# Ethics in Engineering

Fourth Edition

Mike W. Martin
Roland Schinzinger

# ETHICS IN ENGINEERING

FOURTH EDITION

**Mike W. Martin**

*Professor of Philosophy*
*Chapman University*

**Roland Schinzinger**

*Professor Emeritus of Electrical Engineering*
*University of California, Irvine*

Mc Graw Hill

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York
San Francisco St. Louis Bangkok Bogotá Caracas Kuala Lumpur
Lisbon London Madrid Mexico City Milan Montreal New Delhi
Santiago Seoul Singapore Sydney Taipei Toronto

The McGraw·Hill Companies

Higher Education

ETHICS IN ENGINEERING, FOURTH EDITION

Published by McGraw-Hill, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020. 

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 QPF/QPF 0 9 8 7 6 5 4

ISBN 0–07–283115–4

Publisher: *Elizabeth A. Jones*
Senior sponsoring editor: *Carlise Paulson*
Developmental editor: *Michelle L. Flomenhoft*
Lead project manager: *Jill R. Peter*
Lead production supervisor: *Sandy Ludovissy*
Lead media project manager: *Audrey A. Reiter*
Senior designer: *David W. Hash*
Cover designer: *Rokusek Design*
Cover image: © *Dave Soderstrom/Rokusek Design*
Compositor: *Interactive Composition Corporation*
Typeface: *10/12 Times Roman*
Printer: *Quebecor World Fairfield, PA*

**Library of Congress Cataloging-in-Publication Data**

Martin, Mike W.
Ethics in engineering / Martin, Mike W., Schinzinger, Roland. — 4th ed.
p. cm.
Includes index.
ISBN 0–07–283115–4
1. Engineering. I. Title.

2005 2003071043
CIP

www.mhhe.com

# CASES, *Ethics in Engineering*

# ABOUT THE AUTHORS

**Mike W. Martin** and **Roland Schinzinger** participated as a philosopher-engineer team in the National Project on Philosophy and Engineering Ethics, 1978–1980. Since then they have coauthored articles, team-taught courses, and given presentations to audiences of engineers and philosophers. In 1992 they received the Award for Distinguished Literary Contributions Furthering Engineering Professionalism from The Institute of Electrical and Electronics Engineers, United States Activities Board.

**Mike W. Martin** received his B.S. (Phi Beta Kappa, Phi Kappa Phi) and M.A. from the University of Utah, and his Ph.D. from the University of California, Irvine, and he is currently professor of philosophy at Chapman University. In addition to publishing many articles, he is author, coauthor, or editor of eight books, including *Meaningful Work: Rethinking Professional Ethics* (2000) and *Everyday Morality* (3d ed., 2001). He received the Arnold L. and Lois S. Graves Award for Teachers in the Humanities and two fellowships from the National Endowment for the Humanities.

**Roland Schinzinger** received his B.S., M.S., and Ph.D. in electrical engineering from the University of California at Berkeley. Born and raised in Japan where he had industrial experience with Bosch-Japan, Tsurumi Shipyard of Nippon Steel Tube Co., and Far Eastern Equipment Co., he worked in the United States as design/development engineer at Westinghouse Electric Corp. and taught at the University of Pittsburgh and at Robert College/Bosporus University (in Istanbul). He was a founding faculty member to the University of California at Irvine, from which he retired as Professor Emeritus of Electrical Engineering in 1993. He authored or co-authored *Conformal Mapping: Methods and Applications* (1991, 2003), *Emergencies in Water Delivery* (1979), and *Experiments in Electricity and Magnetism* (1961, accompanying a kit he designed for use in Turkey). His honors include the IEEE Centennial and Third Millennium medals, Fellow of IEEE, and Fellow of AAAS. He is a registered professional engineer.

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, ANNELISE,* AND *BARBARA SCHINZINGER*,
FOR *SHIRLEY BARROWS PRICE*,
AND IN MEMORY OF *MARY JANE HARRIS SCHINZINGER*

ROLAND SCHINZINGER

# PREFACE

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.

## ACKNOWLEDGMENTS

Since the first edition of *Ethics in Engineering* appeared in 1983, many students, professors, and reviewers have provided helpful feedback or in other ways influenced our thinking. We wish to thank especially Robert J. Baum, Michael Davis, Dave Dorchester, Walter Elden, Charles B. Fleddermann, Albert Flores, Alastair S. Gunn, Charles E. (Ed) Harris, Joseph R. Herkert, Deborah G. Johnson, Ron Kline, Edwin T. Layton, Jerome Lederer, Heinz C. Luegenbiehl, Mark Maier, Nicole Marie Martin, Sonia Renée Martin, Carl Mitcham, Steve Nichols, Michael J. Rabins, Jimmy Smith, Michael S. Pritchard, Harold Sjursen, Carl M. Skooglund, John Stupar, Stephen H. Unger, Pennington Vann, P. Aarne Vesilind, Vivien Weil, and Caroline Whitbeck, and Joseph Wujek.

We also thank the reviewers who provided many helpful suggestions in developing this edition:

Joseph R. Herkert, *North Carolina State University*
O. J. Hahn, *University of Kentucky*
John Athanasiou, *San Jose State University*
J. Phil Wilbourn, *Tennessee Tech University*
Andrew A. Dzurik, *Florida State University*
Jacqueline A. Hynes, *University of California at Santa Barbara*
Jenny Lo, *Virginia Tech*
Charles R. Glagola, *University of Florida*
Nelson Pole, *Cleveland State University*
Pamela J. Neal, *USAF Academy*
Timothy M. Wick, *Georgia Institute of Technology*
Kevin M. Passino, *The Ohio State University*

And we thank the many authors and publishers who granted us permission to use copyrighted material as acknowledged in the notes, and also the professional societies who allowed us to print their codes of ethics in Appendix B.

Our deepest gratitude is to Shannon Snow Martin and to Shirley Barrows Price, whose love and insights have so deeply enriched our work and our lives.

***Mike W. Martin***
***Roland Schinzinger***

# CONTENTS

# 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.