Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others.**

    a. Engineers shall, whenever possible, name the person or persons who may be individually responsible for designs, inventions, writings, or other accomplishments.
    b. Engineers using designs supplied by a client recognize that the designs remain the property of the client and may not be duplicated by the engineer for others without express permission.
    c. Engineers, before undertaking work for others in connection with which the engineer may make improvements, plans, designs, inventions, or other records that may justify copyrights or patents, should enter into a positive agreement regarding ownership.
    d. Engineers' designs, data, records, and notes referring exclusively to an employer's work are the employer's property. The employer should indemnify the engineer for use of the information for any purpose other than the original purpose.
    e. Engineers shall continue their professional development throughout their careers and should keep current in their specialty fields by engaging in professional practice, participating in continuing education courses, reading in the technical literature, and attending professional meetings and seminars.

"By order of the United States District Court for the District of Columbia, former Section 11(c) of the NSPE Code of Ethics prohibiting competitive bidding, and all policy statements, opinions, rulings or other guidelines interpreting its scope, have been rescinded as unlawfully interfering with the legal right of engineers, protected under the antitrust laws, to provide price information to prospective clients; accordingly, nothing contained in the NSPE Code of Ethics, policy statements, opinions, rulings or other guidelines prohibits the submission of price quotations or competitive bids for engineering services at any time or in any amount."

Statement by NSPE Executive Committee

In order to correct misunderstandings which have been indicated in some instances since the issuance of the Supreme Court decision and the entry of the Final Judgment, it is noted that in its decision of April 25, 1978, the Supreme Court of the United States declared: "The Sherman Act does not require competitive bidding."

It is further noted that as made clear in the Supreme Court decision:

1. Engineers and firms may individually refuse to bid for engineering services.
2. Clients are not required to seek bids for engineering services.
3. Federal, state, and local laws governing procedures to procure engineering services are not affected, and remain in full force and effect.
4. State societies and local chapters are free to actively and aggressively seek legislation for professional selection and negotiation procedures by public agencies.
5. State registration board rules of professional conduct, including rules prohibiting competitive bidding for engineering services, are not affected and remain in full force and effect. State registration boards with authority to adopt rules of professional conduct may adopt rules governing procedures to obtain engineering services.
6. As noted by the Supreme Court, "nothing in the judgment prevents NSPE and its members from attempting to influence governmental action …"

Note: In regard to the question of application of the Code to corporations vis-à-vis real persons, business form or type should not negate nor influence conformance of individuals to the Code. The Code deals with professional services, which services must be performed by real persons. Real persons in turn establish and implement policies within business structures. The Code is clearly written to apply to the Engineer, and it is incumbent on members of NSPE to endeavor to live up to its provisions. This applies to all pertinent sections of the Code.

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