

Ethics in Engineering

Fourth Edition

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Roland Schinzinger

ETHICS IN ENGINEERING

FOURTH EDITION

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FOR SONIA AND NICOLE MARTIN,
FOR SHANNON SNOW MARTIN,
AND IN MEMORY OF THEODORE R. MARTIN
AND RUTH L. MARTIN.

MIKE W. MARTIN

FOR STEFAN, ANNELOSE, AND BARBARA SCHINZINGER,
FOR SHIRLEY BARROWS PRICE,
AND IN MEMORY OF MARY JANE HARRIS
SCHINZINGER

ROLAND SCHINZINGER

Technology has a pervasive and profound effect on the contemporary world, and engineers play a central role in all aspects of technological development. In order to hold paramount the safety, health, and welfare of the public, engineers must be morally committed and equipped to grapple with ethical dilemmas they confront.

Ethics in Engineering provides an introduction to the issues in engineering ethics. It places those issues within a philosophical framework, and it seeks to exhibit their social importance and intellectual challenge. The goal is to stimulate reasoning and to provide the conceptual tools necessary for responsible decision making.

In large measure we proceed by clarifying key concepts, sketching alternative views, and providing relevant case study material. Yet in places we argue for particular positions that in a subject like ethics can only be controversial. We do so because it better serves our goal of encouraging responsible reasoning than would a mere digest of others' views. We are confident that such reasoning is possible in ethics, and that, through engaged and tolerant dialogue, progress can be made in dealing with what at first seem irresolvable difficulties.

Sufficient material is provided for courses devoted to engineering ethics. Chapters of the book can also be used in modules within courses on engineering design, engineering law, engineering and society, safety, technology assessment, professional ethics, business management, and values and technology.

FOURTH EDITION

Chapters 1 through 3 and 6 through 10 are either new or extensively reorganized and developed. Fuller discussions are provided of moral reasoning, codes of ethics, personal commitments in engineering, environmental ethics, honesty and research ethics, and the philosophy of technology. In addition, "micro issues" concerning choices by individuals and corporations are connected throughout the book with "macro issues" about broader social concerns. Lists of Key Concepts are provided at the end of each chapter. Appendix A lists additional pedagogical resources and contains sample codes of ethics. Mike W. Martin prepared this edition, with suggestions from Roland Schinzinger.

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Mike W. Martin
Roland Schinzinger

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CHAPTER 1

ETHICS AND PROFESSIONALISM

*Engineers shall hold paramount the safety, health and welfare of the public
in the performance of their professional duties.*
Accreditation Board for Engineering and Technology (ABET)

Engineers create products and processes to improve food production, shelter, energy, communication, transportation, health, and protection against natural calamities—and to enhance the convenience and beauty of our everyday lives. They make possible spectacular human triumphs once only dreamed of in myth and science fiction. Almost a century and a half ago in *From the Earth to the Moon*, Jules Verne imagined American space travelers being launched from Florida, circling the moon, and returning to splash down in the Pacific Ocean. In December 1968, three astronauts aboard an Apollo spacecraft did exactly that. Seven months later, on July 20, 1969, Neil Armstrong took the first human steps on the moon. This extraordinary event was shared with millions of earthbound people watching the live broadcast on television. Engineering had transformed our sense of connection with the cosmos and even fostered dreams of routine space travel for ordinary citizens.

Most technology, however, has double implications: As it creates benefits it raises new moral challenges. Just as exploration of the moon and planets stand as engineering triumphs, so the explosions of the space shuttles *Challenger* in 1986 and *Columbia* in 2003 were tragedies that could have been prevented, had urgent warnings voiced by experienced engineers been heeded. We will examine these and other cases of human error, for in considering ethics and engineering alike we

can learn from seeing how things go wrong. Technological risks, however, should not overshadow technological benefits, and ethics involves appreciating the many positive dimensions of engineering that so deeply enrich our lives.

This chapter introduces central themes, defines engineering ethics, and states the goals in studying it. Next, the importance of accepting and sharing moral responsibility is underscored. Finally, we attend to the corporate setting in which today most engineering takes place, emphasizing the need for a basic congruence between the goals of professionalism and business.

1.1 SCOPE OF ENGINEERING ETHICS

1.1.1 Overview of Themes

In this book we explore a wide variety of topics and issues, but seven themes recur. Taken together, the themes constitute a normative (value) perspective on engineering and on engineering ethics.

1. Engineering projects are social experiments that generate both new possibilities and risks, and engineers share responsibility for creating benefits, preventing harm, and pointing out dangers.
2. Moral values permeate all aspects of technological development, and hence ethics and excellence in engineering go together.
3. Personal meaning and commitments matter in engineering ethics, along with principles of responsibility that are stated in codes of ethics and are incumbent on all engineers.
4. Promoting responsible conduct is even more important than punishing wrongdoing.
5. Ethical dilemmas arise in engineering, as elsewhere, because moral values are myriad and can conflict.
6. Engineering ethics should explore both micro and macro issues, which are often connected.
7. Technological development warrants cautious optimism—optimism, with caution.

Let us briefly introduce and illustrate each of these themes.

(1) ENGINEERING AS SOCIAL EXPERIMENTATION. When the space shuttle *Columbia* exploded on February 1, 2003, killing the seven astronauts on board, some people feared the cause was a terrorist attack, given the post-September 11 concerns about terrorism. The working hypothesis quickly emerged, however, that the cause was a piece of insulating foam from the external fuel tank that struck the left wing 82 seconds after launch. The panels on the leading edge of the wing were composed of reinforced carbon carbon, a remarkable material that protected it from 3000-degree temperatures caused by air friction upon reentry from

space into the earth's atmosphere. Even a small gap allowed superheated gases to enter the wing, melt the wiring, and spray molten metal throughout the wing structure.

Investigation of the accident continues as this book goes to press, but investigators have already stated they are interested in far more than pinpointing the immediate cause of the disaster.¹ Several previous incidents involved insulating material breaking off from the fuel tank. Why were these occurrences not scrutinized more carefully? And why were so many additional hazards emerging, such as faulty "bolt catchers," which are chambers designed to capture bolts attaching the solid rocket boosters to the external fuel tank after their detonated-release? Had the safety culture at NASA eroded, contrary to assumptions that it had improved since the 1986 *Challenger* disaster, such that the independent judgment of engineers was not being heeded? Even during *Columbia's* last trip, when crumbling shielding hit fragile tiles covering the craft's wings, some knowledgeable engineers were rebuffed when they requested that the impacts be simulated and observed without delay. Had the necessary time, money, personnel, and procedures for ensuring safety been shortchanged?

Very often technological development is double-edged, Janus-faced, morally ambiguous: As engineering projects create new possibilities they also generate new dangers. To emphasize the benefit-risk aspects in engineering, in chapter 4 we introduce a model of engineering as social experiments—experiments on a societal scale. This model underscores the need for engineers to accept and share responsibility for their work, exercise due care, imaginatively foresee hazards, conscientiously monitor their projects when possible, and alert others of dangers to permit them to give informed consent to risks. In highlighting risk, the model also accents the good made possible through engineering discoveries and achievements. And it underscores the need for preventive ethics: ethical reflection and action aimed at preventing moral harm and avoidable ethical dilemmas.

(2) ETHICS AND EXCELLENCE: MORAL VALUES ARE EMBEDDED IN ENGINEERING. Moral values are embedded in even the simplest engineering projects, not "tacked on" as external burdens. Consider the following assignment given to students in a freshman course at Harvey Mudd College:

Design a chicken coop that would increase egg and chicken production, using materials that were readily available and maintainable by local workers [at a Mayan cooperative in Guatemala]. The end users were to be the women of a weaving cooperative who wanted to increase the protein in their children's diet in ways that are consistent with their traditional diet, while not appreciably distracting from their weaving.²

The task proved more complex than it at first appeared. The students had to identify plausible building materials, decide between cages or one open area, and design structures for strength and endurance. They had to create safe access for the villagers, including ample head and shoulder room at entrances and a safe

floor for bare feet. They had to ensure humane conditions for the chickens, including adequate space and ventilation, comfort during climate changes, convenient delivery of food and water, and protection from local predators that could dig under fences. They also had to improve cleaning procedures to minimize damage to the environment while recycling chicken droppings as fertilizers. The primary goal, however, was to double current chicken and egg production. A number of design concepts were explored before a variation of a fenced-in concept proved preferable to a set of cages. In 1997 four students and their advisor, supported by a humanitarian aid group named Xela-Aid, traveled to San Martin Chiquito, Guatemala, and worked with villagers in building the chicken coop and additional structures such as a weaving building.

Moral values are embedded at several junctures in engineering projects, including: the basic standards of safety and efficiency, the structure of technological corporations as communities of people engaged in shared activities, the character of engineers who spearhead technological progress, and the very idea of engineering as a profession that combines advanced skill with commitment to the public good. In engineering, as in other professions, excellence and ethics go together—for the most part and in the long run. In general, ethics involves much more than problems and punishment, duties and dilemmas.³ Ethics involves the full range of moral values to which we aspire in guiding our endeavors and in structuring our relationships and communities. This emphasis on moral aspiration was identified by the ancient Greeks, whose word *arete* translates into English as either “excellence” or as “virtue.”

(3) PERSONAL COMMITMENT AND MEANING. A team of engineers are redesigning an artificial lung marketed by their company. They are working in a highly competitive market, with long hours and high stress. The engineers have little or no contact with the firm’s customers, and they are focused on technical problems, not people. It occurs to the project engineer to invite recipients of artificial lungs and their families to the plant to talk about how their lives were affected by the artificial lung. The change is immediate and striking: “When families began to bring in their children who for the first time could breathe freely, relax, learn, and enjoy life because of the firm’s product, it came as a revelation. The workers were energized by concrete evidence that their efforts really did improve people’s lives, and the morale of the workplace was given a great lift.”⁴

Engineers’ motives and commitments are as many and varied as those of all human beings. The desire for meaningful work, concern to make a living, care for other human beings, and the need to maintain self-respect all combine to motivate excellence in engineering. For the most part, they are mutually reinforcing in advancing a sense of personal responsibility for one’s work. As we emphasize repeatedly, engineering is about people as well as products, and the people include engineers who stand in moral (as well as monetary) relationships with customers, colleagues, employers, and the general public.

All engineers are required to meet the responsibilities stated in their code of ethics. These requirements set a minimum, albeit a high standard of excellence.

The personal commitments of individual engineers need to be aimed at and integrated with these shared responsibilities. Yet some responsibilities and sources of meaning are highly personal, and cannot be incumbent on every engineer. They include commitments concerning religion, the environment, military work, family, and personal ambitions. When we speak of “personal commitments” we have in mind both commitments to shared responsibilities and to these more individual commitments as they affect professional endeavors.

(4) PROMOTING RESPONSIBLE CONDUCT AND PREVENTING WRONG-DOING. Beginning in 2001, a wave of corporate scandals shook Americans’ confidence in corporations.* In that year, Enron became the largest bankruptcy in U.S. history, erasing about \$60 billion in shareholder value.⁵ The following year the scandal-ridden WorldCom bankruptcy set another new record. Arthur Andersen, a large and respected accounting firm charged with checking the books of Enron and other corporations, was charged with complicity and was forced to dissolve. We return to these events later in this chapter.

Compliance issues are about making sure that individuals comply to professional standards and avoid wrongdoing. Procedures are needed in all corporations to deter fraud, theft, bribery, incompetence, and a host of other forms of outright immorality. Equally essential are reasonable laws and government regulation, including penalties for reckless and negligent conduct. We should examine the pressures that sometimes lead engineers to cooperate in wrongdoing, rather than reporting wrongdoing to proper authorities.⁶

Having said this, an important part of engineering ethics is preventing wrongdoing in the first place. There is a need for what we have referred to as “preventive ethics”: ethical reflection and action aimed at preventing moral harm and unnecessary ethical problems. The main emphasis in ethics should be supporting responsible conduct. In fact, the vast majority of engineers are morally committed. So too are most corporations. Reinforcing the connection between ethics and excellence, individuals and corporations should primarily be “value-driven,” rather than simply preoccupied with “compliance-based” procedures, to invoke terms used in management theory.

(5) MYRIAD MORAL REASONS GENERATE ETHICAL DILEMMAS. A chemical engineer working in the environmental division of a computer manufacturing firm learns that her company might be discharging unlawful amounts of lead and arsenic into the city sewer.⁷ The city processes the sludge into a fertilizer used by

*The term “corporation” will be used freely to include companies that may not be incorporated. In its strict sense, a corporation is a legal construct that enables investors to pool their financial resources for carrying out large, costly, and often risky projects without the burden of individual responsibility for the outcome, physically and financially, beyond possible lack of return on investments. A corporation is treated as if it were an individual itself, taking the blame for the real individual investors. Such an arrangement, so common in our modern economy, raises many questions of accountability and responsibility, particularly shared responsibility.