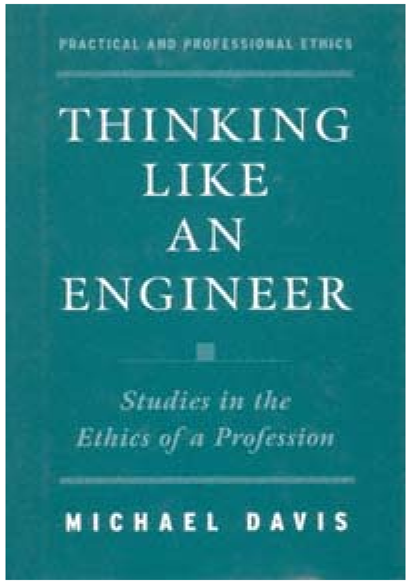

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Thinking Like an Engineer

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Michael Davis

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For Jeffrey, who was an engineer, sort of;
for all my former students who are now;
and for Alexander, who may be, some day.

PREFACE

This book is a contribution both to engineering ethics and to the philosophy of a profession, engineering. Teachers of courses in engineering ethics, the philosophy of any profession, or even philosophy of technology should find much in the book useful, but its proper audience is anyone, engineer or not, scholar or not, who has ever wondered, "What is an engineer?"

What is engineering ethics? The word "ethics" can be used in at least three senses. In one sense, it is a mere synonym for ordinary morality. In another, it names a field of philosophy (moral theory, the attempt to understand morality as a rational undertaking). In a third, it refers to those special standards of conduct that apply to members of a group just because of that membership. When I describe this book as a contribution to engineering *ethics*, "ethics" has both the second and third sense. The ethics in this book is ethics in the second sense, philosophy; but insofar as understanding standards makes both following them and improving them easier, what I do should contribute to engineering ethics in the third sense of ethics as wellthat is, to the interpretation, application, and revision of engineering's special standards of conduct.

As a work in ethics, this book resembles such philosophical textbooks as Harris, Pritchard, and Rabins, *Engineering Ethics: Cases and Concepts.* [1] It nonetheless differs from them in at least two ways. First, it is not a survey but a series of essays, a supplement to textbooks rather than their competitor. The book concentrates on a few particularly important points, corresponding to the book's four parts. Part I, the first three chapters, puts engineering in historical perspective, making clear both how new engineering is and in what that newness consists. Part II is an extended meditation on the Challenger disaster. Each of its three chapters considers one aspect of the complex relationship between engineering ideals and engineering practice today. Here we see in detail how social organization and technical requirements combine to define how engineers should (and presumably do) think. Part III's two chapters clarify the importance of protecting engineering judgment and identify the chief means of doing it. These three parts together give considerable content to the notion of "thinking like an engineer." Part IV, the last three chapters, is concerned with testing this philosophical construction empirically. Chapter 9 reports results of a study of how engineers and managers work together in ten different companies. Chapter 10 attempts to clarify the concept of professional autonomy in such a way that social scientists should be able to tell us how much professional autonomy engineers have. The epilogue draws from the book's argument four questions concerning engineering that the social sciences, including history, could answer in a way helpful to engineering ethics. The epilogue is an invitation to those working in the social sciences to contribute to engineering ethics.

That is one difference between this book and textbooks in engineering ethics, a difference in intensity. The other difference is one of extension. This book is as concerned with the "engineering" in "engineering ethics" as with the "ethics." It is a contribution to the *philosophy* of engineering.

What is the philosophy of engineering? Like the philosophy of science, of law, or of art, the philosophy of engineering tries to understand its subject as a rational undertaking. It does not offer *a* philosophy of engineeringthat is, a (controversial) conception of how engineering *should* be done. It attempts to say what engineering *is*without becoming a mere subtopic in the philosophy (or sociology) of technology. Although the philosophy of technology focuses on what engineers (and others) help make, the philosophy of engineering focuses on engineers themselveson what they try to do and why.

I have learned from Walter Vincenti's *What Engineers Know and How They Know It,* 2 but that book and this one differ substantially. First, Vincenti is both an engineer and a historian. I am neither. He has a grasp of technical principle and historical documents that I never will. Second, although Vincenti's work contributed to mine, his has a narrower focus. He tries to understand engineering as a developing body of technical knowledge, a discipline; I, on the other hand, try to understand engineering as a profession. Knowledge, though of course a part of what makes an engineer, is only a part. At least as important is the way the knower moves (or, at least, is supposed to move) from knowledge to action. That movement from knowledge to action is the "thinking" of my title. The thesis of this book, if it has only one, is that this thinking is fundamentally ethical (in both my first and third senses).

The philosophy of engineering may seem too technical a field for philosophers: Who could know better than engineers how engineers think? The question answers itself. Of course, engineers know better than anyone else how they think. That, however, does not decide who should do philosophy of engineering. Generally, scientists know science better than philosophers of science, lawyers know the law better than philosophers of law, and artists know art better than most philosophers of art. Philosophers still do philosophy of science, law, and art, doing something that scientists, lawyers, and artists cannot do for themselves. Although some of these philosophers are amphibians, philosopher-scientists, philosopher-lawyers, or philosopher-artists, even some of the best are not. That is a fact, but it raises the

question: How is it possible for those who know less to teach those who know more? Answering that question requires a little "philosophy of philosophy."

Philosophy (at its best) puts our tacit knowledge into words. It makes the obvious obvious. The first philosopher, Socrates, distinguished himself from the "wise men" of ancient Greece by asking rather than telling. He asked the pious what piety is, politicians what politics is, and so on. Those he asked had great trouble putting what they knew into words; indeed, much they said turned out, on Socrates' examination, to be false.

How have engineers done compared to the experts Socrates questioned? Certainly, many engineers feel that nonengineers generally do not understand what engineers do, that the achievements of engineers are appreciated less than they should be, and that engineering does not do as well as it should in recruiting the next generation. Scientists, architects, lawyers, and even MBAs generally seem to carry off the prizes. Yet, when engineers try to make their own case, what happens? Even Samuel Florman, as literate a polemicist as any profession can claim, is surprisingly unhelpful. His *The Existential Pleasures of Engineering* [3] is a powerful defense of technology, but one from which engineers are largely absent. Change a few words and the book could be a defense of scientists, industrialists, or even mere inventors rather than engineers. His *The Civilized Engineer*[4] fails in another way, pleasing engineers rather than informing nonengineers.

The power of philosophers is not in their initial knowledge of a field butas Socrates stressedin their initial ignorance of it. That ignorance is not ordinary ignorance, the unassuming or presuming of the benighted; it is, instead, experienced, open, systematic, cooperative, and dogged. Such ignorance can help those who know a field to put their knowledge into words even those who do not know the field can understand. The result is paradoxical. Even the expert seems to learn from having what she said put into a philosopher's wordsas one learns something when seeing for the first time the pattern in a mosaic known by heart. The expert may then conclude that the philosopher "really" knows more about the expert's field than the expert herself, forgetting that the philosopher could only reveal what he revealed by drawing it out of her. While philosophers often seem generators of knowledge, they are, as Socrates put it, merely its midwives.

This book is the product of more than a decade working with engineers, trying to understand what so absorbed them and about which they could say so little. I began by thinking that engineering was primarily about things, a complex but fundamentally unimaginative application of science, mere "problem solving" (as even engineers will describe it, if you let them). I have come to understand engineering quite differently: as the practical study of how to make people and things work together betteran undertaking as creative as art, as political as law, and no more a mere application of science than art or law is. That is the understanding I have tried to put into words here. I will consider myself successful if engineers reading this book say, "Yes, of course, exactly" and nonengineers add, "So, that's what they do: I had no idea!"

I publish this book without apology for the mistakes it must contain. The only way to write without mistakes is to write nothingor, at least, nothing interesting. I have done my best to be interesting, taking controversial positions if I believed them right and defending them as best I could, hoping thereby to incite others to add their views, explained and justified, whether or not they agree with mine. Only through critical discussion that is rational and informed can either engineering ethics or the philosophy of engineering grow as a field of study. If, in the process, I am shown to have erred, I will not complain.

Though I publish this book without apology, I do not publish it without trembling. For his efforts, Socrates was put to death. Apparently, some experts do not take well to philosophical ignorance. If I fare better than that master of philosophy, it will be because of those engineers (practitioners, academics, and students) who pulled me aside, explained what I got wrong, and then patiently answered one question after another until I got it right. My notes thank those I remembered, but my memory for names is not good. I hope those I forgot will forgive the forgetting.

I owe special thanks to two colleagues: to Vivian Weil, for helping me, more than a decade ago, to see that engineers might be at least as philosophically interesting as lawyers, and to Robert Ladenson, for convincing me to join a small band of philosophers following their calling among the engineers at the Illinois Institute of Technology (IIT). Though I accepted the invitation more because I trusted him than because I believed what he said, I now doubt that any other course of action could have had as good an outcome. I had taught at three other universities with engineering schools; IIT was the first where the philosophers and engineers had much to say to each other.

Chapters 1, 3, and 5 through 10 have appeared in print before much as they do here. Chapter 4 is a much enlarged version of an essay

previously published. Chapter 2 and the epilogue see print for the first time. Though acknowledgement of prior publication is made at the appropriate place, I should like to thank the editors of the journals in which those chapters initially appeared, as well as Alan Wertheimer, the editor of this Oxford series, and two of his reviewers, Deborah Johnson and Michael Pritchard, for suggesting many of those improvements now incorporated in the text.

M.D.
CHICAGO
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Research

PART I
INTRODUCTION TO ENGINEERING

This work of philosophy begins with a long foray into the history of engineering. Foraging in another's field is always risky. One can easily get lost, fall into traps the owners long ago learned to skirt, or find oneself suddenly outnumbered and outgunned. I am taking the risk for four reasons. First, I believe that reading history can lead to philosophical insights. The past gives the present context. Second, I believe that some historians, those I have been reading, sometimes miss the obviousor, at least, get the emphasis wrongand therefore tend to mislead those trying to understand engineering. I believe I can do better. Third, although I am trespassing, I have precedent on my side. Philosophers have long made themselves useful by pointing out the obvious in fields not their ownwhich is all I intend to do. Fourth, and most important, I believe that my trespass will pay off. Understanding the history of engineering better, we shall understand engineering better.

This foray has two important outcomes. First, it works out a definition of engineering as an occupation, a way to distinguish engineers from nonengineers. In other words, it defines the field this book is to study. Second, it makes a case for distinguishing between engineering as an occupation and engineering as a profession. It makes clear the importance of understanding engineering as a profession rather than as a mere intellectual discipline or occupation of "knowledge workers." To understand engineering as a profession is, I argue, to make ethics central to what engineers do.

1
Science, Technology, and Values

Is engineering just applied science, a field as free of values as science itself? Or is engineering just technology, a field already well studied by those who study technology? Are the values of engineering, if there are any, just the values of technology, whatever those are? Or does engineering contribute something more? What? Why?

We must answer these important questions as soon as possible. But before we can, we must clarify the terms. "Science," "technology," and "values," like "engineering" and "ethics," are used in enough different ways to be dangerous. Clarifying these five terms and others related to them requires a foray into history. History explains some of the confusion about these terms and helps us choose meanings useful to the work ahead.

Techne and *Sophia*: Twins Ancient but Unequal

I begin with etymology. "Technology" is a compound of two words from ancient Greek, *techne* and *logos*. *Techne* means manual art. So, for example, a *tekton* was a carpenter or builder; an "archi*tect"* was a master builder. The suffix form of *logos*, "ology," means a putting into words, an explanation or study. So, when our word "technology" still meant what Greek tells us it means, technology was the explanation or study of manual art, just as biology is the explanation or study of *bios*, "life". It was a field in which gentlemen entered the workshop to record the artisan's secrets for later publication. [1]

That, of course, is not what technology means now. Despite its Greek root, "technology" is really a new word, recoined in the middle of the last century for a new idea.[2] What idea?

Ancient Greece was a slave-owning society and, like other slave owners, Greeks tended to associate manual labor with slaves. Because no free man would want to be mistaken for a slave, the ancient Greeks generally avoided doing what slaves do. For example, because slaves tended to rush about on their master's business, free men were supposed to walk slowly. [3] Greeks had such a low opinion of manual labor that they even rated sculpture less noble than painting because the sculptor, unlike the painter, had to sweat over his work like a slave.[4]

There were a few exceptions to this low opinion of manual labor. One was athletics. Athletics, however sweaty, was not something slaves did. War was another exception. Hacking one another with swords, though hard and dirty work, was a job for free men.

The Greeks contrasted *teche* with *sophia.* Although often translated as "intellectual knowledge" or even "science," *sophia* is probably better translated as "wisdom." From *sophia* comes our word "philosophy" (the love, that is, the pursuit, of wisdom). For the Greeks, philosophy included mathematics, physics, economics, and similar sciences. Because philosophy was primarily a matter of thought, not manual art, philosophy was appropriate to free men.

The Greeks of Greece's Golden Age loved *sophia,* and she rewarded them accordingly. The Greeks of that period can claim credit for beginning the tradition of philosophy now dominant over most of the world, the one to which I belong. They can also claim credit for beginning a number of the sciences, including geometry, biology, and political science.

Their achievements in poetry, architecture, and history are no less impressive. Not so their contributions to *techne.* Of course, there were some contributionsfor example, improved design of war galleys. But you must hunt for them. Europe's Dark Ages seem to have given us many more useful devices than did Greece's Golden Age.[5]

By now, perhaps, you can see two reasons to distrust that ugly word "technology."[5] First, there is the implicit opposition between *sophia* and *techne.* Today we think of science and technology as related, not opposed. So, for example, one reason politicians give for funding scientific research is that it will pay off in new technologies.[6] Second, there is the word's meaning in Greek. For us, technology is notas its Greek parts suggesta study of manual art but, primarily, our way of referring to all those inventions that make manual labor easier, more productive, or unnecessary. In this sense, technology began with the first tool someone made; the new technologies we hear about are new technologies in this sensenew tools someone has made.

Of course, there is yet another sense of technology, one derived from this second but referring to a studyas in, for example, the title "institute of technology" (or "technological university"). An institute of technology is not, as the Greek suggests, a place to study manual arts (carpentry, machining, and so on)a mere technical school. An institute of technology is, instead, a place to study practical inventions: how to make them and how to organize them (and those who use them) to make other useful things. The Greeks, who had a word for almost everything, seem not to have had a word for that.

What does this history have to do with us? Consider, for example, how we dress for work: Some of us dress in "white collars"that is, fine shirts, ties, good slacks, dresses, sport coats, or the like. Others wear "blue collars"that is, coarse shirts, denim pants, coveralls. Generally, those in white collars have higher status than those in blue. Salary is secondary, as is social usefulness. A carpenter has less status than an accountant earning half as much. Why? Though carpentry requires a trained mind, it requires as well, like other blue-collar work, much sweaty labor surrounded by dust and debris. Because such labor would quickly ruin good clothing, the white collar guarantees some distance between its wearer and such "slavish labor." And, because it does that, the white collar confers status.

No matter the origin of our parents, we are, in this respect at least, all more or less descendants of the ancient Greeks. Even if we ourselves like manual labor, we do not respect it as much as we do mental labor. [7] I doubt that this is good, especially for engineers. But it does seem to be a stubborn fact about us. We are prejudiced against blue collars, not only those who work in them but even those who associate with those who work in them.[8]

That prejudice shows up even in a phrase seemingly having nothing to do with it"science and technology." Why does technology always come second? The explanation cannot be historical. If technology refers to inventions making manual labor easier, technology is older than science by thousands of years. And, even if the "technology" in "science and technology" refers instead to the systematic study of practical invention, technology would be no younger than science in the corresponding sensethe systematic study of nature. Until quite recently, "science" included all systematic knowledge, whether of nature or invention, including even jurisprudence and theology.

Nor can the explanation of the inevitable priority of science be alphabetical order. Substitute "engineering" for "technology" and the order remains the same: science and engineering (as in the journal *Science and Engineering Ethics*), not engineering and science. Nor can the explanation be practical importance. Technology bakes our bread; science only helps us to understand how. Nor can the explanation be mere accident. Accident would produce more variation. The order seems fixed: science and technology. Why?

The answer, I think, is that the order indicates relative status. Science has higher status than technology; hence, it gets first mention.

Well, shouldn't science have higher status? After all, isn't technology just applied science? Doesn't science come first in the order of development? Doesn't science lay down the law, like a master whereas technology merely applies it, like a slave? Even engineers may be tempted to answer yes to these questions. But the answer is: No, technology is not merely applied science.

Science, Technology, and Engineering

One can understand the words "science" and "technology" to refer to comparable concepts. Science is explicit, systematic knowledge of how "nature" works; technology is explicit, systematic knowledge of how to make useful things. Unfortunately, usage today is not so neat. Although the term "science" did once refer primarily to explicit, systematic knowledge of nature, its meaning has now shifted somewhat so that today it refers as much, or instead, to a social undertaking: "a voyage of discovery" (as scientists like to say) rather than merely to what they discover. In this sense, science consists of certain communities engaged in trying to understand how nature works. [9]

Because "technology" refers only to our practical inventions, or to the study of how to make more, we lack a term comparable to this new sense of science. What do we call communities that invent useful things or, at least, add to our knowledge of how to do it? "Technician" is wrong: A technician is an assistant, one who carries out routine work under direction of a scientist, engineer, architect, physician, or the like. "Technologist," though a natural choice, has not caught on; "applied scientist," though once popular with sociologists, natural scientists, and even engineers, is now fading.

Why? I think the reason is that the great majority of people who would have to be called technologist or applied scientist already have a satisfactory name: "engineer."

I said "great majority." I meant it. The United States today has well over two million engineers. That is more than all other technologists together. Most other technologists are either architects, chemists, physicists, biologists, physicians, computer scientists, or mere inventors. The United States has only about 135,000 architects, 388,000 natural scientists (including chemists, physicists, and biologists), 450,000 computer scientists, and 600,000 physicians.[10] I have no figure for "mere inventors," but, since most inventors seem to be engineers, there can't be many "mere inventors." The number of physicians contributing to technology also cannot be large. Most physicians are not in research or development but simply provide health care. So, even assuming that most scientists are in technology, not pure research, engineers must outnumber all other technologists combined by at least two to one.

These numbers suggest an obvious solution to the problem of what to call all those who make technology: Call them engineers. But that would, I think, be a terrible mistake. Chemists, architects, physicians, biologists, and the like are not engineers. Understanding why they are not will help us understand both the values inherent in most technology, the technology engineers develop, and the place of ethics in any technology. It also brings us to the heart of our subject. But it requires more history, though mostly history less ancient than before.

The Beginnings of Engineering

Professions, aping aristocracy, like to trace their origins back to ancient times. So, for example, the American Medical Association's *Principles of Medical Ethics* cites certain provisions of Hammurabi's Code (about 2000 BC) as the earliest known code of medical ethics.[11] There is, of course, some truth in such going back. The healers of ancient Babylonia resemble today's physicians in many ways. For example, like modern physicians, they tried to cure the sick. However, there are many differences as well, and, for our purposes, the differences are more important. For example, Babylon's healers do not seem to have been organized as a profession or even as a guild. We will understand professions better if we start their history with the rise of modern markets about two centuries ago, the accompanying dissolution of the old distinction between trades and "liberal professions," and the slow emergence of something new. Even an old occupation can be a new profession.

By 1850, especially in England, we begin to see the modern pattern. The professions are connected with both a formal curriculum, ending with an examination and a certification of some sort, and explicit standards of practice, a code of ethics. [12] Admittedly, those creating this new pattern seem unaware of doing something new. But there can be little doubt that they misunderstood their own actions. Even some of the terms they used were new. For example, the term "medical ethics" was coined in 1803 by a physician, Thomas Percival, for a book he thought was on an old topic.[13]

What is true of most professions is true of engineering. False pedigrees abound. Some histories of engineering begin with the Stone Age, with the first tools. They confuse engineering with mere technology.[14] Other histories begin more sensibly, recognizing that engineers generally do not do manual labor but prepare instructions for others to carry out. As the first tool almost certainly predates such a division of tasks, these histories begin much later, with the first projects large enough to have some people laying out a plan and others implementing it. They begin with the building of Stonehenge, the Pyramids, or some other wonder of ancient civilization.[15]

Though better than the first, this second way of beginning the history of engineering still has at least two embarrassing consequences. One embarrassment is that it makes architects (or "master builders") the first engineers. This is embarrassing because engineers generally agree that architects today are definitely not engineers. Another embarrassment is that this way of telling the story makes a mystery of why our word for engineer comes from French, rather than Greek, like "architect," and why the French have had the word for barely four hundred years. Generally, we have a word for anything important to us almost as soon as we have the thing. There are no significant "whatchamacallits."

So, when I tell the story of engineering, I start four hundred years ago in France. Back then there were things called "engines"but engine then simply meant a complex device for some useful purpose, a contraption showing intelligence in designin short, a machine. The first people to be called engineers were soldiers associated with catapults, siege towers, artillery, and other "engines of war." They were not yet engineers in the sense that conerns us. They were, rather, engineers in the sense that, even today, the driver of a locomotive is an engineer. They were engineers only in the sense that they operated (or otherwise worked with) engines.

Some soldiers are still engineers in something like this sense: They belong to an engineering corps. Though they do not know what engineers know, they are directly involved in works of engineering, though not precisely with engines of war, a term no longer in common use.

Four hundred years ago the armies of France were led by nobles, men on horseback who learned war from their fathers or on the battlefield or died in the attempt. The foot soldiers came with the nobles. Most were peasants or artisans who

knew little of war until trained in camp. When the war ended, the army dissolved, each noble leading his own people home. In such an army, an engineer was usually a carpenter, stone mason, or other artisan bringing civilian skills to war.

When Louis XIV ended the regency in 1661, France still made war in this way. But, within two decades, France had a standing army of 300,000, the largest, best trained, and best equipped European fighting force since the Roman legions. This achievement was widely copied. To this day, most of our military wordsfrom "army" itself to "reveille," from "bayonet" to "maneuver," from "private" to "general"are French. "Engineer" is just one of these military terms.

Until 1676 French engineers were part of the infantry. But in that year the engineers were organized into special units, the *corps du génie.* 16 This reorganization had important consequences. A permanent corps can keep much better records than isolated individuals; can accumulate knowledge, skills, and routines more efficiently; and can pass them on. A corps can become a distinct institution with its own style and reputation. More than a group of protoengineers, the *corps du génie* were, potentially, both a center of research in engineering and a training ground for engineers (in something like our sense)*officieurs du génie.*

The *corps du génie* did not take long to realize this potential. Within two decades, it was known all over Europe for unusual achievements in military construction. When another country borrowed the French word "engineering" for use in its own army, it was for the sort of activity the *corps du génie* engaged in.17 That was something for which other European languages lacked a word.

The *corps du génie* was not, as of 1700, a school of engineering in our sense; it was more like an organization of masters and apprentices. Indeed, strange as this may seem now, at that time neither France nor any other European state had a permanent military academy (in anything like our sense), much less a school of engineering. There was no settled curriculum for training officers generally or engineers in particular, or even a very clear idea that a curriculum was necessary. Only during the 1700s did the French slowly come to understand what they wanted from an engineering education and how to get it. But, by the end of the 1700s, they had a curriculum from which today's engineering curriculum differs only in detail; they had also invented engineering.[18]

An army needs fortifications for protection, mines under enemy fortifications, roads to march on, and bridges to cross. Civilians either need the same things or need other things that require similar skills to build. So, in 1716, the French established another corps of engineers, the *corps des ponts et chaussés,* to build and maintain the nation's bridges, roads, and canals (as important to the army as to commerce). This corps set up a school for training its officers, the first engineering school to survive long enough to matter. Like the military engineers, these civil engineers were admired all over Europe. Those who copied their method copied their name as well.[19]

What was their method? Engineers, military as well as civil, resembled architects in being able to make drawings for construction projects, develop detailed instructions from those drawings, and oversee the execution of those instructions. They nonetheless seem to have differed from architects in at least three ways.

First, engineers were much better trained in what was then the new mathematics and physics than the architects were. They had the ability to consider systematically questions most architects could only deal with intuitively or ignore. [20]

Second, because the strategies of engineering had their roots in the necessities of war, engineers paid more attention to reliability, speed, and other practicalities. So, for example, the systematic testing of materials and procedures in advance of construction was early recognized as a characteristic of engineers.[21] At least in comparison, the architect seemed an artist, one for whom beauty claimed much of the attention an engineer would devote to making things work.

Third, to be an engineer was to be trained as an army officer, to be disciplined to bear significant responsibility within one of world's largest organizations. Engineers were therefore likely to be better at directing large civilian projects than were architects, most of whom would have had experience only of much smaller undertakings.

These three advantages tend to reinforce one another. For example, not only do large projects require more planning in advance and more discipline in execution, but they are also more likely to require better mathematical analysis and to justify extensive testing of materials and procedures. For this, and perhaps other reasons, civil engineers slowly took over much of the work that once would have been the domain of architects. They were a new power in the world.

Early experiments in engineering education culminated in the École Polytechnique. Begun in 1794 as the École des Travaux

Publics (the school of public works), it changed its name the following year, for the first time connecting engineering and *techne*. I don't know why the French changed the school's name. The school never trained architects, much less artisans or mechanics. It was a school of engineering, deserving the "poly" only for offering preparation for many fields of engineering, military and naval engineering, as well as civil.[22]

The École Polytechnique's curriculum had a common core of three years. The first year's courses were geometry, trigonometry, physics, and the fundamentals of chemistry with practical applications in structural and mechanical engineering. There was a good deal of drawing, some laboratory and workshop, and recitations after each lecture. The second and third year continued the same subjects, with increasingly more application to the building of roads, canals, and fortifications and the making of munitions. For their last year, students were sent to one of the special schools: the school of artillery, the school of military engineering, the school of mines, the school of bridges and roads, the school of geographical engineers (cartographers), or the school of ships.[23]

Engineers will immediately recognize this curriculum, especially the four years, the progression from theory (or analysis) to application (or design), and the heavy emphasis on mathematics, physics, and chemistry.

The École Polytechnique was the model for engineering education for much of the nineteenth century.[24] The United States began using it very early. Our first engineering school was the military academy at West Point. By 1817, it had adopted much of the École's curriculum, its methods of instruction, and even some textbooks.[25] I say more about West Point in the next chapter.

Values in Engineering

What values does engineering incorporate? A decade ago, Eugene Ferguson, an engineer turned historian, drew up a list of "imperatives of engineering." 26 The list is neither complete nor fundamentalnor, indeed, even entirely fair. It will nevertheless help us understand engineering.

Engineers, Ferguson claimed, (1) strive for efficiency, (2) design labor-saving systems, (3) design control into the system, (4) favor the very large, the very powerful, orin electronicsthe very small, and (5) tend to treat engineering as an end in itself rather than as a means to satisfying human need. These imperatives are, according to Ferguson, instincts engineers bring to their work. Although engineers can resist them, just as I can resist drinking water even if I am thirsty, they are, in effect, the engineer's default setting, what engineers will do unless they consciously try to do something else.

Ferguson intended this list to be a criticism of the way engineers work. It is, I think, both less and more than that. The list is less than a criticism because the first four imperatives seem, on reflection, at least as much virtues as vices. The list is also more than a criticism because it highlights certain enduring features of engineering, permitting us to connect engineering's history with today's practice. Let's take a closer look at Ferguson's list.

"Efficiency" is the first imperative Ferguson identifies. Ferguson points out, rightly, that "efficiency" is a slippery term, meaning "most powerful" here, "lowest cost" there, and something else elsewhere. What he overlooks is the concept's utility.

Engineers generally define efficiency so that they can measure it (or its components), assign numbers, and thereafter seek to control it. That is not surprising. Like other professions, engineering tends to analyze a situation so that its distinctive skills can be applied. One distinctive skill of engineers is giving mathematical structure to practical problems. The concept of efficiency allows them to exercise that skill.

Engineers have, no doubt, sometimes paid too much attention to efficiency, especially forms of efficiency that turned out not to matter. Indeed, the history of engineering is in part the history of measurable properties used for a time as proxy for something that could not be measured and then discarded when the proxy proved not to have enough of a relation to what the engineers actually cared about.27 Because engineering is a practical undertaking, it must learn from practice. It cannot learn from practice without making mistakes. Some of engineering's mistakes concern efficiency.

Engineers can be quite slow about giving up one of these proxy measures. But, even this slowness is understandable. Engineers are used to working in large organizations, organizations in which change is difficult and the consequences are often hard to predict. They therefore have a tendency to follow practices they would no longer adopt. (Consider, for example, how American engineers still specify non-metric bolts or screws.) The world is a tough laboratory. Many things better in theory are worse in practice. How daring do we want engineers to be with our lives?

The second imperative on Ferguson's list is a preference for labor-saving devices. Engineers will, Ferguson thinks, design to save labor even when labor is cheap and the end result will be higher production costs and more unemployment.

The engineer's preference for labor saving is understandable as a product of engineering's military origin. Since engineering began, the primary labor pool of most armies has been their own soldiers. Because no general wants his soldiers doing construction when they could be fighting, military engineers have always had an incentive to look for means of saving labor even though the labor saved was, in one sense, cheap (indeed, free).

As military engineering became civil engineering, this tendency might have put engineers at a disadvantage in their competition with other technologists. Their designs might have proved too costly. Those who hired engineers would, however, soon have learned this. They would then have compensated, either by calling in an engineer less often or by making sure that the engineer called in defined the desired outcome taking cost into account.

If, as Ferguson's criticism suggests, such compensation seldom occurs, the most likely reason is that the engineer's preference for labor-saving devices generally serves those who employ engineers. The reason that preference might serve their employers is not hard to see. Labor has a tendency to become scarce, and so costly, when it is not routinely saved.

Of course, that is only a tendency. Many of those thrown out of work by a particular innovation may live out their lives on the dole. Many engineers would, no doubt, like to take such effects into account, and perhaps many of their employers would let them. But, if engineers are to take such considerations into account, they will need both the relevant information and a routine for using it.

Gathering such information belongs to the social sciences, not to engineering as it is or as it is likely to become. Any curriculum that could give engineers the skills to develop significant social statistics would probably be too long to attract many students. Engineers should not be blamed for failing to take into account social consequences about which they can only guess.

However, when such information exists, developing ways to incorporate it into engineering work is certainly something engineers can, and should, do. Indeed, they have long done this with the employer's share of the cost of production. And, over the last two decades, thanks to the Environmental Protection Agency (EPA), engineers have become adept at incorporating environmental costs into their designs (e.g., by designing for disposal as well as for manufacture and use). They could do the same for social impact if they had numerical standards for assessing impact and sources of information from which the relevant numbers could be taken.

Engineers can help to develop such standards, just as they helped to write EPA standards. But, just as with environmental standards, standards for permissible social impact are probably not what most people would want engineers alone to decideor even engineers with the help of lawyers, accountants, corporate executives, and other specialists. Social impact raises political issuesthat is, issues everyone wants a part in deciding. If engineers decline to develop such standards unilaterally, should we blame them? 28

Ferguson's third imperative is designing controls into the system. Engineers generally try to separate planning and execution. Intelligence is designed into the system, requiring as little intelligence as possible of the system's operators. The assembly line is the typical example of this imperative. Engineers generally try to design an

assembly line so that the work is so simple that only a few minutes training is necessary to learn the job. The job is therefore likely to be repetitive and boring; those doing the job are reduced to little more than organic robots.

Engineering's military past certainly explains the origin of this imperative. Soldiers sent over to help on an engineering project, whether digging trenches or putting a bridge over a river, don't have much time to learn the job. The military engineer must design the work so that anybody can do it. (Architects, in contrast, seem, if anything, to have a bias in favor of designs requiring craftsmen.)

But its military past alone does not explain why this imperative persists in civilian engineering (or, at least, why engineers who do such things should be so much in demand). The explanation of that, like the persistence of engineering's second imperative, must be that this tendency is useful in civilian engineering as well. One recent example suggests why that might be.

McDonald's restaurants now have cash-register buttons with pictures of the various items on the menu. The cashier need not know the price of anything or even be able to read; the cashier only has to recognize the pictures and push buttons accordingly. In a business where employee turnover is high and education is low, where prices change frequently and training is expensive, this dumbing down of the cashier's job both saves money for McDonald's and opens employment to many who might not otherwise qualify. Whoever thought of that device, engineer or not, was undoubtedly a hero to McDonald's. 29

The fourth imperative of engineering that Ferguson lists is a tendency to disregard human scale, preferring the very large or the very small. The reason for this imperative is that engineering was, and remains, a creature of large organizations. Louis XIV's army, one of the largest organizations of its day, created engineering to do what civilian artisans could not do (or could not do well enough). Even today, most engineers work in large organizations. You do not need an engineer to construct a single-family house. A carpenter or architect will do, as they always have. If, however, you want to construct a thirty-story building, you need engineers.

The problem, I think, is not so much that engineers disregard human scale as that they are seldom needed for things on a human scale. Generally, asking engineers to work on a human scale is like asking lawyers to prepare a partnership agreement for two children opening a lemonade stand. They can do it, but either they will do what anyone else could do or they will do something out of all proportion to the job.

In this respect, the very small can be like the very large. For example, to make today's tiny electronic circuits requires productive forces and controls of which a single human being is incapable. Hence, there is work for engineers.

Ferguson's last imperative, putting technical brilliance ahead of human need, is unlike the others. It is a failing common to all professions. (We all know the joke about the surgeon who says, "The operation was a success, though the patient died.") But this last "imperative of engineering" is worse than a failing common to all professions; it is a failing inconsistent with one of engineering's fundamental values.

I have stressed the military origins of engineering.30 I have not pointed out that most of the period we have been talking about, roughly the 1700s, is known as the

Age of Enlightenment. This was the time when many Europeans first came to believe that enlightenment, that is, scientific learning, would bring peace, prosperity, and continuous improvement. For countless ages, the best hope of the wise was that the world would not get much worse. With the Age of Enlightenment, people began to act on the belief that the world could be made much better. Engineering has this belief built into it. So, for example, early graduates of the École Polytechnique were noted for "scientific and democratic idealism and a desire to work for human progress." 31 The same attitude was evident in England at about the same time. When, in 1828, the British Institution of Civil Engineers, then nine years old, asked one of its members, Thomas Tredgold, to define the term "civil engineering," he gave an answer engineers still quote: "Civil Engineering is the art of directing the great sources of power in Nature for the use and convenience of man. . . . The most important object of Civil Engineering is to improve the means of production and of traffic in states, both for external and internal trade."32

For Tredgold, engineering was committed to making things "for the use and convenience of man." But, for Tredgold, this was not simply a matter of *maintaining* things as they are. Engineering was supposed to "*improve* means of production and traffic." Engineering was, by definition, an instrument of material progress.

But what about engineering today? Most engineers would, no doubt, want to tinker with Tredgold's definition, for example, by substituting "people" for "man." But few, if any, would want to change its core. Engineering remains an undertaking committed to human progress. So, for example, the most widely adopted code of engineering ethics in the United States begins: "[Engineers uphold and advance the integrity, honor, and dignity of the engineering profession by] using their knowledge and skill for the *enhancement* of human welfare."[33]

Why Engineers are Not Scientists

That is enough about engineering. We are ready to see how engineers differ from other technologists. I have already pointed out some of the ways engineers differ from architects. I shall now explain how they differ from applied *scientists.*

I once did a workshop at the research lab of a large petroleum company. The audience was about half chemists and half chemical engineers. I first asked the chemists, "If you had a choice between inventing something useful and discovering new knowledge, which would you prefer?" The chemists thought this a hard question: "After all," they reasoned, "it's hard to imagine an interesting discovery in chemistry that would not have a practical payoff." Eventually, I asked for a show of hands. About half the chemists voted for "something useful" and about half for "new knowledge." The engineers, on the other hand, *all* voted for usefulness. For them, new knowledge was just a means to improving human life.[34]

Unlike the chemists, the engineers had no commitment to science as such. They *used* science, much as they used other sources of insight. They also contributed to science much as they contributed to lawyering and other social practices, for example, by helping to reduce the cost of chemicals used in the manufacture of computers. But they did this as nonscientists, as participants in a voyage of invention rather than discovery.

This difference between engineers and chemists came as a surprise to these researchers. Many had worked side by side for decades. They thought that they shared the same values. But we do not wear our values on our clothing like an identity badgeexcept, of course, by declaring ourselves to be of this profession rather than of that. These researchers had not taken the difference in profession seriously. That is why they were surprised.

This difference between scientists and engineers is not a mere idiosycracy of one industrial laboratory. I have asked the same question at other industrial laboratories since, with much the same result. Nor is this difference between scientists and engineers restricted to industrial laboratories. I have asked my question at university workshops attended by both engineering and science faculty. The results were even sharper. The only thing rarer than a university scientist who voted for something useful was an engineer who voted for new knowledge. [35] In this respect at least, engineers are not scientists, not even applied scientists. The primary commitment of engineers is not to knowledge, theoretical or applied, as one would expect of scientists, but to human welfare.[36]

Ethics and Engineering

Earlier, I described engineering as a "new power in the world." Power, though neither good nor bad in itself, is always dangerous. Because of the scale on which engineers generally work, engineering is particularly dangerous. Engineers long ago realized this and set about to ensure, as much as possible, that engineering would be used for good rather than evil. They organized as a profession, adopted codes of ethics, and tried to put the codes into practice.

"Ethics" (as noted in the Preface) has at least three common uses. It can refer not only to ordinary morality or the systematic study of ordinary morality but also to those special morally permissible standards of conduct every member of a group wants every other member to follow even if that would mean having to follow the standards too. It is in this third special-standard sense, I think, that members of a profession talk of their "profession's ethics."[37] In this sense, engineers did not have a code of ethics until they adopted one. In the United States, that was not until early in this century.[38]

In this sense, too, their code of ethics is what they make itas long as the standards they lay down are consistent with ordinary morality.[39] That means that engineering ethics can change over time and even differ from country to country or field to field.

There is, then, an important difference between moral values, such as the engineer's commitment to improving human life, and ethics (special standards of conduct). While engineers generally seem to have valued human welfare since early in the history of engineering, failing to treat the public welfare as paramount in their work could not be unethical (in my third sense of "ethical") until engineers adopted a standard of conduct requiring them to treat the public welfare as paramount. Nor could failing to treat the public welfare as paramount as such be immoral until then. Morality imposes no such duty, though it does require us to avoid doing certain kinds of harm and perhaps to render certain kinds of aid.[40] The history of engineering ethics reminds us that ethical standards, like other engineering standards, are not discoveries but useful inventions.

Values such as honesty, safety, or efficiency are reasons for acting, and so reasons for adopting standards of conduct, but values as such, even moral or professional values, do not tell us how we should act. A value as such can only demand consideration, that is, a certain weight in our deliberations. Values such as efficiency, safety, and even honesty are considerations to be taken into account in deciding what to do. They cannot, as such, be obeyed or disobeyed. In contrast, standards of practice, including a code of ethics, do tell us how we should act. They do not lend themselves to weighing. They are imperatives we can only obey or disobey. And, as we see later, they deserve special attention in any discussion of engineering ethics.

2
A History of Engineering in the United States

This chapter continues our foray into the history of engineering, showing (1) that engineering (in the United States at least) is, in part, a fusion of several older activities (managing, craft work, science, and invention); (2) that conceptions of engineering changed substantially over the last two hundred years and also varied somewhat from industry to industry (with one activity, then another, seemingly central); and (3) that there are nonetheless real limits to what can be engineering, limits demonstrated especially by attempts to train engineers that apparently failed because they overemphasized one or another activity. Though engineering is undoubtedly a "social construct" in some sense or other, an engineer is not an engineer simply because society confers the title. The work engineers do has a discipline of its own. Any adequate understanding of engineering must acknowledge that discipline. Central to that discipline is a certain way of educating engineers (a certain curriculum) and a certain way of using what engineers know (a code of ethics).

In the Beginning

The first engineers in the United States, or at least the first to bear the title, were officers in the Revolutionary War; the first school of engineering here was a military academy, West Point. [1] This connection between engineering and the military was no accident. As explained in chapter 1, engineering began with the great army built by Louis XIV after 1661. Though engineers were soon called on for civilian projectsto build roads, bridges, and canals; to construct mines and oversee their operation; or to construct shipsmost of the training of these "civil engineers" was identical to that of military engineers. So, for example, when the French reorganized engineering education in 1794, creating the École Polytechnique, they put students of military and civilian engineering side by side for three years, separating them only in their fourth (and final) year of training, when they were sent to one or another school of "application" (the school of military engineering, the school of bridges and roads, and so on). After 1797, all students at the École Polytechnique wore uniforms and lived under military discipline. [2]

Establishing an engineering school in the United States in the first years of the republic was not easy. The first attempt occurred when George Washington was still only a general. Other attempts followed. Even with an Act of Congress in 1802, more than a decade passed before West Point had examinations, grades, or even a settled curriculum. The curriculum settled on, four years in length, was derived from the École Polytechnique. Along with the curriculum came a small library, recitations, examinations, one French officer, several textbooks, and even the use of blackboards.[3]

Though another two decades would pass before anyone successfully copied West Point, the first attempt came soon. Alden Partridge graduated from West Point in 1805, taught mathematics there for the next fourteen years, and briefly served as superintendent, leaving under a cloud. In 1820, he opened his own schoolthe American Literary, Scientific, and Military Academyin his home town, Norwich, Vermont (just across the Connecticut River from Dartmouth College), to train officers for the army and engineers for public works.[4] In 1824 he moved the academy to Connecticut; in 1829 he moved it back to Norwich. In 1834 the academy became Norwich University, apparently without any change of purpose, and so remains to this day, an experiment complete and forgotten (though it moved once more, in 1865, to Northfield, Vermont).

Though Captain Partridge's school enrolled almost as many students as West Point between 1820 and 1840, it did not do nearly as well as an engineering school. Of West Point graduates through 1837, 231 became civil engineers; of Norwich graduates during the same period, only about 30 did (and they generally held less responsible positions).5

The 1830s were more hospitable to copies of West Point than the 1820s; the next decade, even more so. The Virginia Military Institute was founded in 1839; the Citadel, South Carolina's military college, in 1842; and the Naval Academy at Annapolis in 1845.6 What was true of engineering education in general was certainly true of civil engineering. The late 1830s mark the real beginning of civil engineering education in the United States.

The age of Rensselaer Polytechnic Institute, our oldest school of civil engineering, may seem to refute this claim. But Rensselaer, founded in 1823, is in fact evidence *for* the claim, not against it.

Rensselaer was founded without either "polytechnic" or "institute" in its name. Like Norwich, it went through several changes, though it never moved. Stephen Van Rensselaer, a gentleman farmer with a Harvard degree, gave the school both his name and money to train *teachers* of agriculture and mechanical arts for the grammar schools of his locale. The original curriculum was a single year (as one would expect of a normal school of the day).

But by the 1830s, Rensselaer had become a kind of scientific finishing school for graduates of colleges of liberal arts like Harvard or Dartmouth. It may, in fact,

rightfully claim to be the first American graduate school. Many of the graduates of this period became important in American geology, botany, and geography. [7]

But Rensselaer was not yet an engineering school. It did not award a degree in civil engineering until 1835 and did not have a distinct engineering curriculum until the late 1840s.[8] That curriculum, three years in length, along with the school's present name, seems to owe much to an 1847 trip to Europe by the school's director, young Benjamin Franklin Greene (who himself graduated from Rensselaer in 1842 with one of its first degrees in engineering).[9] Yet, the addition of "polytechnic" to Rensselear's name may not signal any direct connection with the École Polytechnique. By then, Europe had other polytechnics (all modeled, more or less, on the French original).[10] What the new name certainly did signal was that thereafter Rensselaer would focus on training engineers rather than scientists and that French schools, rather than American or English, directly or indirectly, provided the model.[11]

Why did the first engineering schools in the United States use French models? The answer is simple: The French then provided the only practical models. The English, although already leading Europe in manufacture in 1800, would not have a respected school of engineering until well after midcentury,[12] and whether we even say the English had civilian engineers in 1800 depends on how close we judge the analogy between the skills of the mostly self-taught mechanics, industrialists, and builders of England and the French engineers whom they admired and studied.[13] The English did well with what was, in effect, training through apprenticeship in a craft. In 1800, the United States was almost without engineers (or protoengineers) to whom apprentices could be sent.[14] So, like most of Europe, the United States copied France.

All our early engineering schools focused on mathematics, physics, chemistry, and drawing. There was also a good deal of bookkeeping, surveying, measurement, and other practical subjects. There was little of the Latin, Greek, or Hebrew; classical literature; or rhetoric characteristic of the liberal arts college of the day, though there might be enough French (or German) to read untranslated texts.

The difference between these early engineering schools and the liberal arts colleges of the day was not, however, that the engineering schools taught science while the liberal arts colleges did not. By 1800 Harvard, Brown, William and Mary, North Carolina, and the other important colleges already had professors of mathematics and natural science.[15] The early engineering schools differed from the liberal arts colleges primarily in offering an education that was explicitly practical in a way that the college education of the day was not. But practical for what? The historian Charles O'Connell tells a story that suggests an answer.

In 1825, James Shiver led a team of civilians to survey the route for an extension of the National Road in Ohio. Because the road was a project of the Army Corps of Engineers, Shiver reported to Colonel Macomb, the Army's chief engineer, in Washington. Shiver was soon reporting that his team found it impossible to use the Army's standard forms. Macomb wrote back that the forms "were conceived to be more full and distinct, and consequently better adapted to the fulfillment of the purposes for which they were intended," than what Shiver proposed instead. But, because Macomb had dealt with civilians before, he made allowances. The "civilian

brigade" could use Shiver's simpler forms for now but should switch to the Army's forms "as soon as they shall be understood." [16]

Shiver was a competent civilian used to working the way civilians then did. Macomb spoke for an organization more complex than any other in the United States. In truth, the Army's ways made sense only in the Army. The United States was then largely rural, with most citizens living in towns with populations under 2,500. Its industry, although already inventive, still consisted almost entirely of small companies. Such companies did not need, or even understand, the standardization the Army took for granted.[17]

Even a major project like a canal could still be undertaken without engineers. Indeed, the greatest of them all, the Erie Canal, was begun about the time West Point settled on a curriculum (1817) and completed about the time Rensselaer was founded (1825). Though often called "America's first engineering school," the Erie was mostly a school of hard knocks. Those in responsible charge were surveyors, lawyers, or gentleman farmers. They learned as they went, sometimes from visits to other canals or from books and sometimes from experience.[18] Whether these "canal engineers" are properly engineers at all is, like the analogous question about the British "engineers" of the same period, one that can be answered either way, depending on whether one chooses to emphasize the analogies with today's engineers (what they built) or the disanalogies (their training and methods). They are marginal cases. Treating them as clear cases of engineers brings into engineering many who clearly do not belong.

What was true of the early canals was not true of the early railroads. Even the Baltimore & Ohio Railroad (B & O), often compared to the Erie Canal and called "America's first school of railroad engineering," employed school-trained, especially West Pointtrained, engineers from the time work began in 1824.[19]

What explains this difference between the canals and the railroads? At least four factors seem relevant:

1. While canals were an old technology, railroads were not. Insofar as railroads were a new technology, experience counted for less and a knowledge of fundamental principles for more.

2. Second, railroads required more centralized planning than did canals. The chief economic advantage railroads had over canals was speed. Speed was possible only if lines were clear, water and wood were available at set distances, repair crews could be sent out quickly, and so on.

3. By 1824 West Point had been in existence long enough for its graduates to prove themselves likely to be useful to railroads.

4. West Point graduates brought with them styles of organization that suited engineers. So, for example, in 1829 Lieutenant Colonel Long, having worked on the B&O for five years, published the first *Rail Road Manual*, a book on which later railroad engineers, schooled or not, would rely.[20] There are many striking similarities between this manual and the Army's.[21]

Even so, the railroads of the 1820s or 1830s were not the domain of engineers they would become. The true achievements of American engineers of this period are of a different order. For example, between 1825 and 1840, the Army's arsenal in Springfield, Massachusetts, developed procedures eventually much admired in

Europe as "the American System." This system made weapons parts interchangeable to a degree never before achieved; it also subjected skilled workers to a new discipline, including the substitution of an hourly wage for the traditional piece rate. The arsenal was a model for later mass production. [22]

In 1850, the first year the census counted engineers, only about two thousand Americans identified themselves as nonmilitary engineers, two thousand in a population of about twenty-three million (that is, about one in ten thousand).[23] Today, in a population barely ten times larger, we have a thousand times that number of engineers (that is, about one in one hundred).

Engineering is sometimes described as a "captive profession" because most engineers work in large organizations (General Motors, Westinghouse, Dow Chemical, IBM, and so on).[24] Engineering is contrasted with such "free professions" as law and medicine, where most members practice as individuals or in small groups (or, at least, did so until recently). Unfortunately, the term "captive" gives the wrong emphasis to an important insight. Although we do need engineers for the vast undertakings typical of large organizations, engineering is no more a captive of those organizations than the heart is a captive of the body. The relationship between engineering and certain large organizations, like that between the heart and the body, is symbiotic. Work in large organizations is not a nightmare from which engineers will someday wake; it is their natural habitat. We don't need the skills of engineers to do what machinists, draftsmen, architects, carpenters, millwrights, and the like can do alone or in small groups. Engineers are numerous only when there are large organizations to employ them in large undertakings. In 1850 the United States still had few such organizations.

Middle Period: The "Fragmenting" of Engineering

In the United States of 1850, civil engineers still thought of engineering as a single occupation. In 1867, when a few hundred of them established the first national engineering society, the American Society of Civil Engineers, any civilian engineer could join.[25] But, even then, engineering had begun the branching into specialties that would, by 1920, produce five major societies (for civil, mining, mechanical, electrical, and chemical engineering) and many smaller organizations, each with membership requirements excluding most other engineers.[26]

The history of the half century from 1870 to 1920 can be read as tragedy: the loss of the primal unity of engineering under the impact of industrialization. One history of mechanical engineering even titles its chapter on this period "Engineering: The Fragmented Profession."[27] There are at least four reasons not to read history this way:

> First, much of the history of engineering, not just of this period, is a history of such branching. The first branching separated French civil from French military engineering in the middle of the 1700s.[28]
>
> Second, the primal unity of engineering is itself dubious. The period could equally well be portrayed as the one in which engineering became a single identifiable occupation of which civil engineering was but a part. In the United States of 1870, it was, I think,

still not clear what relation civil engineering had to the "mechanic arts," bridge building, mining, or metallurgy. Were they all engineering? Even in 1896, when Columbia finally admitted that its school of mining, founded in 1863, had long since become what *we* would call a school of engineering, the name became "the School of Mining, Engineering, and Chemistry." Apparently, even in the 1890s, "engineering" still did not include everything we now mean by that term. 29

Third, the half century from 1870 to 1920 was a period of great success for engineering. In 1880, the United States, with a population of forty million, counted seven thousand civil engineersmore than triple the number in 1850 (while the general population barely doubled). Yet this impressive increase gave no indication of what would happen during the next four decades. The 1920 census reported 136,000 engineers, twenty times the number in 1880 (in a population that had again barely doubled).30

Fourth, the enormous branching of engineering is inevitable given the enormous growth of industries that rely on engineers.

Engineering has an important connection with mathematics and natural science, as the similarity between early engineering curricula and today's suggests. But engineering is more than mathematics and natural science: Engineers know how to organize work, give instructions, and check outcomes. This knowledge varies from industry to industry. So, for example, a civil engineer designing pipes that ordinary plumbers are to install should *not* use tolerances an aerospace engineer could use without a second's thought.31

This field-specific knowledge is largely the result of experience, originally the experience of individual engineers, "field experience" as well as the results of tests in a laboratory or pilot plant. Because engineers routinely record and report their experience in the same way, this individual knowledge gets passed on to other engineers with whom they work. Eventually, much of it ends up in the tables and formulas that fill the manuals written for those in the field. From there, it works its way into customer specifications, government regulations, and courses taught those entering the field. Though this knowledge generally takes the form of graphs, equations, mathematical formulas, and drawings of things, it has little to do with natural science. It is congealed experience of how humans and things work together.[32]

Engineers often complain that when new technology worksthink, for example, of the space shuttlescientists get the credit, but, when it fails, engineers get the blame.[33] Although engineers are, I think, right about how praise and blame are often distributed, I don't think they should complain. That distribution is a compliment to engineersthough one given with the back of the hand. It implies that scientists only *experiment* and experiments generally fail, whereas engineers *engineer* and engineering generally succeeds. An engineer's failure is noteworthy for the same reason a scientist's success isit is unexpected.[34]

What makes engineers so likely to succeed is not their knowledge of mathematics and natural science. That they share with scientists. What makes them so likely to succeed is their knowledge of particular industries, what works and what does not work *there*, what engineers call "engineering science." Consider, for example, the safety factor for steel struts supporting a bridge. Setting a reasonable margin of safety for such a structural component requires taking into account, among other things, past failures to catch flaws in materials, likely errors in maintenance, and unpre-

dicted changes in use of a structure that, properly maintained, can last for centuries. Such knowledge is not the domain of any natural science. It is sociological knowledge, a knowledge of how people and tools work together, but it is nonetheless engineering knowledge. Only engineers know much about such things.

Here we reach another insight into engineering. Though engineers often describe themselves as applying natural science to practical problems, they could just as easily, and more accurately, describe themselves as applying knowledge of how people work in a certain industry. Engineering is at least as much management as it is natural science. All engineers share the ability to give mathematical structure to the problems they encounter, the ability to draw on the natural sciences for help in developing solutions, and the ability to state each solution as "a design" or set of useful specifications or directions. But these designs, specifications, or directions are, in effect, rules governing someone's work.[35] Engineering is, and always has been, technical management.[36]

Technical management requires detailed knowledge of particular techniques. When such knowledge becomes so great that no one can learn it all, knowledge of techniques in one industry will exclude similar knowledge of techniques in other industries. Engineers will have to specialize and that specialization will tend to break along industry lines.

But other occupationslaw and medicine, for examplespecialized without fragmenting in the way engineering has. Lawyers have the American Bar Association; physicians, the American Medical Association. Why then should engineers not have an American Engineering Association rather than so many interlinking societies, boards, councils, joint committees, and institutes that no engineer knows more than a part? The branching of engineering probably was inevitable; not so this fragmentation. Although I agree that the fragmentation of engineering was not inevitable, I think comparison with law and medicine will help explain why it was nonetheless likely.

Until recently, a majority of lawyers and physicians worked alone. Their employers, the client or patient, might come in with any sort of problem. An unspecialized practice maintained a common body of experience in law and medicine for which engineering had no counterpart since well before 1900.

Today, of course, *that* common experience has largely disappeared. Both lawyers and physicians now frequently specialize and their professional societies, once relatively homogeneous and unified, are now divided into hundreds of "sections" as diverse and almost as independent as engineering's separate societies. Still, few lawyers or physicians work the way engineers long have. Though both lawyers and physicians now commonly work in groups just as engineers do, they seldom work in the same kind of group. Few lawyers, and even fewer physicians, work on projects requiring coordination among even a hundred other lawyers or physicians. Few work on projects in which everyone else has the same specialty. Engineers, in contrast, generally work with engineers in their own field: civils, with civils; mechanicals, with mechanicals; and so on.37 Often engineers must work with hundreds or thousands of other engineers. (For example, a single nuclear power plant needs several hundred engineers on site just to operate.) The names of specialties in law and medicine derive from problems any client or patient can have. The client or patient still provides a common experience for lawyers or physicians. That is not true of engineering. In engineering, the specialties generally take their name from a kind of employer or client, the industry in which engineers of that kind predominate. Engineering could remain a single occupation only when engineers had so little to do that they had little reason to specialize.

Who is an Engineer?

Almost from the beginning of engineering, engineers have disagreed about the relative importance of the scientific (especially, mathematical) knowledge engineers share and the specific practical knowledge that tends to divide them. Those emphasizing practice tended to take an interest in professional ethics; those emphasizing science did not. [38] We can learn a good deal about what engineering isor at least what it has becomeby taking a look at how this disagreement affected the education of engineers.

The practical emphasis in engineering education has long appealed to practitioners, especially those who began as apprentices rather than students: Teach engineers what they need to know to do the job they are going to do, the extremist would say. Forget theory. Get the engineer into the shop as soon as possible.[39]

At this extreme, the practical approach would exclude not only courses in the humanities, social sciences, and other typical elements of a liberal education but also much engineering science. It would, in effect, substitute vocational training for the university education that has long been the norm for training engineers.[40]

The early history of engineering in the United States includes many experiments with practical education in a college or other academic institution, all more or less short-lived. For example, Amos Eaton, who taught civil engineering at Rensselaer in the 1830s, described its program in this way: "The *cloister* begins to give way to the field, where things, not words, are studied." Eaton claimed that no mathematics more advanced than arithmetic was necessary to teach engineering, that the most important part of engineering could not be learned from any book, and that the civil engineering text used at West Point was good only for "closet reading."[41] Yet, during Amos's tenure, Rennselaer was no more successful at training engineers than was Norwich.[42] And, when Greene replaced Amos, Rensselaer moved much closer to the scientific extreme which, by the standard of the times, West Point represented.[43]

Beginning with the Erie Canal, many large undertakings in the United States tried the practical approach as a way of supplying technical skill not obtainable in any other way. Whether these count as attempts to train engineers in the shop is an open question. I will give just one example.

During the 1890s, General Electric offered a course in "practical engineering" for $100. To be eligible, one had to be a "young man" at least twenty-one years old and have *either* a degree in civil, mechanical, or electrical engineering *or* two years' experience in practical electrical work or two years in a machine shop. The course of study, a year long, consisted of rotating through various departments of GE's Lynn Works: four weeks in the shop plant doing wiring, two weeks in the arc department assembling arc lamps, and so on. There was no formal instruction.[44]

What are we to make of this shop training? Notice that for this course in practical engineering, two years of work experience were considered equal to a college degree in engineering. By the 1890s, a first degree in engineering required four years, just as it does today. So, at GE, practice was not only a substitute for formal education, it was, it seems, considered, year for year, twice as good. This is a striking attitude, especially in a company that, like GE, was then among the technologically most advanced. What explains GE's attitude?

We must, I think, recognize that the meaning of engineer (and engineering) has changed over time. The term "engineer" was vague in 1890 and, though less vague than it used to be, is still vague today. But it is not confused.

A term is confused when any case to which it is thought to apply is disputable. A confused term, such as "round square," has inconsistent criteria of application. "Engineer" is not like that. There are clear cases. On the one hand, someone with a degree in civil or mechanical engineering and several years of successful practice is certainly an engineer. On the other hand, train operators and boiler tenders, though usage allows them to be called engineers, clearly are not engineers in the sense relevant here. Such "technicians" are engineers only in a sense belonging to an earlier age.

Though not confused, "engineer," like other terms, is still vague. In addition to the clear cases, there are disputed cases. One contemporary dispute concerns whether an individual can, by getting the right experience, become an engineer without a degree in engineering (for example, with only a degree in physics or chemistry). Complicating this dispute is a subsidiary dispute concerning which experiences are of the right kind. Is supervising engineering work for a decade or so the right kind? Or must an individual actually do some engineering himself? And what constitutes "doing engineering"? Why isn't supervising engineers doing engineering?

Back in the 1890s, the boundaries were vaguer. Then mechanical engineers were still at pains to distinguish themselves from "mere mechanics" who were, in turn, something more than today's mechanics. Mechanics then were still expected not only to repair machines but to make improvements as necessary. They were still regularly allowed to invent. [45] Electrical engineers had a similar problem distinguishing themselves from "mere electricians" who were, in turn, something more than today's electricians.[46] And so on. Perhaps what GE then meant by practical engineering might today be identified by a two- or four-year degree in technology rather than engineering (or even by an advanced degree in technological management). But, back in the 1890s, such distinguishing degrees were not an option. Engineers had to find other ways to explain how they differed from mechanics, electricians, and other craftsmen with whom they shared some tasks and much technical knowledge. Engineers found only two ways to explain the difference.

One way was to understand engineering as a kind of management.[47] Engineers issue orders; those with technical skills merely carry them out. Engineers are officers in the army of production. Though it has strong roots in the history of engineering, this way of distinguishing engineers from craftsmen is plainly inadequate. It fails to explain why engineers *should* be in charge. The explanation cannot simply be that the employer so ordains. If being put in charge of engineering work is all that

distinguishes engineers from other employees, anyone put in charge of engineering work would be an engineer. Engineers have generally supposed that engineering requires more than that (as, indeed, their employers have as well). 48 The other way, then, is to see that engineering requires knowledge craftsmen do not have: Engineers can give orders to craftsmen because engineers know things that mere craftsmen do not. This claim, though plausible, is plausible only if the knowledge in question depends, at least in part, on training outside the shop. Knowledge of natural science and advanced mathematics certainly is such knowledge. Hardly anyone would suppose much of those subjects could be learned in the shop.

That is one advantage of understanding engineering as fundamentally "scientific" rather than "practical". There are at least three others. First, if engineering was to be a profession, like law or medicine, not just a job title such as "manager," engineers could not let being an engineer depend on how an employer happened to define the engineer's job. Credentials, not employment, had to define the engineer. Second, a common academic training is generally considered one crucial mark of a profession. Insofar as engineers considered engineering a profession, or wanted engineering to be one, they tended to emphasize academic training. Third, engineering's unity, insofar as it exists, depends heavily on all engineers having an education that they share with each other (a basis for the "engineering method" engineers believe all engineers share). Emphasis on what goes on in the shop stresses just those features of engineering that threaten to divide engineering into many mutually incomprehensible occupations. In contrast, emphasis on "engineering as science" seems to confirm the sense most engineers have that, for all the immense differences between fields, virtually all engineers share something that distinguishes them both from ordinary workers and from ordinary managers.[49]

The question, "Who is an engineer?," sounds like a philosopher's questionand it is. But it is also a practical question: Every engineering society that decides, as most do, to limit membership (or a certain category of membership) to engineers has to define engineer with more or less precision. The historian Edwin Layton taught us much about the consequences of adopting various definitions. Definitions close to the practical pole tend to turn engineering societies into trade associations; definitions close to the scientific, to exclude many who shape the projects engineers carry out and do much to maintain discipline among engineers.[50]

Layton, however, taught us that while failing to make clear how hard it is to say what an engineer is. In particular, he failed to notice that, at its extreme, engineering as science can be as disastrous for engineering as "engineering as practice." Training engineers as scientists, if only as "applied scientists," tends to turn out scientists rather than engineers.[51] Consider, for example, the Lawrence Scientific School, founded in 1847 as part of Harvard, to teach: "1st, Engineering; 2d, Mining, in its extended sense, including metallurgy; 3d, the invention and manufacture of machinery."[52] Plainly, Lawrence was supposed to be an engineering school. By 1866, Lawrence had graduated 147 students: 94 of these became professors or teachers; 5 became college presidents; but only 41 actually became engineers (as against 126 from Rensselaer during the same twenty years).[53] The Massachusetts Institute of Technology opened in Boston in 1865 in large part because Lawrence had failed as a school of engineering.[54]

Nonetheless, during much of this century, especially after World War II, engineering education moved ever closer to the scientific extreme. Programs in specialized fields of engineeringeverything from agricultural engineering to telephone engineeringdisappeared from the undergraduate curriculum, leaving only the larger divisions: civil, chemical, electrical, and the like. And even courses in these fields tended more and more to emphasize general principles, calculations, and laboratory work. Students were left to learn the art of engineering after graduation, if at all. [55]

Only recently did engineering schools begin to move back toward practice. They did so largely under pressure from industry and the board that accredits engineering schools. But, this countermovement did *not* mean a return to the shop. Engineering schools, instead, began to think of engineering in a new wayas fundamentally concerned with design.[56] Some results of this new thinking are already in placefor example, senior courses in engineering design. Other results are only now showing upfor example, as design elements in junior or even sophomore courses in engineering science. And some results are only at the stage of talk or experimentfor example, as attempts to include in design courses everything from the ethical issues a design might raise to the practical problems of getting colleagues and superiors to adopt one's design.[57]

In retrospect, these recent developments seem both sound and overdue. The stereotype of engineering as the logical or, rather, mechanical, solution of practical problems by deduction from scientific principles misses the creative side of much engineering, something that should have been obvious from the striking newness of so many works of engineering, whether the bridges of the early railroad engineers or the bewildering variety of today's computers.

Of course, engineering is not only inventiveness, just as it is not only science or only management. We want engineering rather than mere invention in many departments of life in part because engineers work within constraints other inventorswhether architects, applied scientists, industrial designers, or mere handymendo not. Engineers have distinctive routines for ensuring safety, economy, reliability, durability, manufacturability, and so on. These routines, and the engineering science behind them, are subordinate to engineering design. But, though subordinate, they are fundamental to engineering, much as a certain pattern of rhyme and meter is to making a sonnet.

Who then is an engineer? Today we must answer: anyone who can design as engineers do.[58] Unfortunately, we have only the roughest idea of what engineering design is. Today, the philosophy of engineering is where the philosophy of science was a hundred years ago. We have barely begun to understand that there is a question.[59]

Ethics and the Profession of Engineering

So far in this chapter, I have discussed engineering primarily as an "occupation," not a "profession." I had a reason. While the old expression "liberal profession" referred to any occupation suitable for gentlemen, the modern use of "profession" requires moreorganization, with standards of admission, including both training and character, and standards of conduct beyond the merely technical. [60] In 1850 engineering was still not a profession in this sense; nor was it so in the United States even in 1900. Today it is. What explains the change?

Until this century, engineering societies in the United States were primarily scientific or technical associations. So, for example, the American Society of Civil Engineers (ASCE) was established with the purpose of "advancing knowledge, science and practical experience among its members, by an exchange of thoughts, studies, and experience."[61] There was no suggestion either of improving the formal education of engineers or of setting standards of conduct.

Indeed, the first efforts to set minimum standards for engineering education came from the engineering *schools*, not from practicing engineers. In 1893, at the Columbian Exposition in Chicago, seventy engineering teachers organized the Society for the Promotion of Engineering Education (SPEE), later to become the American Society of Engineering Education (ASEE).[62] While SPEE undertook a number of valuable studies of engineering education, making many influential recommendations, not until 1932 did the major engineering societies establish the Engineers' Council for Professional Development (ECPD) to accredit engineering curricula.[63]

The adoption of standards of conduct began earlier. Indeed, in one sense, it began when engineers first distinguished themselves from those unable to work the way engineers do. Engineering can be defined, in part, by standards of competenceand standards of competence are, in a sense, standards of conduct. But every skilled occupation has standards of conduct in this sense, and some, like trade associations or scientific societies, may be organized to maintain them. Ethical standards, not standards of competence or organizations, seem to distinguish professions from other skilled occupations.[64]

Engineers in the United States lacked distinctive ethical standards until the second decade of this century. Why did they not adopt such standards earlier? Why did they adopt them then? My guess is that engineers did not adopt ethical standards earlier for the same reason that most of today's professions, including law and teaching, did not. They did not see the need.[65]

Until this century, engineering was a clubby affair. There were relatively few engineers and those few worked in a small world in which gossip maintained what discipline was necessary. But by 1900 that time had passed. Cities grew up where small towns had been. The big cities of 1850 or 1870 had tripled, quadrupled, or quintupled in size. The same thing happened to the companies for which most engineers worked.[66] And engineering itself grew enormously. The few thousand engineers of 1870 had become more than a hundred thousand and seemed likely to continue to increase rapidly. By 1900 most engineers were young. Old systems of apprenticeship were being swamped. College or technical school was, or at least soon would be, the primary route to a career in engineering.

The old men of the profession naturally sought new means to do what they could no longer do by the old. A formal code of ethics must have seemed one way to help the young understand what was expected of them. So, early in this century, each of the major engineering societies set up a committee to draft a code of engineering ethics, but the drafting proved harder than expected.

The committees found that they agreed on less than they had supposed; even determining what that little was took much effort. 67 The societies were not only writing down what they agreed on, they were also hammering out new agreements. What began as an attempt to preserve the past ended in a new professionin two senses. First, engineers began professing something new; they committed themselves to a specific code of ethics. Second, their organizations were no longer mere technical societies; they constituted an occupation organized to carry on certain work in accordance with standards beyond what law, market, and morality demandedthey were a profession.

After World War I, there was a smaller round of code writing; after World War II, another; then, starting in the 1970s, the largest round yet. All this code writing produced much coordination among major engineering societies and substantial agreement on what a code of ethics should contain. Today, engineers have relatively clear standards of conduct they can look to for guidance and can cite when offering advice to one another, when criticizing one another's work, or when seeking to prevent certain conduct. Chapters 4 and 8 provide examples of those standards. What engineers still lack is a systematic way to protect members of their profession who act ethically when an employer or client wants something else. As with other professions, so with engineering: Ethics is unfinished business.

My Method

We all have a tendency to see institutions, professions, and even people as more or less complete, as Platonic ideas dropped into history. This is plainly a mistake when trying to understand people. We all know that however smooth the surface we show the world, we are all beings ever changing or, at least, ever capable of change.[68]

Because I believe this to be true of professions as well, I try to describe engineering as an evolving institution, one that people much like us have made, not always intending what they achieved, imperfect, as all human works are, and therefore capable of improvement. I believe that thinking of engineering in this way will help engineers both to understand and to resolve the ethical problems they face. I also believe that thinking of engineering in this way helps the rest of us understand engineering. In the chapters to follow, we shall see whether that is so.

3
Are "Software Engineers" Engineers?

Today, the field has emerged as a true engineering discipline."
John J. Marciniak, *"Preface," Encyclopedia of Software Engineering* (1994)

If you are a "engineer," you could be breaking the law. It is illegal in 45 states to use that title, warns Computerworld newspaper. People who aren't educated and licensed in 36 recognized engineering disciplines can't call themselves "engineers," and computer professionals often don't qualify.
Wall Street Journal, June 7, 1994, p. 1.

For those interested in professions, the emergence of what may be a new profession should generate the same excitement that the discovery of a new class of objects in the sky generates among astronomers. Not only is it inspiring to watch, it is a chance to put theory to work in unexpected ways, a chance to separate the charming from the true. This chapter begins with the emergence of software engineering as a distinct discipline, occupation, and, perhaps, profession.

The term "software engineering" came into currency after a 1967 North Atlantic Treaty Organization conference on software design and testing used that term in its title. [1] Today, thousands of people are called software engineers, do something called software engineering, and have sophisticated employers willing to pay them to do it.[2] Yet, software engineering is no ordinary engineering discipline. Few software engineers have a degree in engineering.

Some are graduates of a program in computer science who had a single course in "software engineering." (Typically, that course is taught by someone with a degree in computer science rather than engineering.) Most software engineers are programmers with no formal training in engineering.[3] Are software engineers nonetheless engineers? What, if anything, makes this question worth answering?

Let me answer the last question first: Defining a field is more than semantics. How we define a field can affect how it develops. Software engineering may be a field whose progress is threatened by the analogy with engineering, a field pushed toward an unnecessarily rigid curriculum.[4] That is the first reason our questions about software engineering are worth answering. Second is that trying to answer them will help us understand engineering. What are its boundaries? What is at stake when we draw such boundaries? A third is that trying to answer such questions tests the utility of our history of engineering. What insight can this history give us?

The insight may be disappointing. What I show is that we can't tell whether software engineering is engineering. Only the future can tell. The best we can get from engineering's history is insight into why that is so. Getting that insight leads me to defend two theses: First, that software engineers are not engineers merely because they do much that engineers do or know much that engineers know; second, that whether software engineering can or should be a field of engineering depends on whether software engineers can or should be educated in the way engineers are. These two theses rest on a third: Engineering is (or, at least, should be) defined primarily by its curriculum rather than, as we might expect, by what engineers in fact do or know. Because the defense of the other two theses rests on the third, it is with the third that we must begin.

The Standard Definition of Engineer

The standard definition of engineer is something like this: An engineer is a person who has at least one of the following qualifications: (1) a college or university B.S. from an accredited engineering program or an advanced degree from such a program, (2) membership in a recognized engineering society at a professional level, (3) registration or licensure as an engineer by a government agency, or (4) current or recent employment in a job classification requiring engineering work at a professional level. 5

The striking feature of this definition is that it *presupposes* an understanding of engineering. Three of the four alternatives actually use the term "engineering" to define engineer; and the other, alternative (3), avoids doing the same only by using "as an engineer" instead of "to practice engineering."[6]

This definition and others like it are important. They determine who is eligible for admission to engineering's professional societies, who may be licensed to practice engineering, and who may hold certain jobs. Such definitions are also eminently useful. For example, they help the Census Bureau exclude from the category of engineer drivers of railway engines, janitors who tend boilers in apartment buildings, and soldiers wielding shovels in the Army's Corps of Engineers. These, though still called engineer, clearly are not engineers in the relevant sense. They are engineers only in a sense now obsolete.

However, the standard definitions do not suit our purpose. They do not tell us whether a software engineer is an engineeror even how to go about finding out. A software engineer may, for example, work at a job classified as requiring software engineering (at a professional level). That will not settle whether a software engineer is an engineer: What an employer classifies as "engineering" (for lack of a better word) may or may not be engineering in the relevant sense.[7]

What will settle the question? In practice, the decision of engineers. An organization of engineers accredits baccalaureate and advanced programs in engineering. Other organizations of engineers determine which societies with "engineer" in the title are engineering societies and whichlike the Brotherhood of Railway Engi-

neersare not. Engineers also determine which members of their societies practice engineering "at a professional level" and which do not. Government agencies overseeing registration or licensure of engineers, though technically arms of the state rather than of engineering, generally consist entirely of engineers. And, even when they do not, they generally apply standards (education, experience, proficiency, and so on) developed by engineers. Engineers even determine which job classifications require professional-level engineering work and which do not.

The standard definition settles many practical questions, but not ours. Because engineers divide concerning whether software engineering is really engineering, to say that software engineers are engineers if they engage in professional engineering isfor engineers and those who rely on their judgment in such mattersmerely to restate the question. 8

That is a practical objection. There is a related theoretical objection. A definition of engineer that amounts to "an engineer is anyone who does what engineers count as engineering" violates the first rule of definition: `Never use in a definition the term being defined.' That rule rests on an important insight. Though a circular definition can be useful for some purposes, it generally carries much less information than a noncircular definition. So, for example, a dictionary that defines ethics as "morality" and then defines morality as "ethics" helps only those who understand one of the terms but not the other. The smaller the circle, the less helpful a circular definition is.

How can we avoid the standard definition's circularity? The obvious way may be to define engineering without reference to engineer and then define engineer in terms of engineering. The National Research Council (NRC) in fact tried that approach, coupling its definition of engineer with this definition of engineering:

> Business, government, academic, or individual efforts in which knowledge of mathematics and/or natural science is employed in research, development, design, manufacturing, systems engineering, or technical operations with the objective of creating and/or delivering systems, products, processes, and/or services of a technical nature and content intended for use.9

This definition is certainly informative insofar as it suggests the wide range of activities which today constitute engineering. It is nonetheless a dangerous jumble. Like the standard definition of engineer, it is circular: "Systems *engineering*" should not appear in a definition of engineering. The same is true of "technical" if used as a synonym for engineering. (If not a synonym, technical is even more in need of definition than engineering is and should be avoided for that reason.) The NRC's definition also substitutes uncertain listsnote the "and/or"where there should be analysis. Worst of all, the definition is fatally overinclusive. Not only are software engineers engineers according to the definition, but so, too, are many whom no one supposes to be engineers, not only applied chemists, applied mathematicians, architects, and patent attorneys but, thanks to the and/or between mathematics and natural science, even actuaries, accountants, financial analysts, and others who use mathematics to create financial instruments, tracking systems, investment reports, and other technical objects for use.

Though much too inclusive, this definition of engineering shares with most others three characteristic elements. First, it makes mathematics and natural science central to what engineers do. [10] Second, it emphasizes physical objects or physical systems. Whatever engineering is, its principal concern is the physical world *rather than* rules (as in law), money (as in accounting), or even people (as in management). Third, the definition makes it clear that, unlike science, engineering does not seek to understand the world but to remake it. Engineers do, of course, produce knowledge (for example, tables of tolerances or equations describing complex physical processes), but such knowledge is merely (or, at least, primarily) a means to making something useful.[11]

Those three elements, though characteristic of engineering, do not define it. If they did, deciding whether software engineers are engineers would be far easier than it has proved to be. We could, for example, show that software engineers are not engineers simply by showing that they generally do not use the natural sciences in their work. That many people, including some engineers, believe software engineers to be engineers is comprehensible only on the assumption that these three characteristics do not define engineering (except in some rough way). But if they do not define engineering, what does?

Before answering, I describe three common mistakes about engineering to be avoided in any answer. While these mistakes may seem far from software engineering, they bring us to the best point for understanding the relation between software engineering and engineering proper.

Three Mistakes About Engineering

The NRC's definition of engineering uses "technical" twice, once as a catch-all ("or *technical* operations") and once to limit the domain of engineering ("of a *technical* nature and content"). It is the second use of technical that concerns us now. It seems to be a common mistake in usage, one even engineers make. We might summarize the mistake this way: *Engineering equals technology.*

There are at least three objections to this way of understanding engineering. First, engineering can equal technology only if we so dilute what we mean by engineering that any tinkerer would be an engineer (or, at least, be someone engaged in engineering).[12] Once we so dilute engineering, we are left to wonder why anyone might want an engineer rather than some other technologist who could do the same job.[13] Why demand a software engineer rather than a programmer, software designer, or the like to do software design or development? What was the point of inventing the term "software *engineering*"?[14]

Second, the proposition "engineering equals technology" makes writing a history of engineering (as distinct from a history of technology) impossible. The history of engineering, according to this proposition, is the history of technology. Every successful inventor is an engineer; every successful manager of industry is an engineer; and so on. We are left to wonder why our term for engineerunlike our term for architect, mathematician, or artisanis so recent. Why does engineering have a history distinct from technology when engineering is technology?[15] Why do engineering organizations devote any effort to defining engineering? Why don't they just define technology and technologist and then say, "Ditto engineer"?

Third, "engineering equals technology" transforms talk of engineering ethics into talk of the ethics of technology. It turns professional ethics into public policy. Whatever engineering ethics is, it is, in part at least, the ethics of a *profession*not merely standards governing the development, use, and disposal of technology but standards governing a certain group of technologists.

That reference to profession suggests a second mistake commonly made about engineering, one we might summarize this way: *Engineering is, by nature, a profession.* What makes this mistake attractive is the idea that a professional is a "knowledge-worker," that special knowledge defines each profession (as well as the underlying occupation). Any occupation that requires a lot of training is a profession. 16 Engineering requires a lot of training; hence, it must be a profession. Connecting profession with knowledge helps exclude from the profession of engineering those who, though they may function as engineers (or, rather, as "mere technicians"), lack the requisite knowledge to be engineers strictly so called ("engineers at the professional level"). Claiming that engineering is, by nature, a profession provides an antidote to the first mistake, but only by making another.

What is this second mistake? Thinking of engineering as, by nature, a profession suggests that organization has nothing in particular to do with profession. As soon as we have enough knowledge, we have a profession. There could be a profession of one.

Thinking this way makes much of the history of engineering mysterious. Why, for example, did engineers devote so much time to setting minimum standards of competence for anyone to claim to be an engineer? Why did they set *these* standards rather than others? Why did they suppose setting such standards relevant to being a profession? Like other professions, engineering has a corporate history that such nonprofessions as shoe repair, inventing, and politics lack. Any definition of engineering must leave room for that history. What is striking about the history of engineeringindeed, of all professionsis the close connection between organization, special standards, and claims of profession.

A third mistake may help explain the appeal of the second. We might summarize it this way: *The engineering profession has always recognized the same high standards.* There are at least two ways that this mistake is defended. One appeals to the "nature" (or "essence") of engineering. Any occupational group that did not recognize certain standards would not be engineersor, at least, would not be engaged in engineering. Engineers have organized to set standards to avoid being confused with those who are not "really" engineers. The standards simply record what every good engineer knows; they codify rather than legislate.

The other argument for this mistake appeals to the moral nature of the engineer. It is said that engineers are always generally conscientious. To be conscientious is to be careful, to pay attention to detail, to seek to do the best one can. To do this is to be ethical. Professional ethics is being conscientious in one's work. To be a conscientious engineer is, then, to be by nature an ethical engineer.[17] Engineering societies adopt standards to help society know what it should expect of engineers, not to tell a conscientious and technically adept engineer what to do. Informing society is, according to this view, enough to explain the effort engineers put into codes of ethics.

What is wrong with the proposition that engineering is, by nature, ethical? Like the other two mistakes, this third makes understanding the history of engineering harder. Why have engineers changed the text of their codes of ethics so often? Why do experienced engineers sometimes disagree about what should be in the code of ethics (as well as about what should be in their technical standards)? Why do these disagreements seem to be about how engineers should act, not about what to tell society?

If we examine a typical code of engineering ethics, we find many provisions that demand more than mere conscientiousnessprovisions requiring, for example, engineers to help engineers in their employ to continue their education or to make public statements only in a truthful and objective manner. [18] Such codes are less than a hundred years old.[19] Before they were adopted, an engineer only had to be morally upright and technically proficient to do all that could reasonably be expected. In those days, engineers had no responsibilities beyond what law, market, and ordinary morality demanded (and, so, had no need to inform society what to expect). The claim that engineering has always accepted the same high standardsthat, for example, failing to inform a client of a conflict of interest was always unprofessionalis contrary to what we have learned about engineering.

Membership in the Profession of Engineering

As we saw in chapter 2, engineering education in the United States, almost from its beginning, had two strands: One was a series of unsuccessful experiments with various alternatives to the West Point curriculum; the other was the evolution of the West Point curriculum into the standard for engineering education in the United States. The details of that story do not matter now.[20] What does matter is that the education of engineers became more and more the province of engineering schools, and these in turn became more and more alike. For engineers, an engineer became someone with the appropriate degree from an engineering school or, absent that, with training or experience that was more or less equivalent; hence, the standard definition of "engineer" with which this chapter began.

The point of this story is not that engineering will always have the same curriculum it does today. The engineering curriculum has changed a great deal since West Point was founded in 1802; for example, there is now more calculus and less drafting. No doubt, the curriculum will continue to change. Perhaps the second year of calculus will disappear, with ecology or industrial psychology taking its place. The point of the story of engineering as I told it is, rather, that just as today's curriculum grew out of yesterday's, so tomorrow's will grow out of today's. Any new field of engineering has to find a place in that curriculum. Finding a place may mean changing the curriculum; what it cannot mean is starting fresh. Finding a place in a curriculum is a complex negotiation of social arrangements. It is like joining a family. You can change your name to Davis if you like, make yourself look like a member of my family (perhaps even genetically), and declare yourself a member of my family, but that won't make you one. To be a member of my family, you must come in by birth, marriage, or adoption.

Some fields of engineering (for example, nuclear) seem to be born engineering, but others (mining, for example) seem to come in by the occupational equivalent of marriage or adoption. For any field not born engineering, the only way to become a field of engineering is by "marriage" (or "adoption"). Failing that, it cannot be a field of engineering. It can only don quotation marks to show irony, start another family of the same nameas railway engineering has, but without its historical justificationor choose a more suitable name.

The history of a *profession* tells how a certain occupation organized itself to hold its members to standards beyond what law, market, and morality would otherwise demand. The history of a profession is the history of organizations, standards of competence, and standards of conduct. For engineering in the United States, that history began after the Civil War. It is a confused story because the profession was taking shape along with the occupation. Many early members of its professional societies would not qualify for membership today.

Nonetheless, I think we can see that as engineers became clearer about what engineers were (or, at least, should be), they tended to shift from granting membership in their associations ("at a professional level") based on connection with technical projects, practical invention, or other technical achievements to granting it based on two more demanding requirements: (1) specific knowledge and (2) commitment to use that knowledge in certain ways (that is, according to engineering's code of ethics). The first is occupational. This requirement is now typically identified with a degree in engineering. The second is professional. Although many professions (law, especially) make a commitment to the profession's code of ethics a formal requirement for admission, engineering has not (except for licensed professional engineers, or P.E.s). Instead, the expectation of commitment reveals itself when an engineer is found to have violated the code of ethics. The defense, "I'm an engineer but I didn't promise to follow the code and therefore did nothing wrong," is never accepted. The profession answers, "You committed yourself to the code when you claimed to be an engineer." [20]

Attempts to understand software engineering as engineering have, I think, generally missed this complexity in the concept of the *profession* of engineering. Consider, for example, Mary Shaw's observation: "Where, then, does current software practice lie on the path to engineering? It is still in some cases craft and in some cases commercial practice. A science is beginning to contribute results, and, for isolated examples, you can argue that professional engineering is taking place.[21] Substitute "applied science" for "engineering" in the first sentence in this passage and for "professional engineering" in the second, and there is little to argue with. But, as it stands, its final sentence is simply false. There is nothing in what Shaw describes to suggest that "*professional* engineering is taking place."

The Fundamental Problem in Software Engineering

The term "software engineering" was coined in the mid-1960s to describe "the need for software manufacture to be [based] on the types of theoretical foundations and practical disciplines that are traditional in the established branches of engineering." 22 Thinking about software engineering thus began with the assumption that the established branches of engineering share certain theoretical foundations and practical disciplines. This is an assumption that engineers generally share, calling the theoretical foundation "science" or "engineering science" and the practical discipline "engineering method." Yet, even the history of software engineering puts that assumption in doubt.

The early proponents of software engineering disagreed concerning what engineering's theoretical foundations and practical disciplines are. Some understood engineering as essentially applied science, with a theoretical foundation in physics, chemistry, and mathematics. Others understood engineering as primarily a body of techniques for design. For them, engineering was primarily a way of moving from conception, through specification, to prototype, testing, and final fine-tuning. For most, however, engineering was primarily a way of organizing and managing a process of design, development, and manufacture, of ensuring that work would be completed on time, within budget, and to the customer's satisfaction.23

In fact, what the established branches of engineering share, perhaps all they share, is a common core of courses (physics, chemistry, mathematics, and so on), which may or may not provide a theoretical foundation for engineering. Beyond that, there are important overlaps between this and that field, many family resemblances and analogies, but nothing more (or, at least, nothing more of importance). For a long time, perhaps from its very beginning, engineering was a protean mix of activities held together by a common education. The common education clearly had connections with what engineers did, but the connections were not always clear, even to engineers.[24]

So, if software engineering is to be, strictly speaking, a field of engineering, it has to require of its practitioners a degree in engineering (or its equivalent).[25] Right now, the software engineering curriculum is more flexible than engineering's. It is, I think, an empirical question, one that remains open, whether students of software engineering would be better software engineers if they followed engineering's more rigid curriculum rather than, say, taking more computer science, psychology, and management courses than engineering's curriculum allows. How much physics, calculus, thermodynamics, and the like does one need to design, develop, and maintain software?

The answer to this question is not obvious. Indeed, in its present form, the question is probably unanswerable. How much physics, calculus, thermodynamics, and the like a software engineer needs may well depend on the kind of software in question (not whether or not it is "life critical" but what sort of knowledge its designer should have to do it right). Although we might worry about someone developing software for engineering applications who didn't know what engineers know, would we feel the same about such a person developing a computer game for children or a diagnostic program for physicians?

Software engineering was not born engineering. If it is ever to be part of engineering ("an engineering discipline"), it must come in by "marriage" or "adoption". That will require substantial changes in software engineering, engineering proper, or both. Software engineering may have to bring its curriculum up to standards for engineering accreditation, or engineering may have to change its curriculum to make room for software engineering (for example, by dropping the required chemistry course), or both engineering and software engineering may have to change. Software engineering cannot become engineering simply by adopting the name, by copying engineering methods, or even by having some authoritative body like the IEEE declare it engineering. Indeed, software engineers will not necessarily be members of the engineering profession even if they receive an engineering education.

Education only satisfies the occupational requirement. There is also the professional requirement, commitment to the engineers' code of ethics. [26] So far, software engineers seem to believe they can have a code of their own.[27]

Like the occupational requirement, the professional requirement leaves some room for maneuver. Software engineers can have their own code *in addition* to the engineers' code (that is, a code with obligations beyond those all engineers share). Software engineers can also try to work out a common code with engineers, changing what engineers require of themselves. What they cannot do is be engineers "at the professional level" yet refuse to share engineering's professional commitments.

Will software engineering ever join engineering's family? That is a question for prophets. What I tried to do here is to use software engineering to reveal the complexity in the concept of a profession of engineering. However, I must add that the benefits of making software engineering a "true engineering discipline" strike me as less certain than the discussion so far makes them seem. Training in engineering as such will not ensure that projects come in on time, within budget, or to the customer's satisfaction. Although engineering education has always had elements of managementmore in the first half of this century than nowengineers always have problems delivering on time, within budget, and to the customer's satisfaction, especially in fields such as computer development, where experience is thin. The obvious ability of engineers in many fields to keep their promises seems more an indication of the maturity of the field than of any special knowledge of engineers as such. Aren't physicians and auditors just as able to deliver on their promises?

Nothing said here is meant to raise questions about the status of software engineering as a discipline, an occupation, or even a profession. My concern is how to conceptualize this new but already respectable occupation. Perhaps we would understand it better if we stopped trying to borrow concepts from engineering and instead borrowed them from architecture or industrial design, areas in which chemistry, physics, and mathematics are less important, pure invention more so, and codes of ethics less detailed. Or, perhaps we should borrow concepts from construction management. Software engineering may be more like overseeing the building of a great public work (a bridge, skyscraper, or power plant) than like doing the engineering for it. Construction managers are at least as good as engineers at delivering on time, within budget, and to the customer's satisfaction.[28] Or, perhaps software engineering is more like what lawyers do when they create new negotiable instruments or complex land-use agreements.

The question to be asked, then, is not whether software engineers are engineers. Clearly, while some are, most are not. The question is, rather, whether (or when) they *should* be.

My conclusion is that there is no fact of the matter here, only a complex of social decisions about standards of training and conduct in need of attention. Like engineering, software engineering is a social project, not a natural species.

PART II
ENGINEERS IN CONTEXT

Having defined engineering, we are ready to identify the place of ethics in the practice of engineering today. Though this, too, requires some history, I begin with a recent event, the Challenger explosion. Of course, that event is itself important to engineering. For the public, that event was the most traumatic engineering disaster in recent memory, more traumatic even than the two nuclear disasters, Three Mile Island and Chernobyl. Unlike these, it produced an engineer hero, Roger Boisjoly. Engineers found in the Challenger explosion confirmation of much they feared was wrong with corporate decision making. However, I have two other reasons for beginning with the Challenger, both more mundane. First, the enormous documentation the disaster produced allows us to get closer to decisive events than is possible in most engineering. Here is a drama from which we can learn much; here, too, are details to provoke thought about engineering's "mission" and the place of a code of ethics in accomplishing it. Here we may see the profession in action. Second, however dramatic, the events leading up to the disaster have many characteristics of ordinary engineeringespecially, a large organization, cooperation and conflict between engineer-managers and ordinary engineers, a mix of technical and business considerations, the problem of defining what is and what is not a question of engineering, and even ethical considerations in what may at first seem mere technical decisions. The Challenger disaster is, in many respects, no more than ordinary engineering writ large. Both here and in part IV, it will help us understand what engineers do, what can go wrong ethically, and what can be done to prevent ethical wrongdoing.

4
Codes of Ethics and the Challenger

The Public knows that doctors and lawyers are bound to abide by certain recognized rules of conduct. Not finding the same character of obligations imposed upon engineers, people have failed to recognize them as members of a profession.
A.G. Christie (1922), *engineer*

With respect to each separate profession we must begin by analyzing the functions it performs in society. A code of ethics must contain a sense of mission, some feeling for the peculiar role of the profession it seeks to regulate.
Lon Fuller (1955), *lawyer*

On the evening of January 27, 1986, Robert Lund, vice president for engineering at Morton Thiokol, had a problem. The Space Center was counting down for a shuttle launch the next day. Earlier that day, Lund presided at a meeting of engineers who unanimously recommended against the launch. He concurred and informed his boss, Jerald Mason. Mason informed the Space Center. Lund expected the flight to be postponed. The Space Center had a good safety record. It had achieved it by not allowing a launch unless the technical people approved.

Lund did not approve because the temperature at the launch site would be close to freezing at lift-off. The Space Center was worried about the ice already forming on the boosters, but Lund was worried about the O-rings that sealed the boosters' segments. They were a good idea, permitting Thiokol to build the huge rocket in Utah and ship it in pieces to the Space Center two thousand miles away. Building in Utah was so much more efficient than building on-site that Thiokol was able to underbid the competition. The shuttle contract had earned Thiokol $150 million in profits. [1] But the O-rings were not perfect. If one failed in flight, the shuttle could explode. Data from previous flights indicated that the rings tended to erode in flight, with the worst erosion occurring on the coldest temperature preceding lift-off. Experimental evidence was sketchy but ominous. Erosion seemed to increase as the rings lost resiliency and resiliency decreased with temperature. Unfortunately, almost no testing had been done below 40° F. The engineers had had to extrapolate. But, with the lives of seven astronauts at stake, the decision seemed clear enough: safety first.

Well, it had seemed clear earlier that day. Now Lund was not so sure. The Space Center was "surprised" and "appalled" by the evidence on which the no-launch recommendation was based. The Space Center's senior managers wanted to launch, but they could not launch without Thiokol's approval. They urged Mason to reconsider. He reexamined the evidence and decided the rings should hold at the expected temperature. Joseph Kilminster, Thiokol's vice president for shuttle programs, was ready to sign a launch approval, but only if Lund approved. Lund's first response was to repeat his objections. But then Mason said something that made him think again. Mason asked him to think like a manager rather than an engineer. (The exact words seem to have been, "Take off your engineering hat and put on your management hat.") Lund did so and changed his mind. On the next day the shuttle exploded during lift-off, killing all aboard. An O-ring had failed. 2

Should Lund have reversed himself and approved the launch? In retrospect, of course, it seems obvious that he should not have. But we would hardly have any problems at all if we could foresee all the consequences of what we do. Fairness to Lund requires us to ask whether he should have approved the launch given only the information actually available. We need to consider whether Lund, an engineer, should have thought like a manager *rather than* an engineer. But first we need to know the difference between thinking like a manager and thinking like an engineer.

One explanation of the difference would stress technical knowledge. Managers are trained to handle people. Engineers are trained to handle things. To think like a manager rather than an engineer is to focus on people rather than on things. According to this explanation, Lund was asked to concern himself primarily with how best to handle his boss, the Space Center, and his own engineers. He was to draw on his knowledge of engineering only as he might draw on his knowledge of a foreign language, for example, to help him understand what his engineers were saying. He was to act much as he would if he had never earned a degree in engineering.

That explanation of what Mason was asking of Lund seems implausible. But if it seems implausible, what is the alternative? If Mason did not want Lund to treat his knowledge of engineering as peripheral (as it seems Mason, also an engineer, did not do when he earlier reexamined the evidence himself), what was he asking Lund to do? What is it to think like an engineer if not simply to use one's technical knowledge of engineering? As we saw in chapter 2, that is a question engineers have been asking for at least a century. Answers are often expressed as a code of ethics. So, it seems, one way to begin to answer our question is to learn more about those codes.

History of Engineering Codes

The first civilian engineering organization in the United States, the Boston Society of Civil Engineers, was founded in 1848. Others followed, with the first truly national organization appearing two decades later. Though leaders of these early organizations sometimes spoke of the "high character and integrity" engineers needed to serve the interests others committed to them, the history of engineering codes of ethics in the United States begins much later.

In 1906, the American Institute of Electrical Engineers (AIEE) voted to embody in a code the ideas expressed in an address by its president, Schuyler S. Wheeler. After much debate and many revisions, the AIEE's board of directors adopted a code in March 1912. The AIEE code was adopted with minor amendments by the American Society of Mechanical Engineers (ASME) in 1914. Meanwhile, the American Institute of Consulting Engineering, the American Institute of Chemical Engineers (AICHE), and the American Society of Civil Engineers each adopted a code of its own. By 1915, every major engineering organization in the United States had a code of ethics. 3

These first codes were criticized almost as soon as they were adopted.4 One common criticism was that they were too concerned with duties to employers and fellow engineers. Among the provisions so criticized were the following: Section B.3 of the AIEE code required engineers to "consider the protection of a client's or employer's interest [their] first professional obligation, and [to] . . . avoid every act contrary to this duty." An engineer's duties to the public were merely "to assist the public to a fair and correct general understanding of engineering matters, to extend generally knowledge of engineering . . . to discourage the appearance of untrue, unfair or exaggerated statements on engineering subjects," and otherwise to be careful what one said in public (section D.16-19). Another common criticism was that, though they often speak of "employers" as well as of "clients," the early codes seemed designed primarily for engineers who contracted with many clients and were not dependent on any one of them. "Bench engineers," employeed engineers without significant management responsibilities, always the majority, seemed almost forgotten.5 But perhaps the most serious criticism was that occasionally one code permitted conduct that others forbade. For example, the ASCE code (section 1) forbade an engineer to "accept any remuneration other than his stated charges for services rendered his client," whereas the AIEE code (section B.4) permitted payments to the engineer from suppliers or other third parties if the client consented. (These inconsistencies were important, of course, only if all engineers belonged to one professiononly if, for example, civil engineers and electrical engineers would be held to the same standard.)

Attempts to respond to such criticism began almost immediately. Among the first was the code that the American Association of Engineers (AAE) adopted in 1927. However, the AAE, though intended to include all engineers and briefly influential, was almost dead by then. None of the other early attempts to respond to these criticism amounted to much more. But, on the eve of World War II, the American Engineering Council (AEC) organized a committee to develop a code for all engineers. Each major engineering society was represented. When the AEC dissolved, the Engineers Council for Professional Development (ECPD) took over sponsorship. The resulting code was a conscious effort to synthesize the major provisions of earlier codes.

The ECPD code was enormously successful at creating at least the appearance of unity among engineers. All eight major engineering organizations either "adopted or assented" to it in 1947. By 1955, it was accepted, at least in large part, by eighty-two national, state, or local engineering organizations. That was, as one commentator put it, "probably the greatest progress to be made ever before or since toward the realization of a single set of ethical standards for all engineers." 6

But the ECPD code was not as successful as it at first seemed. Some organizations, while "assenting" to the code, retained their own codes as well to preserve certain detailed provisions that seemed to suit their circumstances better than the corresponding provisions of the ECPD code. As time went on, these organizations tended to rely more and more on their own code. The ECPD code slowly lost influence.

The ECPD revised its code in 1963, 1974, and 1977 in an attempt to reverse this trend. Though many of the revisions were substantive, perhaps the most important were structural. Four "fundamental principles" replaced the "foreword," twenty-eight "canons" were reduced to seven "fundamental canons"; and a set of "guidelines" was added. These structural changes were intended to allow an organization to adopt the principles and canons without the guidelines, if it did not want to accept the whole package. Though the Guidelines are supposed to be read in the light of the principles and canons, they are, in fact, an independent code.

The ABET replaced the ECPD soon after these revisions were made. The revisions nevertheless gave the ECPD code new life (though under the new name). The revised code (that is, the fundamental principles and canons) was adopted, at least in part, by most major engineering organizations in place of their own code. There are two important exceptions, however.

The NSPE initially adopted the 1947 version of the ECPD code but substituted its own code in 1964 and has since revised it several times. Though it still has much in common with the original ECPD code, the NSPE code differs somewhat both in structure and content. The NSPE Code is important for two reasons.

First, the NSPE has a "Board of Ethical Review" (BER) which answers ethics questions members of the society submit. Some other engineering societies have similar advisory committees, but the NSPE's is by far the most active in publishing the advice. BER "opinions" are printed several times a year in the NSPE's magazine, *Professional Engineer.* About 250 opinions were collected and published in six volumes, the last covering the period 1981-1989. These opinions are a valuable resource for questions of engineering ethics.

Second, because professional engineers are licensed by states, the NSPEthrough its state societieshas a role in the regulation of professional engineers much like the role of state medical societies in the regulation of physicians. The NSPE code is at least potentially enforceable (though only against registered engineers) in a way that other codes of engineering ethics are not.

The other independent code, that of the Institute of Electrical and Electronic Engineers (IEEE), is important for different reason. The

IEEE, with more than 300,000 members, is the largest engineering organization in the United States. Its

1979 code represented an alternative to the others. Much briefer than the NSPE's (though significantly longer than the ABET code without the guidelines), it applied only to "members" of IEEE. Some of its provisions were unusual as well. For example, Article II enjoined engineers "to treat fairly all colleagues and co-workers regardless of race, religion, sex, age, or national origin"engineering codes generally protect other engineers from unfair treatment but not all coworkerswhile Article III expressly limited what engineers owe employer and client to what was consistent with "other parts of this Code" but did not (as other engineering codes now do) declare the public health, safety, and welfare "paramount." In 1991, the IEEE abandoned that code for a much shorter one hardly distinguishable in content from the ABET code (without the guidelines). Unfortunately, historians have yet to tell us how the 1979 code failed or why the IEEE continues to insist on a code of its own rather than just adopting the virtually equivalent ABET code.

These four codesNSPE code, ABET code, IEEE code (1991), and ABET guidelinestoday serve as ethical benchmarks for engineers generally. No doubt, others will follow.

Codes of Ethics Today

Most professions regularly amend their codes of ethics. Many undertake drastic revisions more than once. But engineering seems to be unique in the number of competing codes proposed and adopted over the years. Why is the history of codes different for engineering? Is engineering, or engineering ethics, itself unique?

Chief among the explanations often advanced for the number of codes is that engineering is simply too diverse for one code of ethics to apply to all. Some engineers are independent practitioners. Some are employees of large organizations. Some are managers. Many are closely supervised. Some, whether in large organizations or on their own, are more or less their own boss. Engineers do too many different things for the same standards to apply to all. In sum, engineering is not a single profession but a family of historically related professions.

There is a false note in this explanation for the number of codes of ethics. If the divisions in engineering were similar to that, say, between medicine and dentistry, why would engineers establish "umbrella" organizations and devote so much time to trying to achieve one code for all engineers? Physicians and dentists have not made similar efforts to write a single code of ethics for their two professions. The three-quarters of a century during which engineers tried to write a code for all engineers islike the existence of schools of engineeringitself evidence that engineers all belong to one profession, however divided and diverse its membership. Indeed, the effort to write a single code might be an attempt to preserve the unity of the profession. On this view, the number of codes proposed and adopted is an instance of what engineers call the "NIH" (not invented here) phenomenon. The number of independent professional organizations, not the existence of several engineering professions, explains the number of competing codes. 7

The NIH phenomenon occurs when each side has good reasons for its view. Perhaps this is such a case. One side is certainly right to point out that a short code is easy to remember or consult. It can be conspicuously posted to remind engineers of their obligations. A short code is also easier to get approved because its necessary generality automatically obscures disagreement over details of conduct. But the other side can also point out that a long code provides much more information. It can take into account special circumstances, make exceptions explicit, and otherwise provide more guidance, at least for those willing to take the time to read it through. A long code makes it less likely that engineers who think they agree on standards will suddenly discover that they do notat a moment that the discovery is costly. Some professionals (for example, lawyers and accountants) long ago opted for a long code like the NSPE's or ABET's guidelines. Others, for example, dental hygienists and social workers, opted for a short code like the IEEE's or ABET's fundamental principles and canons.

Though the various engineering codes differ in length, they differ in content as well. Because these latter differences involve more than pride of authorship, the NIH phenomenon only partly explains why engineers cannot agree on a single code. History doubtless has a part. The NSPE cannot give up its code without substantially reducing the value of its BER opinions. Other considerations may also be relevant. For example, the NSPE's code is designed for use in state disciplinary committees; neither ABET's code nor the IEEE's is. They are designed primarily for self-discipline.

Whatever the explanation of the number of codes, there is no doubt that their variety could make it hard for an engineer to know what to do. An engineerfor example, an IEEE member licensed as a professional engineer (P.E.)might be subject to three codes (the IEEE's, NSPE's, and ABET's). Which should she consult? If the codes differ on some point, which, if any, should she consider binding? What should other engineers think of her if she chooses to do what one code allows even though another forbids it? What should *they* do?

These difficulties are not as serious as they may seem. In general, the various codes are not enforced by the organizations adopting them. Though the language often resembles that of statute, codes of ethics are in fact more like guides to conscience or public judgmentthat is, moral rules. An engineer who violates the code of one of the organizations to which she belongs is not likely to be expelled (or even formally censured). She is even less likely to have her "license to practice" revoked (since most engineers are not licensed at all). Apart from pangs of conscience, the only repercussion she is likely to suffer is the poor opinion of those who know her well enough to know what she did. Her primary concern should be one of justifying her conduct to those concerned, including herself. (We return to the problem of resolving conflicts between codes in chapter 8.)

But thinking of codes of ethics as moral rules rather than legal rules suggests new difficulties. If codes of ethics are merely moral rules, why worry about them at all? Why shouldn't each engineer let his private conscience be his guide? Why should he have to consider what some organization of engineers has to say about what he should do? What expertise can engineering societies have in morals? Aren't the experts in morals, if there are any, philosophers or clergy rather than engineers? To answer these questions, we must look deeper into the relationship between professions and codes of ethics.

Professions and Codes

A code of ethics generally appears when an occupation organizes itself into a profession. Why this connection between codes of ethics and professions? There are three common explanations.

One explanation, "definition by paradigm," has would-be professions imitating the forms of widely recognized professions. To be a profession is to be like the most respected professions, the paradigms. Because the paradigmsespecially law and medicinerequire long training, special skills, licensing, and so on, so should any other group that wants to be considered a profession. Because both law and medicine have a code of ethics, engineering would naturally suppose it needs one too if it is to be a "true profession."

Much may be said for this first explanation of why engineering has a code of ethics. For example, the American Bar Association (ABA) adopted its first code of ethics in 1908four years before the first American engineering society did. Engineers certainly did not ignore the ABA's action. 8

Nonetheless, this explanation is inadequate for our purposes. The emphasis on imitation does not explain why the "paradigm professions" adopted codes or why engineers copied the ABA in adopting a code of ethics but not the code itself, enforcement procedures, or licensing requirement. The emphasis on imitation also makes it hard to understand why engineers think what the code says important. After all, if a profession only needs a code so it can be like other professions, why should it matter much what the code says? Does what the code says matter only because the paradigm profession thinks what the code says matters? Why should the paradigm profession think that? But perhaps most significant, the emphasis on *other* professions does not explain why some early American codes of engineering ethics were modeled on the code of the British Institute of Civil Engineers rather than on some American paradigm like the ABA'sor why, in England, the first professions to adopt codes were the relatively low-status apothecaries and solicitors (rather than the high-status physicians or barristers).[9]

One attempt to make up for these inadequacies of definition by paradigm yields "the contract with society" approach to understanding the relation between professions and codes of ethics. According to this approach, a code of ethics is one of those things a group must have before society recognizes it as a profession. The code's content is settled by considering what society would accept in exchange for such benefits of professionalism as high income, prestige, and trust. A code is a way to win the advantages society grants only to those imposing certain restraints on themselves. A profession has no other interest in having a code of ethics.

Although this second explanation is a significant advance over the first, it is still far from adequate. In particular, it gives us little help in answering such questions as the following: Why should engineers be so concerned about the details of their code when, it seems, society recognizes engineering as a profession and does not care which of the various codes engineers adopt? Why did the original engineering codes take so much space laying down rules about how engineers should treat one another when it seems society is likely not to care about such things or to be positively adverse? The inability of the second explanation to help us answer such questions suggests that we should look for a better one.

A third explanation of the relation of profession and codes of ethics is better than the other two. This explanation views a code as primarily a "contract *between professionals.*" According to this explanation, a profession is a group of persons who want to cooperate in serving the same ideal better than they could if they did not cooperate. Engineers, for example, might be thought to serve the ideal of efficient design, construction, and maintenance of safe and useful physical systems. 10 A code of ethics would then prescribe how professionals are to pursue their common ideal so that each may do the best he can at minimum cost to himself (and to the publicif looking after the public is part of the ideal). The code is to protect each from certain pressures (for example, the pressure to cut corners to save money) by making it reasonably likely that most other members of the profession will not take advantage of his good conduct. A code protects members of a profession from certain consequences of competition.

According to this explanation, an occupation does not need society's recognition to be a profession. It needs only a practice among its members of cooperating to serve a certain ideal. Once an occupation becomes a profession, society has a reason to give the occupation special privileges (for example, the sole right to do certain kinds of work) if society wants to support serving the ideal in question in the way the profession serves it. Otherwise, society may leave the profession unrecognized. So, according to this third explanation, what is wrong with the first two is that they confuse the trappings of profession with the thing itself.[11]

If we understand a code of ethics as the way a profession defines relations between those who want to serve a common ideal, we may construe the number of different codes of ethics as showing that engineers are not yet fully agreed on how they want to pursue their common ideal. Engineering would, in this respect, still be a profession in the making. Thinking of engineering in this way is, under the circumstances, nonetheless consistent with thinking of engineering as a profession. The substantive differences between codes is not great. The differences in structure and language are more obvious than important in the choice of conduct. Engineers agree on all essential terms of their "contract."

Understanding a code of ethics as a contract between professionals, we can explain why engineers should not depend on mere private conscience when choosing how to practice their profession, and why they should take into account what an organization of engineers has to say about what engineers should do. What others expect of us is part of what we should take into account in choosing what to do, especially if the expectation is reasonable. A code provides a guide to what engineers may reasonably expect of one another, what "the rules of the game" are. Just as we must know the rules of baseball to know what to do with the ball, so we must know engineering ethics to know, for example, whether *as engineers* we should merely weigh safety against the wishes of our employer or instead give safety preference over those wishes. A code of ethics should also provide a guide to what we may expect other members of our profession to help us do. If, for example, part of being an engineer is putting safety first, then Lund's engineers had a right to expect his support. When Lund's boss asked him to think like a manager rather than an en-

gineer, he should, *as an engineer,* have responded, "Sorry, if you wanted a vice president who would think like a manager *rather than* an engineer, you should *not* have hired an engineer." 12

If Lund had responded in this way, he would have responded as the "rules of the engineering game" require. But would he have done the right thing, not simply according to those rules but really (that is, all things considered)? This is not an empty question. Even games can be irrational or immoral. (Imagine, for example, a game in which you score points by cutting off your fingers or by shooting people who pass in the street below.) People are not merely members of this or that profession. They are also individualsmoral agentswith responsibilities beyond their profession, individuals who cannot escape conscience, criticism, blame, or punishment just by showing that they did what they did because their profession told them to.

We now have an explanation of why engineers should, as engineers, take into account their profession's code of ethics, but we have no explanation of why anyone should be an engineer in the relevant sense.

We may put this point more dramatically. Suppose Lund's boss had responded in this way to what we just imagined that Lund told him: "Yes, we hired an engineer, butwe supposedan engineer with common sense, one who understood just how much weight a rational person gives a code of ethics in decisions of this kind. Be reasonable. Your job and mine are on the line. The future of Thiokol is also on the line. Safety counts a lot. But other things do too. If we block this launch, the Space Center will start looking for someone more agreeable to supply boosters. We all could be out of a job." If doing as one's professional code says is really justified (that is, justified all things considered), we should be able to explain to Lund (and his boss) why, as a rational person, Lund should support his profession's code as a guide for all engineers and why, under the circumstances, he could not rationally expect others to treat him as an exception.

Why Engineers Should Obey Their Profession's Code

We can begin our explanation of obedience to the code by outlining two alternatives some people find plausible. One is that Lund should do as his profession requires because he "promised," for example, by joining an engineering society that has a code of ethics. We must dismiss this explanation because Lund may never have done anything we could plausibly call promising to follow a code. Lund may, for example, have failed to join any professional association that has a code (as perhaps half of all American engineers do). Would we excuse him from conducting himself as an engineer should? No. The obligations of an engineer do not seem to rest on anything so contingent as a promise, oath, or vow. The "contract" between professionals of which we spoke cannot literally be a contract. It seems more like a "quasi-contract" or "contract implied in law"that is, an obligation resting on what is fair to require of someone given that she benefited by some action of her own (for example, by claiming to be an engineer).

That Lund should do as his profession requires because "society" says he should is another plausible answer. We may dismiss it in part because it is not clear that society does say that. One way society has of saying things is through law. No law binds all engineers to abide by their profession's code of ethics (as the law does bind all lawyers). Of course, society has another way of saying things than by law, that is, by public opinion. But it seems doubtful that the public knows enough about engineering ethics to have a distinct opinion on the questions we are considering. More important, it is not clear why public opinion or law should decide what it is rational or moral to do. Certainly there are both irrational laws (for example, those requiring use of outmoded techniques) and immoral laws (for example, those enforcing slavery). The public opinion supporting those laws could not have been much less irrational or immoral than the laws themselves.

The two answers we dismissed share one notable feature. Either would, if defensible, provide a reason to do as one's profession says independent of what in particular the profession happens to say. The answers do not take into account the contents of the code of ethics. They are "formal." The answer I now give is not formal. I show that supporting a code of ethics with a certain content is rational by showing that supporting codes with a content of that sort is rational.

Consider the ABET code. It is divided into fundamental principles and fundamental canons. The fundamental principles simply describe in general terms an ideal of service. Engineers "uphold and advance the integrity, honor and dignity of the engineering profession by: I. using their knowledge and skill for the enhancement of human welfare, II. being honest and impartial, and serving with fidelity the public, their employers and clients [and so on]." What rational person could object to other people with her skills trying to achieve that ideal? (Or at least, what rational person could object as long as doing so did not interfere with what she was doing?) Surely every engineer, indeed, every member of society, is likely to be better off overall if engineers uphold and advance the integrity, honor, and dignity of engineering in this way.

If the fundamental principles lay down goals, the fundamental canons lay down general duties. For example, engineers are required to "hold paramount the safety, health and welfare of the public," to "issue public statements only in an objective and truthful manner," to "act in professional matters for each employer or client as faithful agents and trustees," and to "avoid all conflicts of interest." Each engineer stands to benefit from these requirements both as ordinary person and as engineer. *As ordinary person*, an engineer is likely to be safer, healthier, and otherwise better off if engineers only make truthful public statements, and so on. But how can engineers benefit *as engineers* from such requirements? To explain that, we have to try a thought experiment.

Imagine what engineering would be like if engineers did not generally act as the canons require (while satisfying the requirements of law, market, and ordinary morality). If, for example, engineers did not generally hold paramount the safety, health, and welfare of the public, what would it be like to be an engineer? The day-to-day work would, of course, be much the same. But every now and then an engineer might be asked to do something which, though profitable to the employer or client and legal, would put other people at risk, some perhaps about whom the engineer cared a great deal. Without a professional code, an engineer could not object *as an engineer.* An engineer could, of course, still object "personally" and refuse to do the

job. But, if he did, he would risk being replaced by an engineer who would not object. An employer or client might rightly treat an engineer's personal qualms as a disability much like a tendency to make errors. The engineer would be under tremendous pressure to keep "personal opinions" to himself and get on with the job. His interests as an engineer would conflict with his interests as a person; his conscience, with his self-interest.

That, then, is why each engineer can generally expect to benefit from other engineers' acting as their common code requires. The benefits are clearly substantial enough to explain how individuals could rationally enter into a convention that would equally limit what each can do. I have not, however, shown that every engineer *must* benefit *overall* from such a convention, or even that any engineer will consider these benefits sufficient to justify the burdens required to achieve them. Professions, like governments, are not always worth the trouble of maintaining. Whether a particular profession is worth the trouble is an empirical question. Professions nonetheless differ from governments in at least one way relevant here. Professions are voluntary in a way that government is not. No one is born into a profession. One must claim professional status to have it (by taking a degree, for example, or by accepting a job for which professional status is required). We therefore have good reason to suppose that people are engineers because, on balance, they prefer to have the benefits of being an engineer, even given what is required of them in exchange. 13

If, as we shall now assume, the only way to obtain the benefits in question is to make it part of being an engineer that the public safety, health, and welfare come first, every engineer, including Lund, has good reason to want engineers *generally* to adhere to (something like) the ABET code. No one wants to be forced to choose between conscience and self-interest. But why should an engineer adhere to the code himself when, as in Lund's case, he may seem likely to benefit by departing from it? The answer should be obvious.

Lund would have to justify his departure from the code by appeal to such considerations as the welfare of Thiokol and his own self-interest. Appeal to such considerations is just what Lund could not incorporate into a code of ethics for engineers or generally allow other engineers to use in defense of what they did. Lund could not let such an exception be incorporated into the code because its incorporation would defeat the purpose of the code. A code is necessary in large part because, without it, the self-interest of individual engineers would lead them to do what would harm everyone overall. Lund could not allow other engineers to defend what they did by appeal to their own interests or that of their employer for much the same reason. To allow such appeals would contribute to the breakdown of a practice Lund has good reason to support.

I believe this argument explains why, *all things considered,* Lund should have done as his profession's code requires, *not* why he should have done so in some premoral sense. I am answering the question "Why be ethical?" *not* "Why be moral?" I therefore have the luxury of falling back on ordinary morality to determine what is right, all things considered, that is, taking into account the fact of profession. The moral rule on which this argument primarily relies is "the principle of fairness" ("Don't cheat"). Because Lund voluntarily accepts the benefits of being an engineer

(by claiming to be an engineer), he is morally obliged to follow the morally permissible convention that helps to make those benefits possible. [14] What I have taken pains to show is how that convention helps to make those benefits possible and why, even now, Lund has good reason to endorse the convention generally.

Of course, I am assuming that engineers do in fact generally act in accordance with the ABET code (whether or not they know it exists). If that assumption were mistaken, Lund would have no *professional* reason to do as the code says. The code would be a dead letter, not a living practice. It would have much the same status as a "model statute" no government ever adopted, or the rules of a cooperative game no one was playing. Lund would have to rely on private judgment. But relying on private judgment is not necessary here. Lund's engineers made their recommendation because they thought the safety of the public, including the astronauts, paramount. They did what (according to the ABET code) engineers are supposed to do. Their recommendation is itself evidence that the code corresponds to a living practice.[15]

So, when Lund's boss asked him to think like a manager rather than an engineer, he was in effect asking Lund to think in a way that Lund must consider unjustified for engineers generally and for which Lund can provide no rationally defensible principle for making himself an exception. When Lund did as his boss asked, he in effect let down all those engineers who helped to build the practice that today allows engineers to say no in such circumstances with reasonable hope that their client or employer will defer to "professional judgment" and that other members of their profession will aid them if the client or employer does not defer.

Lund could, of course, explain how his action served his own interests and those of Thiokol (or, rather, how they *seemed* to at the time).[16] He could also thumb his nose at all talk of engineering ethics (though that might lead to the government's barring him from work on any project it funds, to fellow engineers refusing to have anything to do with him, and to his employer coming to view him as an embarrassment). What he cannot doassuming we have identified all relevant considerationsis show that what he did was right, all things considered.

But have we identified all relevant considerations? I certainly think so. But, for our purposes, it does not matter. I did not examine Lund's decision to condemn him but to understand the place of a code of ethics in engineering. There is more to understand.

Using a Code of Ethics

So far, we have assumed that Lund did as his boss asked: he thought like a manager rather than like an engineer. Assuming that allowed us to provide a relatively clear explanation of what was wrong with what Lund did. What was wrong was that Lund acted like a manager when he was an engineer and should have acted like one.

We must now put that assumption aside and consider whether engineering ethics actually forbids Lund to do what it seems he did, that is, weigh his own interests, his employer's, and his client's against the safety of the seven astronauts. Ordinary morality seems to allow such weighing. For example, no one would think I did something morally wrong if I drove my child to school rather than let him take the

bus, even though being on the road increases the risk that someone will be killed in a traffic accident. Morality allows us to give special weight to the interests of those close to us. If engineering ethics allows it, too, thenwhatever he may have thought he was doingLund would not actually have acted unprofessionally. Let us imagine Lund reading our four "benchmark" codes. What would they tell him? What could he infer?

Of the seven fundamental canons of the current ABET code, only two seem relevant: (1) "[holding] paramount the safety, health and welfare of the public" and 4) "[acting] in professional matters for each employer or client as faithful agents or trustees." What do these provisions tell Lund to do? The answer is not obvious. Does "public" include the seven astronauts? They are, after all, employees of Thiokol's client, the Space Center, not part of the public as, say, those ordinary citizens are who watch launches from the beach opposite the Space Center. And what is it to be a "faithful agent or trustee" of one's client or employer? Is it to do as instructed or to do what is in the client's or employer's interests? And how exactly is one to determine those interests? After all, the actual result of Lund's decision was a disaster for both employer and clientbut a disaster Lund, his employer, and his client (or, at least, their representatives) thought themselves justified in risking. And what is Lund to do if the public welfare requires what no faithful agent could do? What is it to "hold paramount" the public welfare?

The IEEE code of 1979-1990, for all its innovations, would not have helped Lund much. Article III.1 more or less repeats the faithful-agent requirement of ABET canon 4. Article IV.1 more or less repeats the requirement of the ABET canon 1 (though without formally declaring the public interest "paramount"). Members of the IEEE are supposed to "protect the safety, health and welfare of the public and speak out against abuses in these areas affecting the public interest." The duties of a faithful agent are, however, limited by other provisions of the code whereas the duty to protect the public is not. The public welfare takes precedence *whenever* it conflicts with the duties of a faithful agent. The old IEEE code thus provides a plausible interpretation of "hold paramount." This would be helpful if we knew what was included in the public safety, health, and welfare. Unfortunately, the IEEE code (like ABET's) tells us nothing about that. The only relevant provision of the new IEEE code is the first: "to accept responsibility in making engineering decisions consistent with the safety, health, and welfare of the public, and to disclose promptly facts that might endanger the public or the environment." Although the new code does not declare the public safety, health, and welfare paramount in just those words, it achieves the the same effect by combining omission of all references to employer or client with a requirement that IEEE members take responsibility for the public health, safety, and welfare.

Though the NSPE code is much more detailed than the other two, its details are only somewhat more helpful here. The first "rule of practice" simply repeats the language of ABET canon 1; the fourth rule does the same for canon 4. Rule 1a follows the IEEE code in giving priority to the public safety, health, and welfare over all other considerations but gives more detail to how one should "disclose" any danger. If overruling Lund's judgment were to endanger the public "safety, health, property, or welfare," then, according to NSPE rule 1a, Lund would have a positive

duty to bring the matter to the attention of "the appropriate authority." The appropriate authority might, it seems, be someone other than the client or employer. Rule 1b partially defines "safe for public health, property, and welfare" in terms of conformity to "accepted standards." That would be helpful if the problem that concerned Lund were conventional enough for certain standards to win acceptance. Unfortunately, the use of O-rings in question here was so new that the engineers had no manual of "safety specs" to which to turn. That was part of Lund's problem.

The NSPE code illustrates the advantage of detailed provisions. The more detailed a code, the more guidance it is likely to provide on questions an engineer is worried about. The current NSPE code could, for example, have contained a provision like canon 11 of the NSPE code of 1954: "[The engineer] will guard against conditions that are dangerous or threatening to life, limb or property on work for which he is responsible . . ." That would have made Lund's duty clear. Unfortunately, the NSPE code no longer contains that provision. Why? One possibility is that the drafters of the current code thought the provision redundant given the duty to hold the public safety paramount. Another possibility is that the NSPE codeand ABET guidelinesnow require engineers to be concerned only for the *public* safety, health, and welfare rather than, as canon 11 seems to be, everyone's. Perhaps, after due consideration, the drafters of the various codes decided it was too much to ask engineers to worry about the safety of their client's or employer's *employees* as well as the safety of the public. How is an engineer to understand a code of ethics if, as often happens, it does not clearly address a problem?

That question is surprisingly easy to answer if we keep in mind the connection between professions and codes of ethics. The language of any document must be interpreted in light of what it is reasonable to suppose its authors intended. For example, if the word "bachelor" appears undefined in a marriage statute, we interpret it as referring to single males, but if the same word appears undefined in directions for a college's graduation ceremony, we instead interpret it as referring to all students getting their baccalaureate, whether male or female, single or married. That is the reasonable interpretation because we know that marriages usually involve single males (as well as single females) *rather than* people with baccalaureates while just the reverse is true of graduation ceremonies. So, once we figure out what it is reasonable to suppose engineers to intend by declaring the *public* safety, health, and welfare paramount, we should be able to decide whether interpreting "public" so that it includes employees is what they intend (or, at least, what, as rational persons, they should intend).

The "authors" of a code of engineering ethics (both those who originally drafted or approved it and those who now give it their support) are all more or less rational agents. They differ from most other rational agents only in knowing what engineers must know to be engineers and in performing duties they could not perform (or could not perform as well) but for that knowledge. It is therefore reasonable to suppose that their code of ethics would not require them to risk their own safety, health, or welfare, or that of anyone for whom they care, except for some substantial good (for example, high pay, easy application of the code, or service to some ideal to which they are committed). It also seems reasonable to suppose no code they

"authored" would include anything people generally consider immoral. Engineers being generally much like the rest of us, we have, all else equal, no reason to suppose engineers as a group to be bent on immoral conduct.

But what if that were not true? What if most engineers were moral monsters or self-serving opportunists? What then? Interpretation of their code would certainly be different, and probably harder. We could not understand it as a *professional* code (a system of morally permissible rules). We would have to switch to principles of interpretation we reserve for mere folkways, Nazi statutes, or the like. We would have to leave the presuppositions of ethics behind.

But, given those presuppositions, we can easily explain why a code of engineering ethics would make holding the public safety paramount a duty taking precedence over all others, including the duty to act as a faithful agent or trustee of one's employer: Rational engineers would want to avoid situations in which only their private qualms stood between them and a use of professional knowledge they considered wrong or otherwise undesirable. Each would want to be reasonably sure the others' knowledge would serve the public even when the interests of the public conflicted with those of employer or client. Given this purpose, what must "public" mean?

We might interpret "public" as equivalent to "everyone" (in the society, locale, or whatever). On this interpretation, the public safety would mean the safety of everyone more or less equally. A danger that struck only children, or only those with bad lungs, or the like, would not endanger the public. This interpretation must be rejected. Because few dangers are likely to befall everyone more or less equally, interpreting public to mean everyone would yield a duty to the public too weak to protect most engineers from having to do things that would make life for them (and those for whom they care) worse than it would otherwise be.

We might also interpret public as referring to "anyone" (in the society, locale, or whatever). On this interpretation, the public safety would be equivalent to the safety of some or all. Holding the public safety paramount would mean never putting anyone in danger. If our first interpretation of public made provisions protecting the public too weak, this second would make such provisions too strong. For example, it is hard to imagine how we could have airplanes, mountain tunnels, or chemical plants without some risk to someone. No rational engineer could endorse a code of ethics that virtually made engineering impossible.

We seem, then, to need an interpretation of public invoking some relevant feature of people (rather than, as we have so far, just their number). We might, for example, think that what makes people members of a public is their relative innocence, helplessness, or passivity. On this interpretation, "public" would refer to those persons whose lack of information, technical knowledge, or time for deliberation renders them more or less vulnerable to the powers an engineer wields on behalf of his client or employer. An engineer should hold paramount the public safety, health, and welfare to ensure that engineers will not be forced to give less regard to the welfare of these "innocents" than they would like.

On this interpretation, someone might be part of the public in one respect but not in another. For example, the astronauts would be part of the public in respect of the O-rings because, not knowing of that danger, they could not abort the launch

because of it. The astronauts would, in contrast, *not* be part of the public in respect of the ice forming on the boosters because, having been fully informed of that danger, they could abort the launch if they were unwilling to risk the effects of the ice. On this third interpretation, public seems to create none of the difficulties it did on the two preceding interpretations. We now have a sense of "holding the public safety paramount" we may reasonably suppose rational engineers to endorse.

On this interpretation, all four codes of ethics would require Lund either to refuse to authorize the launch or to insist instead that the astronauts be briefed to get their informed consent to the risk. Refusing authorization would protect the public by holding the safety of the astronauts paramount. Insisting that the astronauts be briefed and decide for themselves would hold the safety of the public paramount by transferring the astronauts from the category of member of the public to that of informed-participant in the decision. Either way, Lund would not, under the circumstances, have treated his own interests, those of his employer Thiokol, or those of his client, the Space Center, as comparable to those of the public.

Is this the right answer? It is if we took every relevant consideration into account. Have we? How are we to know whether we have? We can, of course, go through a checklist. But how are we to know that the list is complete? Past experience is an indication, but now and then something unprecedented occurs. So, what are we to do? In engineering ethics, as in the rest of engineering, it is often easier to demonstrate the fault of alternatives than to demonstrate that this or that answer must be right. This is such a case. Although we cannot demonstrate that our third interpretation is the right one, we can demonstrate that the only obvious alternative is wrong.

That alternative is that public refers to all "innocents" *except* employees of the client or employer in question. Employees might be excluded because they are paid to take the risks associated with their work. On this interpretation, Lund would not have to hold the safety of the astronauts paramount. They would not be part of the public.

What is wrong with this fourth alternative? Consider how we understood innocents. These are persons whose lack of information, training, or time for deliberations renders them vulnerable to the powers an engineer wields on behalf of his client or employer. An employee who takes a job knowing the risks (and being able to avoid them) might be able to insist on being paid enough to compensate for them. She might then be said to be paid to take those risks. But she would, on our *third* interpretation, also not be part of the public to which an engineer owed a paramount duty. She would have given informed consent to the risk in question. On the other hand, if the employee lacked information to evaluate the risk, she would be in no position to insist on compensation. She would, in other words, be as innocent of, as vulnerable to, and as unpaid for the risks in question as anyone in the public. Nothing prevents an engineer, or someone for whom an engineer cares, from being the employee unknowingly at risk. So, rational engineers have as much reason to want to protect such employees as to protect the public in general. "Public" should be interpreted accordingly. [17]

Lesson

One notable feature of engineering disasters is that they seldom have just one cause, whether bad design, natural catastrophe, operator error, or even conscious wrong-doing. Engineering creates systems relatively immune to disaster, systems that require many failures before anything big can happen.

Like most engineering disasters, the Challenger explosion could not have occurred without many things going wrong. Disputes about "the" cause are therefore "academic" (in the bad sense of that otherwise honorable word). The Challenger's design was certainly imperfect (but what engineering design is not?). The O-rings were just one of many troubles. Thiokol's (and NASA's) decision procedure was imperfect, too. The redesign of the O-rings should have had top priority at least a year before the explosion. There were also budget problems, as Congress came to take the Space Program for granted. Morton's purchase of Thiokol may have changed Thiokol's decision making in subtle ways, making it less engineering oriented. And so on. [18] Had any of these factors been otherwise, Lund might have had an easy decision to make on January 27, 1986.

Any engineer who has had an important part in some large project will find the Challenger story familiar. The complex causal chain that led from the early 1960s to the Challenger's explosion is not alien to engineering. Quite the contrary, engineering is inseparable from budgets, problems of coordinating work, choice of design on practical (as well as purely technical) grounds, and so on. Such "political" considerations help to explain why one night Lund became the last barrier to disaster, but they do not explain away his decision or render it irrelevant. Among the many lessons the Challenger's story has to teach is that, in practice, the ethics of engineers is as important to the success of engineering as good design or testing is.

Professional Responsibility

Given the argument developed so far, engineers clearly are responsible for acting as their profession's code of ethics requires. Do their professional responsibilities go beyond the code? That depends on what we mean by "responsibilities" here. If we mean (special) "obligations" or "duties," that is, acts required, then the answer is no; it takes a convention, the code of ethics itself, to create those. If, however, we mean less, (something like) "tasks they have good reason to take on or assign," then engineers certainly do have professional responsibilities beyond the code.[19] Engineers should not only do as their profession's code requires but also support it less directly by encouraging others to do as the code requires and by criticizing, ostracizing, or otherwise calling to account those who do not. Engineers should support their profession's code in these auxiliary ways for at least four reasons.

First, supporting the code helps protect engineers and those they care about from being injured by what other engineers do. Second, supporting the code helps ensure each engineer a working environment in which resisting pressure to do what the engineer would rather not do is easier than it would otherwise be. Third, engineers should support their profession's code because supporting it helps make their profession a practice about which they need feel no morally justified embarrassment, shame, or guilt. And fourth, considerations of fairness call on an engineer to take on his share of these additional responsibilities insofar as other engineers do the same and he (by claiming to be an engineer) benefits from their doing so.

5
Explaining Wrongdoing

How often is a man, looking back at his past actions, astonished at finding himself dishonest!
Cesare Beccaria, *On Crimes and Punishments,* chap. 39

What first interested me about professional ethics were the social questions: the problems faced by those trying to act as members of a profession, the options available, the reasons relevant to deciding between those options, and the methods of assessing those reasons. I thought of myself as advising decision makers within a complex institution. I could, it seemed, contribute to right action in the professions simply by applying skills developed in political and legal philosophy to this new domain. But, like many others who began to do applied ethics in this way, I soon learned that matters are not that simple.

Part of studying professional ethics is reading the newspaper accounts, congressional testimony, and court cases that wrongdoing in the professions generates. I read such documents to identify new problems. But, in the course of reading so much about wrongdoing, I began to wonder how much use my advice could be. Though the wrongdoers were usually well-educated and otherwise decent (like the characters in chapter 4), much of what they did seemed clearly wrong. Surely they did not need a philosopher to tell them so. I also began to wonder at how little the wrongdoers themselves had to say about why they did what they did. They seemed far less articulate about that than many illiterate criminals. [1]

Having begun to wonder about the motivation of the wrongdoers I was studying, I turned to the philosophical literature explaining wrongdoing. I was surprised at how little there wasand at how unhelpful it was. The wrongdoers I studied did not seem to do wrong simply because they were weak-willed, self-deceiving, evil-willed, ignorant, or morally immatureor even because they combined several of those failings. At most, those failings seemed to play a subsidiary part in what they did. Yet the philosophical literature offered no sustained discussion of anything else. Only when I turned to the more practical literature of organization analysis did I find more. And, even there I did not find enough. I still did not have a satisfactory explanation of the wrongdoing I was studying. I concluded that we lack an adequate psychology of wrongdoing.

This lack is unfortunate for both a practical and a theoretical reason. The practical reason is that the less well we understand wrongdoing, the less able we are to devise strategies likely to reduce wrongdoing. The theoretical reason is that insofar as we cannot explain wrongdoing, there is a substantial hole in our understanding of engineering ethics.

This chapter has three objectives: (1) to provide some evidence for the claim that evil will, weakness of will, self-deception, ignorance, and moral immaturity, even together, do not explain much wrongdoing of concern to students of engineering ethics; (2) to add one interesting alternative to the explanations now available; and (3) to suggest the practical importance of that alternative. Ultimately, though, this chapter has only one objective: to invite others to pick up where I leave off. Those interested in engineering ethics need to think more about the psychology of wrongdoing.

Three Examples of Wrongdoing

Let's begin with the testimony of a minor figure in the General Electric price-fixing scandal of the 1950s. No longer facing criminal or civil charges, he described how he got into trouble as follows: "I got into it . . . when I was young. I probably was impressed by the manager of marketing asking me to go to a meeting with him [where price-fixing discussions took place]. I probably was naive." [2]

This explanation of our price fixer's wrongdoing is more interesting for what is missing than for what is actually there. We hear nothing about greed, temptation, fooling oneself, or anything else we tend to associate with those destined to do wrong. What we do hear about is *ordinary* socialization. After working nine years at GE as an engineer, our price fixer (at age 32) was promoted to "trainee in sales." His superior then showed him how things were done. Yet, something is wrong. The witness twice indicates that this is only "probably" what happened. Though the acts in question are his, he talks about them like a scholar analyzing someone else's acts. A screen has come down between him and the person he was only a few years before.

An inability to understand their own past wrongdoing is, I think, not uncommon in wrongdoers such as this engineer. One more example shows that he is not unique. In 1987, the *Wall Street Journal* carried a follow-up on the fifty people by then convicted of inside trading during the 1980s. Here is part of what we learn from one of them, a civil engineer: "When it started, I didn't even know what inside information was." But around 1979, he says, he began reading about people being arrested for inside tradingyet he continued trading even though he knew it was illegal. It's a decision he wouldn't repeat. "In the long run," he says, "you are going to get caught."[3]

This testimony comes from a small investor, not a broker, analyst, arbitrageur, or the like. Unlike the price fixer, this inside trader was never really inside the relevant organization. He simply received information from inside that he had no right to receive. Yet, for our purposes, it doesn't matter. What matters is that he knew early on that he was doing something illegal and stood a fair chance of being arrested. He went on trading nonetheless. Why? He doesn't say and, more important, he doesn't seem to know. He does not object to the law (as many economists do). He does not claim that what he was doing was "really" all right. Nor does he report himself overcome by greed, temptation, or evil will. All that he says is that he would not have done it if he had known *then* what he knows *now*. What changed? What does he know now that he did not know then? It cannot be what he says, that is, "In the long run, you are going to get caught." He has no way to know that every inside trader will get caught in the long run. Statistics on the occurrence of illegal inside trading do not exist; but, if inside trading is like other crimes, a substantial percentage of those engaged in it will never be caught. 4

Our witness's overstatement of the risks of being caught is, I think, better understood as a way of calling attention to *what* he risked and would not risk again. He now regrets doing what he did because he now appreciates what was at stake in a way he did not at the time. He does not so much have new information as a new perspective on the information he had all along. It is this new perspective that makes it hard for him to understand how he could have done what he did. The person we are listening to differs in an important way from the person who engaged in insider trading a few years before, even if he does not know anything he did not know before. It is as if he sees the world with new eyes.

Explaining Lund's Decision

These two wrongdoers are minor figures in major scandals. We may therefore wonder whether the major figures differ in some significant way. I don't think they do. Recall the events the night before the Challenger exploded (described in chapter 4).

The story of the Challenger resembles many cases discussed in engineering ethics. Although no one broke the law, as many did in the General Electric price-fixing scandal, there was wrongdoing. And, in retrospect, everyone recognized thator at least sensed it. Mason quickly took early retirement. Kilminster and Lund were moved to new offices, told they would be "reassigned," and left to read the handwriting on the wall. Morton Thiokol didn't treat them as if their errors were merely technical, nor did it defend their decision the way it would a decision it believed in. Thiokol's defense consisted largely of lame excuses, attempts to suppress embarrassing information, and similar self-convicting maneuvers.

What went wrong? From the perspective of engineering ethics, it should now be obvious. Lund, an engineer who held his position in part because he was an engineer, had a professional duty to act like an engineer. He was not free to take off his engineering hat (though he could wear other hats in addition). For an engineer, public safety is the paramount consideration. The engineers could not say the launch would be safe, so, Lund should have delayed the launch. Seven people died, in part at least because Lund did not do what, as an engineer, he was supposed to do.5

One of the features that made the Challenger disaster an instant classic is a clear clash of legitimate perspectives. Lund was not just an engineer. He was also a manager. Managers are *not,* by definition, evil doers. Government openly supports institutions to train managers. Few people would want to forbid managers to practice their trade. As a vice president of Morton Thiokol, part of Lund's job was to wear a management hat. What then was wrong with his giving approval after putting on that hat?

The answer must be that, in the decision procedure of which he was part, his job was to stand up for engineering. He was supposed to represent engineering judgment in management decision. He was vice president *for* engineering. When he took off his engineering hat, he simply became another manager. He ceased to perform the job for which he was needed. That, in retrospect, is why, even from management's perspective, he did something wrong.

Why then did he take off his engineering hat that night? Lund's explanation for deciding as he did was, and remains, that he had "no choice" given the Space Center's demand. Self-interest does not explain what Lund means by "no choice." To approve the launch was in effect to bet his career that the Challenger would not explode, to bet it against the best technical advice he could get. If he refused to approve the launch, he would *at worst* be eased out of his position to make way for someone less risk averse. He would have no disaster on his record and a good chance for another good job either within Thiokol or outside. Self-interest seems to support a decision *not* to launch.

What about moral immaturity? 6 This is a possibility, but only that. The records tell nothing about anyone's moral development. Participants said nothing about social pressure, law, ordinary morality, or professional ethics. They spoke entirely in the bland technical language engineers and managers use to communicate with one another. Whatever we say about Lund's moral development as of that night would be mere speculation. Something similar is true of the hypothesis that Lund acted with evil intent. By all reports, Lund was too decent a person for that.

What about carelessness, ignorance, or incompetence?[7] I think none of these explanations will do. Too much time went into the decision to dismiss it as simply careless. Because Lund had the same training as his engineers and all the information they had, we can hardly suppose him to be ignorant in any obvious sense. Nor can we declare him to be incompetent. Too many experienced peopleboth at Thiokol and at NASAconcurred in Lund's decision for it to be incompetent. Lund may well have been operating at the limit of his ability or beyond. But that is not necessarily incompetence. We generally speak of incompetence only when we have competent alternatives. Here we have no reason to believe that anyone who could have occupied Lund's place that night would have done better.

Can we then explain Lund's decision by weakness of will?[8] Did he know better but yield to temptation, give in to pressure, or otherwise knowingly do what he considered wrong because he lacked the will to do better? The evidence does not support this explanation either. Mason's advice, "Take off [your] engineering hat and put on [your] management hat," does not sound like tempting Lund to act against his better judgment. It sounds much more like an appeal *to* Lund's better judgment, an appeal from engineering instinct to management rationality.

Lund did, of course, give in to pressure. But "pressure" does not so much explain his decision as describe it on the model of a physical process (for example, the collapse of a beer can when we stamp on it). We still need to explain why the appeal

to management rationality was so convincing when nothing else was. (We need something like the physical theory that allows us to understand why the beer can collapses under our weight but not under the weight of, say, a cat.) Well, we might say, that's easy enough. The appeal to management rationality allowed Lund to fool himself into thinking he was doing the right thing.

Explaining Lund's decision in this way, as a result of self-deception, is, I think, much closer to the mark. Mike Martin, coauthor of a text in engineering ethics, recently published a book on self-deception. Among his many examples of self-deceivers are participants in the GE price-fixing scandal. I have no doubt that he could find some self-deception in Lund as well. 9

Yet, if we can, we should avoid explaining Lund's act by self-deception. Self-deception, though common, is an abnormal process. It is something we *do*, not simply something that happens to us. We must knowingly fail to think about a question in the way we believe most likely to give the right answer. We must then not think about the unreliability of the answer we get even, or especially, when we must act on it. In its extreme form, self-deception may involve believing something while being aware that the evidence decisively supports the opposite belief. Self-deception is, as such, a conscious flight from reality.10

We should not explain the conduct of responsible people in this way unless the evidence requires it. The evidence hardly requires it in Lund's case. We can explain why Lund did what he did by a process which, though similar to self-deception, is normal, familiar, and at least as probable on the evidence as any of the explanations we have considered so far. Let's call the process "microscopic vision."[11]

Microscopic Vision Examined

What is "microscopic vision"? Perhaps the first thing to say about it is that it is *not* "tunnel vision." Tunnel vision is a narrowing of one's field of vision without any compensating advantage. Tunnel vision is literally a defect in vision and figuratively a defect in our ability to use the information we have available, a radical single-mindedness, a monomania. Tunnel vision is often associated with self-deception. Any advantage it might yield would be accidental.

Microscopic vision resembles tunnel vision only insofar as both involve a narrowing of our field of vision. But, whereas tunnel vision reduces the information we have available below what we could effectively use, microscopic vision does not. Microscopic vision narrows our field of vision only because that is necessary to increase what we can see in what remains. Microscopic vision is enhanced vision, a giving up of information not likely to be useful under the circumstances for information more likely to be useful. If tunnel vision is like looking through a long tunnel to a point of light at the other end, microscopic vision is like looking into a microscope at things otherwise too small to see. Hence, my name for this mental process.

Microscopic vision is also not nearsightedness or myopia. A nearsighted person has lost the ability to see things far off. His acuity close up is what it always was. But when he looks into the distance, he sees only a blur. Like tunnel vision, myopia is partial blindness; microscopic vision is, in contrast, a kind of insight. The nearsighted person needs glasses or some other aid to regain normal vision. A person with microscopic vision need only cease using his special powers to see what others see. He need only look up from the microscope.

Every skill involves microscopic vision of some sort. 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, that the wearer walks in a particular way, and so on. 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. Microscopic vision is a power, not a handicap, but even power has its price. We cannot look into the microscope *and* see what we would see if we did not.

Though every skill involves microscopic vision, the professions provide the most dramatic examples. In part, the professions provide these examples because the insight they give is relatively general. The microscopic vision of a lawyer, engineer, doctor, minister, or accountant concerns central features of social life, which the microscopic vision of a shoemaker does not. In part, though, professions provide the most dramatic examples of microscopic vision because both the long training required to become a professional and the long hours characteristic of professional work make the professional's microscopic vision more central to his life. A profession is a way of life in a way shoemaking is not (or, at least, is not anymore).

Consider, for example, the stereotypes of professionalsthe pushy lawyer, the comforting doctor, the quiet accountant, and so on.

There are no similar stereotypes of the shoemaker, the carpenter, or the personnel director. These skills don't seem to shape character as much. We joke about professional myopiafor example, the engineer who, about to be excused from a death sentence because the guillotine's blade jammed during the preceding execution, volunteers to "fix the problem." Behind the joke is an appreciation of the power a profession has to shape, and therefore, to misshape, the consciousness of its members. Real professional myopia is probably rare. Few professionals seem to lose altogether the ability to see the world as ordinary people do. Common, however, is a tendency not to look up from the microscope, a tendency unthinkingly to extend the profession's perspective to every aspect of life.

Managers are not professionals in the strict sense. Though managing now has schools like those of the professions, managers lack two features essential to professionals strictly so called: first, a formal commitment to a moral ideal, *and* second, a common code of ethics. Indeed, managers seem to me to lack even a clear sense of themselves as *managers*that is, as *custodians* of other people's wealth, organization, and reputation. I am surprised by the number of managers who think of themselves as entrepreneurs or capitalistsas businesspeople who risk their own money, not someone else's.

Nonetheless, managing today does have many of the characteristics of a profession, including distinctive skills and a corresponding perspective, butmost importanta way of life that can make their microscopic vision seem all that matters. We have the stereotype of the manager who can't see the toxic waste beyond the end of his budget. Behind that stereotype is a certain reality. Managers, especially senior managers, work almost entirely with other managers. Their days are spent

"in the office" doing the things that managers do. Often, those days are quite long, not 9 to 5 but 8 to 7 or even 7 to 8. They read management magazines and go to management meetings. They come to see the world from the perspective of a manager.

There is a natural process by which people are made into managers. But most companies are not satisfied with "normal acculturation." They have special programs to train managers in a certain style of management. Roger Boisjoly, one of the engineers who tried to get Lund to stick to his no-launch recommendation, was himself briefly a manager. He went back to being an engineer because he wanted to be closer to work on the shuttle. Though he mocked Thiokol's management programs as "charm schools," he has also pointed out that they helped to make the managers at Thiokol a cohesive team. They helped to give the engineer turned manager a clear sense of the priority of the manager's way of looking at things. [12]

What is the difference between the way an engineer might look at a decision and the way a manager might? For our purposes now, what is important is the way engineers and managers approach risk.[13] I think engineers and managers differ in at least two ways. First, engineers would not normally include in their calculations certain risksfor example, the risk of losing the shuttle contract if the launch schedule were not kept. Such risks are not their professional concern; such risks are properly a manager's concern. Second, engineers are trained to be conservative in their assessment of permissible risk. Often they work from tables approved by the appropriate professional association or other standard-setting agency. When they do not have such tables, they try not to go substantially beyond what experience has shown to be safe. Engineers do not, in general, balance risk against benefit. They reduce risk to permissible levels and only then proceed. Managers, on the other hand, generally balance risk against benefit. That is one of the things they are trained to do.

So, we have two perspectives on the same problem: the engineer's and the manager's. Which is better? The answer is neither. The engineer's perspective is generally better for making engineering decisions; the manager's perspective is generally better for making management decisions. Either perspective has a tendency to yield a bad result if applied to the wrong kind of decision. Indeed, that is nearly a tautology. If, for example, we thought a certain decision better made by managers than engineers, we would describe it as (properly) a management, rather than an engineering, decision.[14]

If that is so, it's not too hard to understand why Lund changed his mind the night before the Challenger exploded (and why he might still claim that he had "no choice"). Once he began thinking about the launch as an ordinary management decision, he could rationally conclude that the risk of explosion was small enough to tolerate given the demands of NASA and how much was at stake for Morton Thiokol. But why *would* Lund think about the launch like a manager rather than an engineer?

As I described the difference between the engineer's perspective and the manager's, the two approaches to risk are inconsistent. Lund had to choose. In a way, Mason's plea to Lund to take off his engineering hat and put on his management hat accurately stated the choice Lund faced. In another way, however, it did not.

Mason's plea assumed that Lund's decision to launch was an ordinary management decision. This would be just what any manager would normally assume (unless trained to think otherwise), especially a manager who was himself an engineer. For an engineer to be made a manager is generally considered a promotion, an opening of new horizons. Managers are in charge of engineers. They regularly receive engineering recommendations and then act on them, taking into account (supposedly) more than the engineers did. Engineers generally defer to managers. 15

Anyone who thought of relations between engineers and managers in this way would, I think, succumb to Mason's plea*unless* he had a clear understanding of what made him different from other managers. Lund, it seems, had no such understanding. Indeed, Mason's plea probably shows that no one in the senior management at Morton Thiokol did. Mason could hardly urge Lund to take off his engineering hat in front of so many managers if it was common knowledge that Lund had a duty to keep his engineering hat on. Perhaps those who originally organized the decision procedure at Thiokol understood things better. If so, they failed to institutionalize their understanding. Without some way to preserve that understanding, ordinary management understanding would eventually take over. The Challenger explosion was the natural outcome of ordinary management.

My purpose here is not to defend Lund's decision but simply to understand how he might have made it without being careless, ignorant, incompetent, evil-willed, weak-willed, morally immature, or self-deceiving. I explained his decision as rational from the perspective of an ordinary manager and then explained why that perspective might seem the right one at the decisive moment. Earlier, I pointed out that, in retrospect, everyone seemed to see not only that Lund made an unfortunate decision but that the decision he made was wrong. I have now explained why. Lund was not an ordinary manager; he was supposed to be an engineer among managers.

Next, I would like to generalize what we learned from Lund: We have a tendency to suppose that doing the right thing is normal, doing the wrong thing is abnormal, and when something goes wrong, the cause must be something abnormal, usually a moral failing in the wrongdoer. What the analysis so far suggests is that sometimes at least the wrong may be the result of normal processes.16

The analysis also suggests something more: Managers sometimes say of obeying the law, of doing what's morally right, or of maintaining professional standards, "That should go without saying"or, in other words, that the importance of such things is so obvious that pointing the importance out is unnecessary. The truth, I think, is almost the reverse. I return to this point later.

Price Fixing and Inside Trading

Lund represents one category of wrongdoerthose whose conduct is merely unprofessional. There is anotherthose whose wrongdoing is illegal. Could what I said of Lund apply to this other category as well? Let's try to answer that question by briefly examining the two lawbreakers with whom we began. We are now ready to understand why they might have done what they did.

First, the price fixer at General Electric. Arriving at his new job eager to learn, he found that much he had learned as an engineer did not quite fit. Everyday was

a struggle to "get up to speed." One day his superior invited him to go to a meeting. The meeting consisted of sales managers from the other two major turbine manufacturers, clearly respectable people and clearly engaged in fixing market prices. There was no question that the meeting was secret. But what conclusion should he draw from that? A company like GE has many secrets. The meeting did not take long and soon the future price fixer was doing other things. After a few more meetings like this, he was allowed to go without his superior. Soon the meetings were routine.

He may initially have had qualms about the meetings. We often have qualms about a practice with which we are unfamiliar. But we learn to suspend judgment for a decent interval. Often the qualms disappear as understanding increases. Of course, the price fixer may have had more than the usual reasons for qualms. He may have received in the mail a copy of a GE policy that forbade what he was doing ("policy 20.5"). But the policy would have come from the law department, not from anyone in his chain of command. Nothing would have made that mailing seem more important than other mailings from law or other non-line departments that managers routinely ignore. What occupied the price fixer's time, his field of vision, as we might say, was learning to be a manager. He had little time to think about matters that seemed to matter to no one with whom he dealt. Eventually, he would stop thinking about the price fixing as price fixing. 17

I have now told the price fixer's story in terms appropriate to microscopic vision. I described him as developing in a normal way a sense for what matters and what does not matter in a certain environment. The process is similar to the "desensitization" that a surgeon must undergo before she can calmly cut off a human limb or put a knife into a still-beating heart. Though the process I described does *not* require learning to block anything out, only failing to use some information because one is busy using other information, it does share at least one important feature with self-deception (something ordinary desensitizing does not): The price fixer was misled. The process nonetheless differs from self-deception in at least two ways:

> 1. Although self-deception presupposes in the self-deceiver some sense of the unreliability of the procedure he is using to learn about the world, the process I described presupposes no such thing. The price fixer might well have believed his procedure would yield an accurate, albeit incomplete, picture of the world in which he worked.
>
> 2. Although self-deception presupposes that the procedure used is in fact generally unreliable, we need not presuppose that here. The procedure I described might well be *generally* reliable. The problem is that the price fixer's procedure was not "designed" to distinguish legal from illegal management. That procedure may well have made sense in the 1950s. Who then would have thought that the managers of a company like GE would have engaged in extensive illegal conduct? The discovery must have astonished many people, including our price fixer.

Next consider the inside trader. He got warnings of a sort the price fixer did not. He actually read about indictments of people for inside trading. Yet, he continued to trade on inside information. Why? Perhaps he deceived himself about the chances of being caught. A more interesting possibility, though, is that he never thought about being caught. He began inside trading with a clear conscience. He read of its illegality only after he had grown used to inside trading. Perhaps those with whom he cooperated showed no fear. Busy with many things beside inside trading, normal prudence would have told him that, if he feared everything the newspapers invited him to fear, he would live with numberless terrors. We must use the judgment we develop in daily life to put newspaper stories in perspective. His immediate environment seemed as safe as ever. So, why should he worry about what he read in the newspaper? Again, we have a normal process leading to an abnormal result.

I do not, of course, claim that this is how it was. I am suggesting a hypothesis, not demonstrating it. However, I should, I think, point out one piece of evidence that suggest that my explanation is at least partly right. Recall that neither of these wrongdoers seems to understand how he came to do what he did. That is what we should expect if my version of their stories is more or less right. As I told their stories, each did wrong in part at least because he did not use certain factspolicy 20.5 in one case, arrests of inside traders in the otherin a way that would have led him to a true understanding of what he was doing or to the conduct such an understanding would normally lead to. The facts did not trigger the fear of punishment or concern about doing wrong that seems normal outside the environment in which they were working. The facts seemed to have been pushed from consciousness by other facts, as most of the world is pushed aside when we look into a microscope.

Once the two wrongdoers were pulled from the microscope, they would cease to see the world as they had. They would not, however, have that sense of having "known it all along" so characteristic of coming out of self-deception (because they could not have known it until they looked at the world somewhat differently). They would instead be aware of seeing something thatin the light of the evidence now before them*must* have been there all along. Microscopic vision is a metaphor for a mental process, a "mind-set" or "cognitive map." Because the mechanics of such mental processes are no more visible to the person whose mind it is than it is to an outside observer, these two wrongdoers need not have been aware of what made them attend to other things until now. They could honestly be perplexed about how they could have missed for so long what is now as plain as day.

Some Practical Lessons

In this chapter, I tried to describe wrongdoing as the outcome of a social process the literature on wrongdoing overlooked. I tried to avoid assuming such serious moral failings as weakness of will or self-deception. Of course, I did not describe my wrongdoers as paragons of rationality or virtue. The price fixer and inside trader were certainly naive; they lacked enough insight into the way the world works to recognize obvious signs of trouble. Lund, however, seems no more naive than the rest of us. I can imagine myself doing what he did.

If the process I described in fact explains much wrongdoing in large organizations, we may draw some interesting conclusions about how to prevent that wrongdoing. The most obvious, perhaps, is that screening out potential wrongdoers is probably impractical. Who would be let in by a procedure that screened out the wrongdoers we discussed here? We must instead consider how to prevent wrongdoing by the relatively decent people an organization must employ.

The problem as I described it is that normal processes can lead to important information going unused at a decisive moment. Lund's training as a manager would not prepare him to see how special his role was. The future price fixer's way of learning his job would not alert him to the risks of illegality, much less to any moral objections to fixing prices. The inside trader's experience would make him discount the warning signs in the newspaper. Though microscopic vision is not a flight from reality, it does involve a sacrifice of one part of reality to another. Usually, the sacrifice is worth it. Sometimes it is not. When it is not, we need to change the microscopic vision of those working in the environment in question or change the environment. Sometimes we need to change both. Often, changing one changes the other too.

How might we change the environment? One way is simply to talk openly and often about what we want people to notice. For example, Lund would probably have refused to do as Mason suggested if the people back at Morton Thiokol's headquarters in Chicago regularly reminded him that he was no ordinary manager: "We are counting on you to stand up for engineering considerations whatever anyone else does." Indeed, had *Mason* heard headquarters say that to Lund a few times, he could hardly have said what he did say. He might well have deferred to Lund's judgment even though NASA was pressuring him. "Sorry," he could have said, "my hands are tied."

Business professors especially, but ordinary managers as well, often decline to talk about what they call ethics because they do not want to "sermonize." Sermons, they say, cannot lead people to do the right thing. If adults haven't learned to be ethical by now, or don't want to, what can a sermon do?

These professors and managers seem to use the word "ethics" as a catch-all for whatever "value" considerations seem so obvious that they would be embarrassed to raise them. I must admit to some doubts about their consistency here. These same people regularly sermonize about profit. They do not find mention of profit embarrassing though we might suppose that, for them, profit would be the most obvious value consideration of all.

Still, whatever doubts I have about their consistency, I can easily respond to their concern about the ineffectiveness of sermonizing. However obvious the sermon's content, the sermon itself can help to keep legal, moral, and professional considerations in an organization's collective field of vision. That, I think, is why both business professors and ordinary managers talk so much about profit. That is how they keep profit a primary concern. So, doing the same for ethical considerations should, by itself, be a significant contribution to getting decent people to do the right thing.

Sermons are, of course, hardly the best way to do that. Better than sermons are such familiar devices as a code of ethics, ethics audit, ethics seminar for managers, discussion of ethics in the course of ordinary decision making, and rewards for those who go out of their way to do the right thing ("reward" including not only praise but also the other valuables that normally go to those who serve their employer well, especially money and promotion). But, whatever the merits of these particular devices in themselves, they all have this important characteristic in common. They help to keep employees alert to wrongdoing. They help to maintain a certain way of seeing the world.

What about teaching? Part of teaching is getting people used to thinking in a certain way. What academics call disciplines are in fact forms of microscopic vision. We should, therefore, pay as much attention to what we don't teach as to what we do teach. If we limit ourselves to teaching technical aspects of a discipline, those we teach tend to develop a perspective including *only* those technical aspects. They do not automatically include what we don't teach. Indeed, they would be quite unusual students even to see how to include such extras. If, then, we teach engineering without teaching engineering ethics, our graduates will begin work thinking about the technical aspects of engineering without thinking about the ethical aspects. They will not dismiss the ethical aspects. They will not even see them. [18]

Of course, we can teach what we should and still do little good. Good conduct in business or a profession presupposes a suitable social context. If a morally sensitive graduate goes to work in a company where ethics is ignored, he will, if he stays, slowly lose his sense of the ethical dimension of what he does. His field of vision will narrow. Eventually, he may be as blind as if we had taught him nothing. This claimI should stressis not about moral development (as that term is now commonly understood). Our graduate may well score no worse on a Kohlberg test than he did before.[19] He will simply cease to think of a certain range of decisions as raising questions to which moral categories are important. The questions will seem "merely technical," "an ordinary business decision," or in some other respect "merely routine."

To develop such "moral blindness" is, of course, a misfortune. Insofar as it results from circumstances over which one has little or no controlfor example, ignorance of what a company is really likeit is a misfortune for which one cannot be held responsible. Even so, the resulting moral blindness does not provide an excuse for wrongdoing. Moral blindness is itself a character flaw. That an act arose from a flaw in character (rather than from good character) adds to the grounds for condemnation rather than reduces them.

That an organization can make the teaching of ethics ineffective by blinding its employees to moral concerns is no reason not to teach ethics. But it is good reason to conceive ethics teaching as part of a larger process, and good reason too, to try to transmit that conception to our students. Caroline Whitbeck provides a good example of what can be done. As part of a course in engineering design, she had her students contact local companies to find out how an engineer in the company could raise an issue of professional ethics related to design. Her students thus learned to think of their future employers as in part "ethics environments." But that is not all her students did. Their inquiries made it more likely that their future employers will think about how an engineer could raise an ethics issue. So, Whitbeck was also helping to improve the ethics environment in which her students would someday work.20

6
Avoiding the Tragedy of Whistleblowing

The strength of the pack is the Wolf, and the strength of the Wolf is the pack.
Rudyard Kipling*, "The Law of the Jungle"*

I focused on the decision to launch the Challenger to help us understand some of the complex interrelations between technical and organizational factors so characteristic of much that engineers do. Yet what the Challenger disaster is most remembered for today is an engineer, Roger Boisjoly. Boisjoly stepped forward after the event, against the wishes of his employer and at the risk of his career, to tell the truth about what happened. He was not the first engineer to "blow the whistle" on an employer, nor is he likely to be the last. Not without reason does the literature of engineering ethics and the teaching of it emphasize the subject of whistleblowing. Whistleblowing is one way engineers have to show that the public health, safety, and welfare means more to them than employer, career, and even their own material welfare. Whistleblowing also reminds us of the political side of engineering, the importance of what engineers say and how they say it.

Most discussions of whistleblowing seek to justify whistleblowing or to distinguish justified from unjustified whistleblowing, or they report who blows the whistle, how, and why; or they advise on how to blow the whistle or how to respond to an employee about to blow the whistle or what to do once she has; or they make recommendations for new laws to protect whistleblowers. In one way or another, such discussions treat whistleblowing as inevitable. I do not do that here. Instead, I consider ways to *avoid* whistleblowing.

It is not that I oppose whistleblowing. I think whistleblowing is, on balance, a necessary evil (and sometimes even a positive good). I certainly think justified whistleblowers should be protected legally. [1] They should not be fired for their good deed or punished for it in any other way. But I doubt that much can be done to protect them. This chapter explains why.

The explanation stresses the destructive side of whistleblowing, making it easier to understand those who mistreat whistleblowers. Insofar as it does that, it both gives the organization's case for mistreatment and shows the importance of avoiding whistleblowing. We must get the benefits of whistleblowing without making people and organizations pay the enormous price that whistleblowing typically exacts. [2]

I address this chapter *both* to those who have a substantial say in how some organization runs *and* to those who may someday have to blow the whistle on their own organization. These groups overlap more than most discussions of whistleblowing suggest.[3] However, that is not why I chose to address both here. My reason runs deeper. I believe that even if those two groups did not overlap, they would still share an interest in making whistleblowing unnecessary; that both groups can do much to make whistleblowing unnecessary; and that each will be better able to do its part if it understands what the other group can do.

The Informal Organization Within the Formal

No matter how large or small, every formal organization includes one or more informal groups. An academic department, for example, is a network of poker buddies, movie buffs, cooks, and so on. Departmental conversation is not limited to what must be said to carry on departmental business. Ordinary life, ordinary attitudes, permeate the formal structure. Much of what makes the formal organization succeed or fail goes on within and between these informal groups. Who likes us is at least as important in most organizations as what we do. Success is not simply a matter of technical skill or accomplishment. We must also have enough friends properly placedand not too many enemies. Perhaps only at hiring time do academics talk much about personality, but every academic knows of a department that fell apart because certain members did not get along and others that survived financial troubles, campus disorders, and tempting offers to individual members in part at least because the faculty got along so well with each other.[4]

Though my example is an academic department, nonacademics will confirm that much the same is true in industrial plants, research laboratories, and even government bureaus. Most of what makes such organizations work, or fail to work, can't be learned from the table of organization, formal job descriptions, or even personnel evaluations. Thinking realistically about whistleblowing means thinking about the informal aspects of formal organization as well as the formal. I focus on those informal aspects here.

Blaming the Messenger

"Whistleblower" is a capacious term. Whistleblowers can be anonymous or open, internal or external, well-intentioned or not so well-intentioned, accurate or inaccurate, justified or unjustified. Perhaps strictly speaking, some of these are not whistleblowers at all.[5] But I have no reason to speak strictly here. For my purposes, "whistleblower" may refer to any member of a formal organization who takes information *out of channels* to try to stop the organization from doing something he believes morally wrong (or to force it to do something he believes morally required).[6]

Almost any organization will fire a whistleblower if it can, whether she was right or not; will ruin her job prospects if it can; and if it can do neither will still do what it can to make her life miserable. An otherwise humane organization can treat a whistleblower savagely. 7 Why?

The most frequent answer is that those who mistreat whistleblowers do so because they expect to benefit from having fewer whistleblowers. The self-interest of individuals or their organization explains the mistreatment.

Though no doubt part of the truth, this explanation is only a small part. In general, we are far from perfect judges of self-interest. Our judgment does not improve simply because we assume an organizational role. We can still be quite irrational. Recall how Shakespeare's Cleopatra responds to her messenger's report that Antony married Octavia:

> . . . Hence
> Horrible villain! or I'll spurn thine eyes
> Like balls before me; I'll unhair thy head;
> Thou shalt be whipp'd with wire and stew'd in brine . . .
> . . . let ill tidings tell
> Themselves when they be felt.8

Though Cleopatra ordered him to spy on Antony, the messenger hears more harsh words, receives several hard blows, and has a knife angrily put to his throat before he is allowed to leave with a small reward.

Today's formal organizations can treat the bearer of bad news much as Shakespeare's love-sick Cleopatra did. So, for example, in a recent book on corporate life, Robert Jackall grimly recounts what happened to several executives with bad news to tell their respective organizations. Though each discovered wrongdoing it was his duty to discover, reported it through channels, and saw the wrongdoer punished, though none of them was responsible for the wrong reported, and though the organization was better off for the report, the lucky among Jackall's executives had their part in the affair forgotten. Some paid with their career.[9]

We usually think of information as powerand it is. But thinking of information that way is no small achievement when the information wrecks our plans. Even experienced managers can find themselves telling subordinates, "I don't want to hear any more bad news."

The rationality of a formal organization is an ideal never more than partially achieved. We must keep that in mind if we are to understand what happens to so many whistleblowers. An organization that would "whip with wire and stew in brine" the simple bearer of bad news is not likely to respond well to the whistleblowereven if, as often happens, the whistleblower serves the organization's longterm interests. The whistleblower is, after all, not only a bearer of bad news; he *is* bad news.

Whistleblowing as Bad News All Around

Discussions of whistleblowing tend to emphasize the undeniable good the accurate whistleblower does (both directly, by revealing wrongdoing, and indirectly, by deterring further wrongdoing). The incidental harm tends to be overshadowed, perhaps because so much of it seems deserved. The harm done by inaccurate whistleblowing receives much less attention. 10

Whatever the reasons for ignoring the bad news about whistleblowing, the fact remains that much bad news is ignored and, for our purposes, the bad news is crucial. So, let us recall how much bad news there is:

Whistleblowing is always proof of organizational trouble. Employees do not go out of channels unless the channels seem inadequate.

Whistleblowing is also proof of management failure. Usually several managers directly above the whistleblower have heard his complaint, tried to deal with it in some way, and failed to satisfy him. However managers view the whistleblower's complaint, they are bound to view their own failure to "keep control" as a blot on their record.

Whistleblowing is also bad news for those on whom the whistle is blown. What they were doing in obscurity is suddenly in the spotlight. They have to participate in "damage control" meetings, investigations, and the like that would not otherwise demand their scarce time. They have to write unusual reports, worry about the effect of publicity on their own career, and face the pointed questions of spouse, children, and friends. And they may have to go on doing such things for monthsor even years.

Insofar as whistleblowing has such effects, no one within the organization will be able to hear the whistleblower's name without thinking unpleasant thoughts. No manager will be able to make a decision about the whistleblower without having bad associations color her judgment. The whistleblower not only makes conscious enemies within his organization but also creates enormous biases against himself, biases hard to cancel by any formal procedure.

And there is more. What must the whistleblower suffer to blow the whistle? At the very least, he must lose faith in the formal organization. If he kept faith, he would accept whatever decision came through formal channelsat least once he exhausted all formal means of appeal.

For anyone who was a loyal employee for many years, losing faith in the organization is likely to be quite painfulrather like the disintegration of a marriage. My impression is that few whistleblowers accept a job thinking that they might someday have to blow the whistle. They seem to start out as loyal employeesperhaps more loyal than most. One day something happens to shake their loyalty. Further shocks follow until loyalty collapses, leaving behind a great emptiness. Managers tend to think of whistleblowers as traitors to the organization, but most whistleblowers seem to feel that, on the contrary, it is the organization that betrayed them.[11]

Moreover, before the whistleblower was forced to blow the whistle, she trusted the formal organization. She took its good sense for granted. Now that is no longer possible. Faith becomes suspicion. Because what we call organizational authority is precisely the ability of the organization to have its commands taken more or less on faith, the "powers that be" now have as much reason to distrust the whistleblower as she has to distrust them.[12] She no longer recognizes their authority. She is much more likely to blow the whistle than before. She is now an enemy within.

Something equally bad happens to relations between the whistleblower and her coworkers. Whistleblowing tends to bring out the worst in people. Some friends will have become implacable enemies. Others hide, fearing "guilt by association." Most simply lose interest, looking on the whistleblower as they would someone dying of cancer. These desertions can leave deep scars. And even when they do not, they leave the whistleblower an outsider, a loner in an organization in which isolation for any reason makes people vulnerable.

All this suggests some hard questions: How can a whistleblower work as before with people whose loyalty he no longer shares? How can coworkers treat him as they did before when he is no longer quite one of them? How can he hope for promotion, or even retention, in an organization in which he can put no trust, in which he has no friends, and for which he is likely to make further trouble? These are questions a law cannot answer.

Helping the Whistleblower and the Organization

What then can be done for whistleblowers? One option is to find them other jobs. That is not easy. Potential employers generally shun known whistleblowers. Then, too, the whistleblower may not be as good an interviewee as before. Many whistleblowers seem to signal the bad news even when they do their best to conceal it. They may, for example, sound emotionally exhausted, ask questions that suggest distrust, or just seem prickly. They are like people going through a bad divorce.

Because few potential employers want someone else's troubles, we must draw this paradoxical conclusion: The whistleblower's best hope for continuing her career may be her old employer. That the old employer may be her best hope is the chief reason to support laws protecting whistleblowers. Though a law can offer the whistleblower little direct protection, it can prod the organization to think about making peace with the whistleblower. This, however, is still a small hope. The organization can make peace with the whistleblower *only if* it can reestablish her loyalty to the organization and her trust in those with whom she must work. That is not easy.

Clearly, the formal organization itself must change enough for the whistleblower to have good reason to believe that she will not have to go out of channels again. The changes probably have to be substantial. Most organizations automatically resist substantial change. But formal changes alone are not enough to reestablish the whistleblower's informal relations with superiors, subordinates, and coworkers. What is needed in addition is something like marriage counseling, group therapy to expose and resolve all the feelings of betrayal, distrust, and rejection whistleblowing inevitably generates. The whistleblower will not be safe until she is reintegrated into the informal organization.

Some government agencies require employees involved in a whistleblowing case to participate in such group therapy. The results so far have not been good. Managers, especially, seem to view such therapy as just one more hoop to jump through on the way to the inevitable. 13 To work, the therapy probably needs to be voluntary for all participants, something not easily legislated.

That is why even this best hope for the whistleblower, reconciliation with the organization, is so small. We need to find better ways to protect whistleblowers. In the long run, peace between the whistleblower and the organization is as good for the organization as for the whistleblower. The whistleblower is not really an enemy. An organization that has whistleblowers needs them. The whistleblower is like the knock at the door that wakes someone in a house on fireunwelcome, but better than sleeping until the fire reaches the bed. An organization that punishes its whistleblowers blinds itself to troubles better faced. So, for example, when the Bay Area Transit Authority (BART) fired three electrical engineers for reporting trouble with the program that was to run its new operatorless trains, it merely turned a technical problem into scandal waiting to happen. When a train jumped the tracks after rushing through a station at which it was supposed to stop, BART had to face the technical problem the engineers had identified, to deal with public concern over the operatorless trains, and to explain why it had ignored the problem until then.

To say that whistleblowers generally tell an organization what it needs to know is not to deny the disadvantages of whistleblowing described earlier but to explain why we should try to make whistleblowing unnecessary rather than try to prevent whistleblowing in other ways. I now turn to the chief means of making whistleblowing unnecessary.

How Organizations can Avoid Whistleblowing

If whistleblowing means that an organization has trouble using bad news, one way for an organization to avoid whistleblowing is to improve its ability to use bad news. We may distinguish three approaches: procedural, educational, and structural.

The "procedural" approach builds invitations to report bad news into the ordinary ways of doing business. These procedures can be quite simple, for example, a space on a form for "disadvantages" or "risks." Such a blank almost forces the person filling out the form to say something negative. Those above him are also more likely to treat bad news reported in this way as part of "doing the job" than they would the same bad news reported without that specific invitation. 14

The first approach also includes more complicated procedures, for example, "review meetings" the purpose of which is to identify problems. The review meeting works like a blank space. When the emphasis is on revealing bad news, more bad news is likely to come out. Revealing bad news is more likely to seem part of the job.

Of course, how things seem is in part a matter of the mental set that the people involved bring to the procedure. That set is determined in large part by what happened in the organization before. Organizational atmosphere can turn any procedure into a mere formality. If, for example, people who fill in the disadvantage blank or speak up at a review meeting are commonly treated like Cleopatra's messenger, the procedures will bring in little bad news. Part of making procedures work is making sure those involved think about them in the right way. That is especially important when the procedures are new and patterns of response have not yet developed.15

In a way, then, my first approach, the procedural, presupposes the two others. Those participating in various procedures need to understand how important bad news can be. They also need regular reminders because everyday experience tends to teach them how much bad news hurts. Education can provide one reminder; a structure of formal incentives can provide another.

I intend "education" to be understood broadly (so broadly in fact that the line between education and formal incentives all but disappears). Training sessions in which superiors or special trainers stress the importance of hearing the worst are only part of what I have in mind. Everyday experience is also part of education. Subordinates are more likely to take the formal training to heart if they are regularly thanked for giving superiors bad news, if they see that bringing bad news is treated much as bringing good news is, and so on.

Superiors are, of course, more likely to treat well those subordinates who bring bad news if the organization makes it rational to do so. But treating such subordinates well is generally rational only if the organization routinely uses bad news in ways that encourage reporting itor, at least, do not discourage reporting it. An organization's ability to do this routinely depends on its structure.

For example, suppose an organization holds a manager responsible only for what gets reported "on her watch." Suppose, too, that her subordinate informs her that her predecessor improved the division's profits by skipping routine maintenance and now much of the machinery is in poor condition. The manager will *not* want to report this to her superiors. She would be bringing news that threatens everyone who must pass it on. She therefore does not want to hear the bad news herself. She has good reason to tell her subordinate, "Let sleeping dogs lie." Perhaps the dogs will not howl until her successor takes over.

Now, suppose instead that the organization has routine ways of assigning responsibility to a manager for what she does while in a position even if the bad consequences only become apparent later. In such an organization, a manager has good reason to want subordinates to report the bad news about her predecessor's work as soon as they learn of it. She need not fear such "sleeping dogs." They will not wake to howl for her blood. And, if she lets them lie, she may later have to explain how *she* could have missed them.

Most organizations tend to treat the person in charge as responsible for whatever bad news he must report. Few have any routine for assigning responsibility to anyone else (perhaps because such a routine would be quite expensive). [16] Hence, in that respect at least, most organizations have structures tending to discourage bad news. Leaving managers in charge for long terms, say, ten or twenty years, would probably compensate for this tendency. Few problems lie dormant that long. Today, however, managers seldom stay in one position for even five years. If they do not rise quickly within an organization, they are likely to move to another. This mobility means that most organizations must rely on other means of giving managers reason to welcome bad news.

The most common approach these days is to create alternative channels for bad news so that no one in an organization is in position to block its flow upward. The oldest of these alternative channels is probably the regular outside audit. Another is an "open door" policy that allows subordinates to go directly to a senior official, bypassing several layers of management. Another is changing the traditional chain of command into something much more like a lattice, so that subordinates have less to fear from any particular superior and have routine access to more than one. (I say more about such arrangements in chapter 9.) Such arrangements give a manager reason to be thankful that he heard the bad news from a subordinate rather than from a superior and reason to try to respond in a way likely to satisfy the subordinate. The subordinate saved the manager from being "blindsided." Such arrangements tend to make whistleblowing unnecessary.

We are now ready to consider how individuals can avoid becoming whistleblowers.

How to Avoid Having to Blow the Whistle

The simplest way to avoid having to blow the whistle may seem to be to join an organization in which whistleblowing will never be necessary. Unfortunately, things are not that simple. Organizations are human contrivances; none is perfect.

Still, organizations differ quite a bit. By choosing the right organization, an individual can substantially reduce the chance that he will have to blow the whistle (much as, it is said, one can reduce substantially the chance of repenting "at leisure" by not "marrying in haste"). The question is how the organization handles bad news. The answer is found in the organization's procedures, educational programs, and structure, not the ones "on paper," of course, but the ones actually in effect. The difference can be crucial. For example, if the organization has an open-door policy, is the door ever used?

Because organizations always work imperfectly, an open door that is never used is probably not an unnecessary channel but one no one dare use. Using such a channel will probably be treated as whistleblowing.

Any organization described as "one happy family" should be examined with special care. Organizations, like families, generally have arguments, tensions, and the like. That is how they grow. The organization that recalls only good times is not the one that had no bad times but the one that has no use for bad news. It is exactly the kind of organization in which whistleblowing is most likely to be necessary. I prefer an organization in which old battles are recalled blow by blow and the general happiness must be inferred from the fact that all participants survived to work together again. [17]

Having chosen the right organization, can an individual do anything more to reduce the chance that he will someday have to blow the whistle? Certainly. But he will have to think in strikingly political terms.

First, he will want to develop his own informal channels to augment formal channels. So, for example, suppose a new engineer W officially reports to A, but B carries more weight with their common superior. W might want to get to know B. Perhaps they share an interest in chess. Once W makes friends with B, W is in position to pass information around A should A try to suppress it. A can hardly object to W playing chess with B. Yet, once A knows W and B are chess buddies, A will be less likely to suppress information W wants passed up. A knows W has a channel around him.

Second, employees should form alliances with colleagues and subordinates, people who share their responsibilities. No one should have to stand alone against a superior. Whenever possible, the superior should have to respond to a common recommendation. Managers are likely to treat a group concern much more seriously than a single individual's. Employees should try to work through groups as much as possible.

Third, however, not any group will do. The group should be sensitive to the moral concerns likely to force an individual to blow the whistle. The organizations most in need of whistleblowers are also most likely to be so organized that employees become morally less sensitive the longer they work for the organization. [18] So, an individual hoping to avoid whistleblowing probably should cultivate the moral sensitivity of potential allies. There are many ways to do this. The simplest is to bring in items from the newspaper raising problems similar to those the organization could face and pass them around at lunch, asking how "we" could handle them. If potential allies share the same profession, they might try getting the local professional society to host discussions dealing with the ethical problems that come up in work they do.[19]

Fourth, but not least, an individual hoping to avoid whistleblowing needs to cultivate his own ability to present bad news in a way most likely to get a favorable response. Part of doing this, of course, is presenting the information clearly, with enough technical detail and supporting evidence. But there is more to it than that. Some people become whistleblowers for lack of a pungent phrase.[20] A master of words is less likely to have to blow the whistle than someone who, though understanding a peril, has trouble communicating it.

That is not all. Presenting bad news in a way likely to get a favorable response also includes what used to be called rhetoric. A little sugar helps the medicine go down. Is there a good side to the bad news? If so, why not present that first? If there is no good side, how about presenting the bad news in a way likely to bring out the personal stake the decision maker has in responding favorably? Such tactics are usually not mentioned in a discussion of whistleblowing. Yet, it seems to me, many people end up as whistleblowers because they did not pay enough attention to the feelings of their audience.

Those who have substantial say in how an organization runs might, then, want to consider some educational programs that our earlier discussion did not. In particular, they might want to consider training employees in such political skills as how to present bad news effectively and how to maneuver it through channels. They also might want to review their hiring practices. For example, will the personnel office reject an applicant who asks whether the company has an open-door policy, treat such a question with indifference, or consider it as a plus? Any organization that does not treat such questions as a plus will not select *for* people with skills needed to make whistleblowing unnecessary.

Concluding Remarks

The world can be a hard place. Individuals can do everything in their power and still end up having to choose between blowing the whistle and sitting by while innocent people suffer an injustice that can be prevented. Whistleblowers are tragic characters. Their decency pushes them to bring great suffering on themselves and those about whom they care most. Their only alternative, sitting by, would save from harm those about whom they care mostbut at an incalculable cost (failing to do what they have a duty to do). Their organization will probably be better off in the long runif it survives. But, in the short run, it too will suffer.

When events leave only this choice, most of usat least when we are not directly involvedwould hope the individual on whom that choice is forced will find the strength to blow the whistle. Heroism is the best we can hope for then. But, looking up from this chain of unhappy events, we can see how much better off everyone would have been had heroism been unnecessary. That is why I focus on making whistleblowing unnecessary.

PART III
PROTECTING ENGINEERING JUDGMENT

Until recently, no texts concerned with the engineering profession devoted significant space to conflict of interest. Perhaps that was because the topic struck most text writers as foreign to engineering, as a subject belonging to business ethics rather than to the ethics of a profession concerned with shaping the material world. Yet, conflicts of interest turn up in engineering quite often. All engineers must exercise professional judgment on behalf of a client or employer; indeed, there is little to engineering beside the exercise of engineering judgment. Insofar as conflicts of interest (those tugs, whether of desire or duty, that tend to bias professional judgment) undermine the reliability of engineering judgment, conflicts of interest threaten the utility of engineering. Unnoticed, conflicts of interest can interfere in ways both subtle and gross with the ability of engineers to do what they should.

The two chapters in this part approach the subject of conflict of interest in quite different ways. Chapter 7 examines an important case of conflict of interest, bringing out the relevant principles and discussing their importance for engineers as professionals *and* as moral agents. The case is an absorbing cautionary tale. It is, however, given pride of place for two other reasons. First, we know more about it than we know, or are likely to know, about most other instances of conflict of interest in engineering. Second, it reveals something of the role professional societies have in both the practice of engineering and the control of technology. Along the way, it offers occasions to think more about the relation between professional ethics and ordinary morality.

Chapter 8 reaches many of the same issues from another perspective, that of an occupation "born" engineering (as we would say after chapter 3). We are invited to consider what its code of ethics should say about conflict of interest, and, indeed about whether it should remain a part of engineering. We have an opportunity to think further about the rationale for controlling conflict of interest in engineering, about how much freedom a profession has when writing a code of ethics, about what considerations are relevant to writing a code, and about what the relation is between the code and a profession.

7
Conflicts of Interest in Engineering

On May 17, 1982, the United States Supreme Court upheld a civil judgment against the American Society of Mechanical Engineers (ASME) for violating the Sherman Anti-Trust Act. 1 *ASME v. Hydrolevel* (*Hydrolevel* as the case is commonly called) may be to engineering ethics what Watergate was to legal ethics. Most of the individuals involved were engineers, persons who held high office in industry and in ASME. Some may in fact have engaged in conduct they knew to be unlawful. Certainly it was widely believed that they did. But the special interest of *Hydrolevel* here is that there was something seriously wrong with the way the principals conducted themselves, supposing (as all claimed) that each acted with the best motives and without realizing that what he was doing was wrong. Whatever else *Hydrolevel* is, it is a case of conflict of interest in engineering. To understand what the principals did wrong (even if they acted with the best motives) is to understand much about conflict of interest and engineering.

Hydrolevel: the Facts

On April 12, 1971, ASME received an inquiry concerning a forty-three-word paragraph in its eighteen-thousand-page "Boiler and Pressure Vessel code." The code is one of about four hundred model standards that ASME maintains. While only advisory, these standards have a powerful influence. Federal regulations have incorporated many of them by reference, as have many cities, states, and Canadian provinces. Because of the influence and complexity of the codes, it is often necessary to have them interpreted. ASME responds to at least ten thousand requests for interpretation each year. Like the codes themselves, these interpretations are only advisory.[2]

The inquiry concerned paragraph HG-605a, which provides in part: "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." [3] The purpose of the paragraph is to prevent the "dry firing" that can damage (or even cause an explosion of) a boiler with too little water in it. The inquiry came from McDonnell and Miller, Inc. of Chicago (M&M), which had for decades dominated the market for low-water fuel cutoffs. The inquiry simply asked, "Is it permissible to incorporate a time-delay feature in the cutoff so that it will operate after the boiler water level reaches some point below the visible range of the gauge glass?"[4]

The inquiry was signed by Eugene Mitchell, M&M vice president for sales. Mitchell made the inquiry because a competing firm, Hydrolevel Corporation of Farmington, New York (Hydrolevel), had entered the low-water cutoff market a few years before with a cutoff that included a time delay and early in 1971 had won a contract from the Brooklyn Gas Company, an important M&M customer. If ordinary use of Hydrolevel's time-delay cutoff was consistent with ASME safety standards (and it was commonly believed to be consistent), M&M might well lose its predominance in the market. If, however, there was even a little doubt about the safety of Hydrolevel's cutoff, M&M sales staff could easily protect M&M's share of the market. Mitchell knew that Hydrolevel's cutoff *could* be installed safely. But he also thought the cutoff could not be installed to cut off before the water level fell below the visible range of the gauge glass without being positioned much higher than other cutoffs.[5] The unusual position would itself introduce unattractive complexity into Hydrolevel's marketing (because installers would put a new gauge exactly where the old gauge was unless they were carefully instructed to put it someplace else). If Mitchell could get ASME to say that HG-605a meant that the water level in the gauge could not drop from sight without *immediately* triggering a fuel cutoff, M&M sales staff could argue that the Hydrolevel cutoff would violate ASME standards if positioned in the ordinary way. They might also argue that it would violate ASME standards wherever positioned. The same sixty-second delay that could prevent unnecessary cutoffs could, it seemed to Mitchell, also allow a hot and suddenly almost waterless boiler to crack or explode.

Mitchell discussed this sales strategy several times with John W. James, M&M's vice president for research. James had been a member of the ASME subcommittee responsible for heating boilers (the "Heating Boiler Subcommittee of the Boiler and Pressure Vessel Committee") since 1950 and also had a leading part a few years before in rewriting the code of which HG-605a was part. James suggested a meeting with T.R. Hardin, chair of the Heating Boiler Subcommittee. The meeting occurred in late March 1971. Hardin (in town for other business) came by the M&M office and the three (along with M&M's president) went to dinner. During dinner, Mitchell asked Hardin about HG-605a. Hardin answered that he believed it meant what it said: The water level should not drop from sight without triggering the cutoff immediately. Soon after that meeting James drafted a letter of inquiry to ASME, sending a copy to Hardin, who made some suggestions that were incorporated into the final draft.

The inquiry was addressed to W. Bradford Hoyt, secretary of the Boiler and Pressure Vessel Committee. Hoyt treated it as a routine inquiry, directing it to the appropriate subcommittee's chair, T.R. Hardin. Hardin then prepared a response without referring his action to the whole subcommittee for approval. He was entitled to do this provided the response was treated as an "unofficial communication." Hoyt signed the unofficial communication that Hardin drafted and sent it out on ASME stationery. That letter, dated April 29, 1971, advised that a low water cutoff must "operate immediately" when the water level falls below the lowest visible point of the gauge glass and that a cutoff with a time delay gave "no positive assurance that the boiler water level would not fall to a dangerous point during a time delay period." 6 Although the response did not say that Hydrolevel's time delay was dangerous, that was a plausible inference. M&M used the ASME letter to discourage potential customers from buying Hydrolevel's cutoff. The strategy seemed to work.

Hydrolevel learned of the ASME letter early in 1972 through a former customer and immediately requested a copy from ASME. This was duly sent on February 8, 1972, the name of the inquirer (Mitchell) being omitted as ASME policy required (to preserve confidentiality).

Hydrolevel was, of course, not happy with the interpretation. On March 23, Hydrolevel wrote Hoyt a nine-page letter explaining why ASME should change its ruling. Hoyt sent Hydrolevel's request to the Heating Boiler Subcommittee. On May 4, the subcommittee voted to confirm the intent of the original response. James, who by then had replaced Hardin as chair of the subcommittee, abstained from participation in the subcommittee deliberations on that question but reported the vote to the Boiler and Pressure Vessel Committee. The full committee voted to send Hydrolevel an "official communication." Dated June 9, 1972, it "confirmed the intent" of the letter of April 29, 1971, but advised Hydrolevel that, although cutoffs with time delay were *not* expressly forbidden, they had to be positioned to cut off before the water level fell from sight.[7] While James did not participate when his committee decided how to respond to Hydrolevel, he did (at the drafting committee's request) help to draft a critical sentence of that response.[8]

Hydrolevel found the response insufficient to permit it to compete successfully with M&M. There still seemed to be doubt about the safety of Hydrolevel's low-water cutoff.

That is where events stood for two years. Then, on July 9, 1974, the *Wall Street Journal* published an article describing Hydrolevel's difficulty trying to sell a fuel cutoff many in the industry thought to be in violation of ASME's code. The article suggested "close ties between a dominant company in an industry and the professional society that serves as its watchdog." The only close tie the article noted was that James, an M&M vice president, was vice chair of the appropriate ASME subcommittee when M&M made its original inquiry and chief drafter of the code involved.[9]

The article produced an uproar within ASME. For example, the vice president of ASME's Region 11 wrote: "If the facts are as stated in the article, it would seem that Mr. James should not only be relieved of his duties on the Board of Codes Committee but he should also be kicked out of ASME for unethical conduct." [10] ASME's Professional Practices Committee then investigated, found nothing improper or unethical in James' conduct, and commended him for conducting himself in a forthright manner as chair of his subcommittee. But the Professional Practices Committee did not have all the facts. James did not inform the Committee of his meeting in Chicago with Hardin, of his (or Hardin's) part in drafting the original inquiry, or of his part in drafting the June 9 response to Hydrolevel. None of this came out until March 1975 during hearings before the Senate's Subcommittee on Antitrust and Monopoly.[11] Hydrolevel filed suit a few months after those hearings, charging M&M, ASME, and Hardin's employer, Hartford Boiler Inspection and Insurance Company, with unlawful restraint of trade.

Names to Remember

Hardin	Chair of Heating Boiler Subcommittee (of ASME Boiler and Pressure Vessel Committee and vice president of Hartford Boiler Inspection and Insurance Company.
Hoyt	Secretary of ASME Boiler and Pressure Vessel Committee, in charge of correspondence for that committee and its subcommittees.
Hydrolevel	Hydrolevel Corporation of Farmington, New York, the company M&M wanted to put out of business, the plaintiff in *Hydrolevel*, the legal case.
James	M&M vice president for research, a drafter of relevant sections of the Boiler and Pressure Vessel code, vice chair of Heating Boiler Subcommittee when Hardin was chair, and chair of that subcommittee after Hardin retired.
M&M	McDonnell and Miller, Inc. of Chicago, makers of the

	low-water cutoff dominating the market before the entry of Hydrolevel's time-delay cutoff.
Mitchell	M&M vice president for sales.

What Did they do Wrong?

Assuming that Hardin and James acted from honest motives,[12] what, if anything, was morally wrong with what they did? There are at least three ways we might try to answer that question.

One way would point to the consequences of what Hardin and James did. For example, they might have driven Hydrolevel out of business or prevented an improvement in boiler safety. Let us call this way of explaining what makes an act wrong consequentialist.

A second way to explain what makes an act wrong would be to point to a violation of some social rule, for example, to the violation of an ASME procedure or federal law. We might call this way of explaining what makes an act wrong moral relativism (because it makes the act's moral rightness or wrongness entirely relative to how *social* roles happen to be defined).

A third way to explain what makes an act wrong is to point to something about the act itself (given the context in question) that makes the act objectionable whatever its actual or probable consequences and whether any social rule permits it. For example, an act might be morally wrong simply because it is an instance of lying or a betrayal of trust. This way of answering our question is sometimes called "moral absolutism" because the answer is not relative to this or that social rule. But it is probably less misleading to call it duty-based (or "deontological") because it relies on considerations of *duty* directly (even though the duties may themselves be defended in part at least by appeal to the overall consequences of having such duties). These duties are sometimes called natural (or "absolute") to distinguish them from the "conventional" (or "relative") duties imposed by law or other merely social rules. [13]

Which of these three ways of explaining why an act is wrong should we employ to determine what, if anything, Hardin and James did wrong? Let us consider them one at a time.

Consequences

What Hardin and James did certainly had consequences. For example, M&M printed ASME's April 29 response in a booklet entitled "The OppositionWho They Are, How to Beat Them." The booklet, distributed to sales staff late in 1971, included a message from Mitchell describing Hydrolevel's time-delay cutoff and stating that such a device "would defeat the intent of the ASME code and this should definitely be brought to the attention of anyone considering a device which included a time delay in the low water cutoff circuitry."[14] The ASME letter gave legitimacy to Mitchell's opinion and seems to have had much to do with driving Hydrolevel out of business.[15]

So, on the one hand, what Hardin and James did had some bad consequences. Their acts helped to drive Hydrolevel out of business, and that was bad for Hydrolevel. On the other hand, what they did helped M&M keep its share of the cutoff market and that was certainly good for M&M. But the evaluation of consequences cannot end with that. The consequences of what Hardin and James did went on. Hydrolevel sued. M&M settled out of court for $750,000. Hartford also settled. It paid Hydrolevel $75,000. ASME went to trial and lost. The judgment against ASME*$7,500,000*was equal to three-fourths of its annual budget. That litigation was bad for M&M, Hartford, and ASME but good for Hydrolevel. ASME appealed, lost on the decision but won rehearing on the damages. The case was settled when ASME agreed to $4,750,000 in damages.[16] In the end, Hydrolevel (or rather its owners) may have gained more than it lost (ignoring substantial attorney's fees). Its winnings in court amounted to far more than its profits over a decade. But how should we balance all these good and bad consequences to decide whether what Hardin and James did was right? Do they merely balance out (because one side's loss seems to be another's gain)? Or do they total up to a bad outcome overall? Or to a good one? Consequentialism requires some method of balancing consequences one against another to reach an overall evaluation. What method should we use?

Might other consequences let us get around this problem of method? Certainly. For example, driving Hydrolevel out of business *might* have suppressed a new boiler cutoff which, if widely used, would have reduced boiler explosions and otherwise improved boiler operation (for example, by reducing unnecessary boiler shutoffs).

Driving Hydrolevel out of business would then have had consequences so bad that few people would think they could be outweighed by any advantage to M&M or Hydrolevel.

Was Hydrolevel's cutoff that much better than M&M's? If that is the sort of question we must answer before we can say what was wrong with what Hardin and James did, we cannot say what was wrong with what they did. We do not have the answer and we are not likely to get it. Laboratory tests are only suggestive and we are not likely to have a good "field test" now.

So, any decision we make based on the consequences of Hydrolevel's demise must rely either on educated opinion or on something less reliable. Educated opinion is the judgment of those whose experience and learning make them relatively reliable guides in answering questions of the sort posed. Educated opinion seems to be divided. Both Hydrolevel and ASME had outside experts at trial, some testifying to the superiority of Hydrolevel's cutoff, others testifying to the possible dangers of its use. [17] When outside experts disagree, we naturally turn to some body of experts capable of sorting out the opinions of individuals and arriving in that way at an authoritative consensus. Because our concern here is boiler safety, the natural place for us to turn for such an authoritative statement on boiler safety would, of course, be ASME's boiler code and the committee with authority to interpret it. Unfortunately, that code and committee are part of our problem.

But there is one more alternative to consider. The market itself is a possible source of the information we need. Victory in a free market is good evidence that the victorious product is better than its competitors (and victory in a perfect market, decisive evidence).

M&M's victory over Hydrolevel is, however, not good evidence that M&M's cutoff was safer than Hydrolevel's. There are two reasons for this. First, the market measures overall value, not safety, as a distinct factor. One product might be less safe than another but sell better for other reasons, for example, because its low cost more than pays for the higher insurance premiums its use entails. Second, Hydrolevel in effect charged that M&M used unfair means to win its victory. If M&M did rig the market, the market cannot tell us even whether M&M's cutoff was better than Hydrolevel's overall. The verdict of this market may not have been the verdict of a *free* market. Did M&M rig the market? We don't know. If ASME's letter of April 29 was a sensible reading of the code and the code itself was correct, then M&M's use of that letter to discredit Hydrolevel would not have been unfair (unless there was something wrong with the *way* M&M obtained the letter). All else equal, information should not distort the market.[18]

So, it seems, we cannot make a reliable judgment that Hydrolevel's demise served or disserved the public good. If we cannot do that, we cannot make a reliable judgment that overall, the consequences of ASME's response of April 29, 1971, and June 9, 1972, were bad (or good). Without such a judgment, we cannot provide an appealing consequentialist explanation of what was wrong with what Hardin and James did. So, if we are to explain what was wrong with what Hardin and James did, we must, it seems, do it by showing that they violated a social rule or that they failed to act in accordance with some natural duty.

Social Rules and Individual Conscience

"Rule" (as used here) includes standards of conduct evident from practice (that is, so-called unwritten rules) as well as those standards expressly adopted. A "social rule" is a rule that may vary from one society to another just because one society chooses one rule while another society chooses another rule. (I reserve the term "moral rule" for rules that do not vary in this way.) We can distinguish at least three sorts of social rules Hardin or James might have violated: (1) ASME rules, (2) rules governing all engineers (in the United States), or (3) federal law. Let us consider each possibility one at a time.

ASME Rules

Did Hardin or James violate any ASME rule? Hardin did meet with M&M executives to discuss a question likely to come before him as chair of the Heating Boiler Sub-committee. Indeed, he expressed his opinion on the question and helped draft an inquiry to obtain that opinion from ASME. The Senate subcommittee investigating the Hydrolevel case found that objectionable. But ASME officials did not. For example, Melvin R. Green, managing director of the Research Codes and Standards Section of ASME, defended what Hardin did in this way:

> I think you must recognize that you are trying to get words in a letter, so that you clarify a provision in the code. And to get the proper words, I do not really see that there was anything wrong with that, because I, when I was secretary of the Boiler and Pressure Vessel Committee, had people who would telephone inquiries to me and they would sayI would give an answer on the telephone and then they would say, "Well, how can I get this in writing?" I would suggest the

> wording for the inquiry, so that they could get the response to clarify that particular part of the code. 19

So, Hardin's meeting with M&M executives and his help in drafting the inquiry to his own committee may not have violated an express or tacit ASME rule. Indeed, they seem to fit in with ASME's ordinary procedures.

Hardin's other acts also seem to be consistent with ASME rules. As noted earlier, Hardin was entitled to answer M&M's inquiry if he thought it sufficiently routine (provided his response was treated as an "unofficial communication"). He apparently thought the inquiry was sufficiently routine, a case of the code meaning just what it said.20 And it is not clear even now that he was wrong to think so. The Heating Boiler Subcommittee and the entire Boiler and Pressure Vessel Committee later "confirmed the intent" of his original response. Hardin treated the response as an unofficial communication just as ASME rules required.

Hardin did not, it is true, reveal to the Professional Practices Committee his meeting with M&M executives or his part in drafting the inquiry. We do not know why he did not. The most favorable explanation is that he was not asked directly and did not see why he should raise the matter himself. If ordinary ASME procedure was as Green indicates, the Professional Practices Committee would not have cared what part Hardin had in drafting the original inquiry (and so, they probably would not have found that revelation worth the trouble of a hearing). Indeed, Green told the Senate subcommittee that he considered Hardin's conduct perfectly ethical, even taking into account what the subcommittee uncovered. 21

ASME rules seem to be equally kind to what James did. Green defended James's self-effacing part in drafting the April 12 inquiry in this way:

> Well, here again, I think you must understand the voluntary standard system. Many people, who serve a great deal of their time in a code activity, try to identify themselves with the code activity. And there is another part [of their life] where they would be in the Government or employed by industry. If they have [to make] an inquiry from the Government agency or that company, they will have an associate within the [agency or] company, who will sign the inquiry and send it to us. . . . [It] is just a matter of trying to keep their house in order.22

In other words, having someone else sign the letter was James's way of keeping his work on the Heating Boiler Subcommittee distinct from his work at M&M. That he wrote the inquiry should be irrelevant to the response it received. If signed by Mitchell, the inquiry would not have the authority that might come from having the name of the subcommittee's vice chair subscribed to it. *Should* James have signed the inquiry? Nothing in ASME rules required him to. Indeed, Green makes it sound as if ASME practice would have condemned James for signing the inquiry had he done so. James would not have "kept his house in order." So, even according to ASME practice, there was no reason for James to inform ASME's Professional Practices Committee of his part in drafting the original letter.

What about James's part in drafting the official ASME communication of June 9, 1972? Again, James seems to have done as ASME rules allowed. A subcommittee chair would *not* normally step down even though he helped to draft the inquiry the response to which was under review (and, it seems, even though he worked for a company that had an interest in the outcome). According to Hoyt, James stepped down *only* because Hydrolevel's letter to ASME complained that ASME seemed to be out to destroy a new product. That James should help draft the June 9 response to Hydrolevel was, Hoyt said, "perfectly normal because the chairman is in the best position, on the basis of experience, to know what the intent of his subcommittee is."[23] James was "merely trying to be helpful in selecting words that would be appropriate to clarify the subject."[24] Green concurred. As far as he was concerned, there was nothing in what James did contrary to ASME practice.[25]

NSPE Code of Ethics

That Hardin and James did not violate any ASME rule does not mean that they did what was professionally proper. As engineers, their conduct is also subject to evaluation under the code of Ethics of the National Society of Professional Engineersat least insofar as the code itself expresses a well-articulated standard of conduct for engineers. (ASME, like many other engineering societies, also has a code of ethics of its own, basically, the ABET code, but at the time that code also lacked a general provision concerning conflict of interest and its interpretation of the provisions it had did not differ from the NSPE's.) A cursory reading of the NSPE code may indicate that Hardin or James violated several provisions.[26] But a closer reading makes everything much less clear. Let us consider those potentially relevant provisions one at a time beginning with the most specific.

"Faithful Agent."

The Senate subcommittee investigating the Hydrolevel complaint suggested that Hardin and James each did something wrong because each had a conflict of interest that should have stopped him from doing what he did. A federal court of appeals made the same point. [27] Section III.5 of the NSPE code of ethics specifically discusses "conflicting interests." "Engineers shall not," it says, "be influenced in their professional duties by conflicting interests." This *seems* clear enough, but the only examples the code gives of such conflicting interests are (1) accepting "financial or other considerations, including free engineering designs, from material or equipment suppliers for specifying their products," and (2) accepting "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." So, if this is all NSPE means by conflicting interests, neither Hardin nor James had a conflict of interest. They accepted no consideration from material or equipment suppliers for specifying their product. They also accepted no commission in connection with work for which they were responsible. Is there any reason to limit the term "conflicting interest" (or "conflict of interest") to cases like those expressly listed in section III.5? Well, that depends on considerations beyond the mere letter of this section, doesn't it? We must look further.

Section II.4 also deals with matters most people would think involve conflicts of interest. "Engineers shall," it says, "act in professional matters for each employer or client as faithful agents or trustees." Would a "faithful" agent or trustee allow himself to act as Hardin or James did? There are really three questions here. First, can one be a faithful agent or trustee and yet have a conflict of interest of the sort Hardin or James had? (Of course, we haven't yet concluded that Hardin or James had any conflict of interest as the code of ethics defines that term.) Second, how would a faithful agent or trustee act if he had such a conflict? And, third, did Hardin or James act differently?

Section II.4(a) provides at least a partial answer to the first two of these three questions. "Engineers shall," it says, "disclose all known or potential conflicts of interest to their employers or clients by promptly informing them of any business association, interest, or other circumstance which would influence or appear to influence their judgment or the quality of their services." Section II.4(a) thus understands the term "conflict of interest" to include more than the two examples of conflicting interests mentioned under section III.5. A conflict of interest can, it seems, be *any* business association, interest, or other circumstance that *could* influence or even just *appear* to influence an engineer's judgment or the quality of his service. Both Hardin and James had conflicts of interest in this sense. That Hardin gave his opinion on the cutoff inquiry informally (and perhaps without due consideration) *could* reasonably be supposed to have influenced his judgment when he later actually undertook to respond more formally (and, because that can reasonably be supposed, there is at least an *appearance* of such influence). Similarly, James could not be certain that his contribution to the ASME letter of June 9, 1972, was not influenced in part by how the exact wording seemed to affect his company's prosperity. 28

Section II.4(a) does not, however, rule out conflicts of interest. All it requires is that a faithful agent or trustee *disclose* any conflict he has to his employer or client. A faithful agent or trustee may have a conflict of interest and still be faithful, but only if he discloses the conflict to his employer or client.

What then can we conclude from the rules? Neither Hardin nor James seems to have concealed any conflict of interest from their respective employer (M&M and Hartford). Both, it is true, concealed conflicts from ASME (or, at least, failed to disclose them to anyone at ASME). So, section II.4(a)and section II.4 itselfwould condemn both Hardin and James if, but *only* if, serving as a volunteer on an ASME committee constituted "acting in professional matters" *and* ASME was their "employer" or "client." Is it proper to interpret "professional matters" to include working as an unpaid volunteer for an engineering society? (Must not a professional be paid if he is to act as a professional?) Is it proper to interpret "employer" or (more likely) "client" to include ASME?

The code provides little help with these questions. Among the other examples of being a "faithful agent and trustee" listed under section II.4 only two seem worth noting. Section II.4(d) provides that "engineers in public service as members, advisors, or employees of a 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." Section II.4(e) adds that "engineers shall not solicit or accept a professional contract from a governmental body on which a principal officer of their organization serves as member." There is nothing under section II.4 about professional societies or other *non*governmental bodies.

Only one conclusion of interest to us seems to follow from these two examples of being a faithful agent or trustee. There *may* be enough of a distinction between "employer" and "client" so that ASME could reasonably be thought Hardin's or James's "client" (even though ASME could *not* be the employer of either in any but the most strained sense). Though section III.4 itself only refers to "employer or client," (d) refers to "service" as a "member" of a governmental body or as an "advisor" (as well as of "service" as a governmental "employee"). So, if an engineer is a member of a governmental body (or even an unpaid advisor of one), the body might be his "client" (in the appropriate sense) even though he is not being employedthat is, paidas an engineer. On the other hand, the section can also be read so that "client" is just another word for "employer" or at most for someone whom an engineer is *paid* to serve in some professional capacity (for example, when serving the customer of his employer).

Section III.4(e) does not clarify which interpretation is intended. According to (e), an engineer does something wrong if he solicits or accepts a professional contract from a governmental body on which he serves. But the section does not tell us why that would be wrong. There are at least two reasons why soliciting or accepting such contracts might be wrong. The reasons point to different interpretations of "client." One reason soliciting or accepting such contracts might be wrong is that the engineer would fail to be a faithful agent or trustee of the *government* in question. He would have taken advantage of someone, the government, that is already his client (because

he is serving on one of its bodies). The other reason soliciting or accepting such contracts on behalf of a client might be wrong is that an engineer cannot be a faithful agent or trustee of a *private* client he is working for if he risks getting that client into trouble by obtaining governmental contracts for the client through misuse of his public trust. Section III.4(e) does not help us to understand whether just any service on a governmental bodyand so, by analogy, on an ASME committee*is* acting in a "professional matter" (so that the duty to act as a faithful agent or trustee applies at all). For example, is helping one's committee draft a letter a case of acting in a *professional* matter?

Miscellaneous Provisions.

Three other seemingly promising provisions of the code turn out to be even less helpful. Section II.3(c) provides that "engineers shall issue no statements, criticisms or arguments on technical matters which 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." This section would certainly condemn what Hardin and James did if, for example, Hardin responded as he did in part because he hoped to benefit his employer (or because he hoped to postpone his own overdue retirement from M&M by proving himself especially useful). The statements Hardin and James made would then have been "inspired" (if not exactly "paid for") by interested parties they had not explicitly identified. *We* are, however, assuming that both Hardin and James acted from the best motives, that is, that the acts in question were not paid for by an interested party or inspired by anything but concern for the public safety and welfare. So, section II.3(c) cannot help us decide what was wrong with what Hardin or James did.

Section III.1 may, in contrast, seem likely to be more helpful just because it is more general. "Engineers shall," it says, "be guided in all their professional relations by the highest standards of integrity." Section III.1(f) gives as an example of being so guided that "engineers shall avoid any act tending to promote their own interests at the expense of the dignity and integrity of the profession." These two sections seem promising because, if Hardin and James *improperly* misled others about their intentions, their interest in M&M's inquiry, or their part in ASME's response, they could not have been guided by the "highest standards of integrity." If, in addition, they did all that to endear themselves to their respective employers, they would also have promoted their own interests at the expense of ASME and so at the expense of the profession as a whole. If, however, what Hardin and James did was not "improper," their acts could still be consistent with the "highest standards of integrity" and so not something the code of ethics condemns. So, were their acts proper or improper? That depends on what the "highest standards of integrity" are. We must look elsewhere in the code for guidance concerning that.

Section III.3(a) may seem to provide such guidance. This section provides that "engineers shall avoid the use of statements containing a material misrepresentation of fact or omitting a material fact necessary to keep statements from being misleading." Hardin and James both omitted statements of fact necessary to keep others (for example, the Professional Practices Committee) from drawing false conclusions (for example, that Hardin had no part in drafting the original inquiry or that James had no part in drafting the response of June 9, 1972). But were these facts "material"; that is, were they facts that should have been revealed to keep others from drawing conclusions they had a right to be protected against (for example, the conclusion that Hardin or James had acted properly when in fact they had not)? Well, that depends on what the ultimate conclusion should have been, doesn't it? If, for example, Hardin and James would have been judged to have acted just as properly had all the facts they failed to reveal been revealed, would we consider those unrevealed facts "material"? It seems not. So, it seems we cannot know that their conduct fell below "the highest standards of integrity" until we know whether what they did was proper. Appeal to the NSPE code thus seems to lead us to a dead end just as appeal to actual or probable consequences did.

But that is not quite true. We have one turn yet to take. Written rules are seldom self-interpreting. We must bring to the "letter" of a rule an understanding of the "spirit"that is, the underlying purposes, policies, and principles that provide a context we can use to understand what the rule is supposed to do. For example, to understand what is ruled out by a general prohibition of "conflicting interests," we need to know what the community that prohibited such interests means by the term. We also need to know what reasons it had for such a prohibition and how the rule would have to be interpreted to do what the community wants done.

BER as Authority.

Where then should we go for help with interpreting the NSPE code of ethics? One place is NSPE's Board of Ethical Review (BER).

That brings us to the most difficult problem generated by trying to provide a relativist explanation of what makes an act wrong. What if we do not find the BER's interpretation convincing? What if we think engineers should *not* do as the BER says they should? Are we necessarily wrong either about what the code says or about what engineers should do? The relativist answer is plain. If what makes an act right is that it is permitted or required by the appropriate social rule, and if the appropriate social rule means what those with authority to interpret it say it means, then of course, we *must* be wrong if we disagree with the BER's interpretation of the code. 29 The BER has authority to interpret the code (because the NSPE gave the BER that authority). We are disagreeing with those who speak for the society in question.

So, here is the problem with moral relativism. Certainly it seems that the BER (or even the NSPE as a whole) can be wrong. The BER might, for example, issue an opinion interpreting the code in a certain way. Everyone might agree that this is in fact how the code should be interpreted if, say, "read strictly." Yet a majority of the society might think that the code should *not* be read strictly in cases of this sort. The BER itself might eventually change its mind about how the code should be interpreted (or undergo a change of membership leading to a changed interpretation). And even if the BER did not change its interpretation, the NSPE might itself change the code to prevent such "strict" interpretation. Now, if the BER (or NSPE) can be wrong about what engineers should do, there must be a standard of what engineers should do beyond what the BER (or NSPE) says, some standard of right action for engineers beyond what this or that engineering society happens to say. What might that standard be?

Conscience as Authority.

One answer often given is "individual conscience." We have, it is said, an inborn sense of right and wrong. We need only be "true to ourselves" to do right. We must do what we "feel" to be right whatever anyone else thinks. That is all we can require of ourselves and all we should require of one another. The right act is, it is said, simply that act the individual feels to be right.

Though this appeal to individual conscience may appear the very opposite of appeal to social rules, it really is similar. If the appeal to social rules for a standard of rightness can accurately be described as group-centered moral relativism, this appeal to individual conscience might, with equal accuracy, be called individual-centered moral relativism.

Individual-centered moral relativism (or "subjectivism") is not without attractions. We all recognize that individuals are beings not to be operated entirely from the outside. Each must do what *she* chooses, and each should choose by her own standards. What right have we to ask a person to do other than she thinks right? We often go out of our way to respect each other's moral integrity. We sometimes let others do what we think wrong because each "has a right" to act on her own conception of the good. We sometimes even excuse wrong acts because the person who did them "meant well." Nevertheless, there are at least two reasons to reject individual conscience as the *ultimate* standard of moral right and wrong.

One reason for rejecting individual-centered moral relativism is that such relativism makes it impossible for an individual to do wrong as long as he feels that what he is doing is right. The distinction between an act appearing right (to the actor) and its being right dissolves if the ultimate standard of right and wrong becomes how the act appears to the actor, how he "feels" about it. That someone feels no horror at the prospect of committing murder, no remorse or regret afterward, would (according to individual-centered relativism) be enough to show that he did not do wrong. A person's moral insensitivity would be a guarantee of the propriety of what he did. That certainly seems inconsistent with our understanding of moral right and wrong.

The other reason for rejecting individual-centered relativism is related to this first one. We began this chapter by assuming that all the engineers involved in *Hydrolevel* acted from honest motives, that all of them felt that what they were doing was right. There is no evidence that any of them had a pang of conscience beforehand or experienced any remorse afterward. If we accepted individual-centered moral relativism, we would have to agree that Melvin Green's concluding remarks to the Senate subcommittee constituted the last word on the professional propriety of what Hardin and James did. "Every professional works by a canon of ethics," he explained, "and I think it is up to the professional who is serving in that position at that time to make this kind of judgment." 30 Hardin and James made their judgment and (according to Green) that is all we can require of them.

Individual-centered relativism thus cuts off ethical discussion as soon as it begins. As long as Hardin and James acted in a way they judged best, there is nothing to criticize in what they did. Indeed, even if they asked *in advance* what to do, the best advice anyone could give them would be to do what they felt proper, whatever that might be. Telling them any more would be telling them what *we* should do were we in their place, not what *they* should do. Individual-centered moral relativism makes most reasoning about moral right and wrong a lonely and pointless activity. The work of the BERindeed, the work of all those who advise others what to docould be helpful only insofar as it helps the individual to reach some judgment, whatever it might be. One might as well throw dice as ask the BER. That also seems inconsistent with our understanding of right and wrong.

Laws

It may seem that these problems of group-centered moral relativism could be resolved simply by appealing from the rules of the NSPE to those of some more inclusive society, for example, the laws of the United States. But that is not so. All the problems simply follow along. The law in question here, the Sherman Anti-Trust Act, prohibits "[*unreasonable*] restraint of trade." "Unreasonable" is a word that leaves plenty of room for the interpretive problems we already encountered in the NSPE code of ethics. Of course, courts do have authority to interpret laws (just as the BER has authority to interpret the code). But, though they have such authority, their interpretation is not necessarily right (no more so than the BER's is). Not only do courts sometimes change their mind and "overturn" precedent, they may also find the rules they laid down repudiated by the legislature. There is nothing unreasonable about telling a court that it made a mistake and should decide differently next time. Nor is there anything unreasonable about telling Congress that it was wrong to pass a certain law. There appear to be standards of right and wrong independent of the particular rules of this or that society, even if the society is a whole nation. If we are to explain what if anything

Hardin and James did wrong, we must eventually appeal to such an independent standard.

Natural Standards

What standard of right and wrong could there be beside social rules? The traditional answer is "rules of reason" (or "natural laws"). What is a rule of reason? For our purposes, the following rough definition will do: A rule of reason is a statement of how one should act that all rational persons support, advocate, endorse, or recognize as somehow binding (or, at least, would recognize as binding if they were to consider the statement *in a certain way,* for example, impartially, in a "cool hour," or at their rational best). There are many such rules. The rules of arithmetic, for example, are rules of reason (as defined here). They state standards every rational person recognizes (or, at least, would recognize if she gave them much thought) as the way to add, subtract, multiply, and divide if she wants to get answers other rational persons can accept as accurate. Rules of prudence, though different from rules of arithmetic, are also rules of reason. Prudence is choosing actions most likely to serve our overall long-term interests. All rational persons recognize their own interests as relevant to determining what to do (relevant but, of course, not necessarily decisive). 31

Rational persons support, advocate, endorse, or recognize rules of reason only because, and only insofar as, there is good reason for so doing. (Acting for good reason is a large part of what it means to be rational.) Thus, another way to understand what a rule of reason is is to understand it as a rule that, all things considered, is better supported by good reasons than any alternative. Rational persons support, advocate, endorse, or recognize certain rules as rules of reason at least in part because the weight of evidence and argument support treating them (rather than any alternative) as binding.

Among rules of reason, the most important for our purposes are moral rules. What is a "moral rule?" A moral rule, let us say, is any rule instructing rational persons how to act, which each rational person would want all others to follow even if their following it meant that he would have to follow it too. [32] Moral rules do not necessarily state what people in fact do (except insofar as they are good people). Moral rules tell us only what rational persons have good reason to want each other to do, what it would be in a rational person's overall interest to have others do whether or not he followed the rules himself. Unlike the rules of arithmetic or prudence, moral rules presuppose that rational persons are able to help or harm one another if they choose. Moral rules lay down requirements for the treatment of others, acts due others as persons, our "natural" duties.[33]

We must, however, be careful to distinguish between the reasons for supporting, advocating, endorsing, or recognizing moral *rules* in general (*their* justification) and what may lead us as individuals to follow or ignore any particular rule (*our* reason or motive for acting as we do). What justifies moral rules is that having them is in everyone's interest. But people may in fact do what morality requires (when they do) for any number of reasons. Some may act as morality requires because they were brought up to do so and doing wrong has no appeal. They act morally because they are of morally good character. Some may act morally because they wish others well. Such persons act morally because they possess the special virtue of altruism or benevolence. Others may do what morality requires because, though tempted to do wrong, they try to do what they believe right (and succeed). Such persons act morally to preserve their moral integrity. Others may do what morality requires because they fear criticism, prison, or divine wrath. Such persons act morally because they are prudent.

Most people probably act morally from a combination of these or other motives. As long as they do what is required (with the appropriate intention), what they do is right and their motive will be relevant only in assessing their character or moral worth. If, however, they do something wrong, their motive may be relevant in another way. "He meant well" cannot justify an act (that is, show it to have been right), but it may provide a reason for not blaming someone as much as would otherwise be appropriate. For example, the man who steals bread to feed his family is still a thief, but he does not deserve as much blame or punishment as the man who steals the same amount to gamble or because he enjoys the thrill of crime. The man who steals bread to feed his family clearly means well in a way the gambler or thrill seeker does not.

Moral rules are, in one sense, absolutethat is, they take precedence over any consideration conflicting with them. But they take precedence only in a sense. They do not take precedence in the sense that they in fact always win out in the deliberations of a rational person. They may not. Winning out in the deliberations of even the most rational person involves considerations other than those that justify moral *rules.* (I may, for example, benefit from breaking my promise to you even though I would suffer were there no general practice of keeping promises. It would then be in my interests both to support promise-keeping in general and to break my promise in this case.) Moral rules also do not take precedence in the sense that reason requires me to do what morality says, whatever other interests are at stake. Reason does not require that. (For example, breaking a morally-binding promiseat great cost to othersis not necessarily irrational even if my only reason for breaking it is that I would suffer somewhat more if I kept it than if I broke it.) Moral rules take precedence over other considerations only in the sense that we want them to win out in general, that we want everyone else to be taught that they should win out all the time, that we would help make them win out by condemning those who do not give them precedence, and so on. Moral rules are, in this sense, absolute almost by definition.

There are, however, also two senses in which moral rules are *not* absolute. They are, first, not absolute in the sense that would be captured by saying that "reason requires" them to take precedence. Reason does not require that much. Moral rules are those rules everyone wants everyone *else* to follow. They are not necessarily the rules any *rational* person, merely because he is rational, wants to follow *himself*. His following them is not itself necessarily desirable (unless he is a person of good character). For example, when I keep an expensive promise I wish I had not made, I ordinarily do it not because it is rational to "want to" but because I "must." Reason requires moral rules to take precedence over other considerations (and so, to be "absolute") only from "the moral point of view." (The moral point of view is the way rational persons must look at things when laying down rules to guide all rational persons in their relations with one another.) The merely prudent person (the person not moved by benevolence or his own moral dignity) may break her promise without being irrationalif she can get away with itthough a person of good character or high purpose may not. Good character or high purpose can change what it is rational to do. [34]

That brings us to the second sense in which moral rules are not absolute. They are not *exceptionless.*[35] The rule "Don't kill" might, for example, better be written "Don't kill except. . . ." Although all rational persons would agree that killing should *in general* be prohibited, few, if any, would agree that *all* killing should be prohibited. Perhaps the easiest exception to justify is killing in self-defense. If the reason we support a general prohibition against killing is that we fear involuntary death at the hands of others, the exception for self-defense might be justified by reasons much like those justifying the general prohibition: An exception for self-defense would in general be invoked only against those breaking the rule against killing, would tend to discourage rule breaking by making rule breaking more risky than it would be if people of good character or moral integrity could not in good conscience kill in self-defense, and would otherwise serve our rational interest in a safe life. Exceptions to moral rules help make it easier to do what is right, heading off possible conflicts between morality and prudence.

Our quest for a standard of right and wrong by which to evaluate what Hardin and James did leads us to ask whether Hardin or James did anything morally wrong. The answer we must now consider is that they did do something morally wrong *because* each had a conflict of interest making it *morally* wrong to do what he did. Because the NSPE code includes a general prohibition of conflicts of interest, justifying that answer in effect provides a moral justification for a certain reading of the code. 36 And because moral considerations take precedence over all others (in the sense explained earlier), that answer would take precedence over those already considered even if they had not proved inconclusive.

What is Morally Wrong with a Conflict of Interest?

Section II.4(a) of the NSPE code of ethics assumes a certain understanding of conflict of interest. Let us begin by trying to make that understanding explicit. The section assumes, on the one hand, that an engineer will be acting for an "employer" or "client" and, on the other, that he will be exercising "judgment" (or providing a "service") of a certain sort the quality of which might be influenced (for the worse) by certain associations, interests, or circumstances. The sort of "judgment" of concern to the code is that judgment (or service) an engineer provides when "acting in a *professional* matter"that is, when exercising the special skills, powers, or authority he has *because* he is an engineer rather than, say, a mere citizen, business-person, or employee. Though competent to provide the judgment, his ability to do so is nevertheless compromised because he has a conflict of interest. His judgment is subject to "influences" by improper considerations or, at least, appears to be. There is reason to believe he may not do what a "faithful agent or trustee" with his skills, powers, and authority (as an engineer) would ordinarily do for the person in whose interests he is supposed to be acting.

The NSPE code limits its concern to "professional matters." That very limitation suggests that an engineer might have a conflict of interest even when *not* acting as an engineer. The code seems to apply an analysis of conflict of interest more general than engineering ethics. The notion of conflict of interest the code assumes is, it seems, one any rational person should be able to understand, engineer or not. So, let us try to state that general analysis of conflict of interest first, see how it works in a case with which we are all familiar (and about which we have relatively settled opinions), assure ourselves that the analysis implicit in the code is one we can accept (if indeed it is), and only then try to understand what it tells us about Hardin and James.

General Analysis of Conflict of Interest

We might generalize the code's analysis of conflict of interest in this way:

> A conflict of interest is any situation in which (1) a person (for example, an engineer) is in a relationship with another person (for example, a client or employer) requiring him to exercise judgment on behalf of that other person and (2) there is good reason to believe that, though competent to provide that judgment,[37] he may not do it as he should (for example, as an equally competent agent or trustee of that client would) because of some special interest, obligation, or other concern of his.[38]

Does this analysis fit our settled opinions about conflict of interest in general? Can we provide a moral justification for those opinions? Let us consider a relatively clear case of conflict of interest that has nothing to do with engineering.

Suppose that a judge is to hear a case between two large corporations, that she is known to be a good judge in general and an expert in the law affecting this case. But suppose, too, that she has substantial holdings in one of the two corporations. Such a judge certainly has a conflict of interest. Does she have a conflict of interest according to the analysis we derived from the code? The answer seems to be yes. She is in a relationship with another requiring her to exercise judgment. Her role as judge puts her in the position of having to decide the case before her according to her judgment of what the law requires. She is supposed to provide impartial judgment to both parties to the case. And that is exactly what there is reason to believe she may not do. The circumstances are such that, although she is exceptionally competent to judge cases of this kind, she may nevertheless be unable to judge this one as she should. Her interest in one of the corporations *may* bias her judgment in favor of that corporation. Money talks.

Of course, there is no guarantee that *she* will listen. This judge might, for example, be able to allow for her natural bias when deciding the case. She may be able to "bend over backward" to cancel its effect. But, even if she can in fact cancel the effect of her bias, how can she or anyone else know that she has succeeded? This is not the sort of bias judges routinely cancel out. Canceling the effect of pecuniary interest is not part of ordinary judicial training or skill. We cannot then rely on this judge's judgment that she has canceled the effect of that interest because her judgment of that may itself be affected by the same influences. It is also unlikely that she will be able to show in some other way that she succeeded in canceling the effect of that interest. Judging is in part a matter of forming an informed opinion about controversial questions. There is no mechanical way to check such judgments for the effect of interest. (If there were, we could replace judges with clerks.) We can, of course, bring in other judges to examine the same evidence the first judge examined and form opinions of their own. But beside being impractical (why not just replace the first judge instead?), such double-checking would simply produce other opinions. We would learn that other judges would agree or disagree with the first judge, but not whether she succeeded in canceling the effect her interest had on her judgment. There would remain the question whether *she* would have decided differently had she not had that conflict of interest. So her ownership of the stock cannot be shown not to affect her judgment. Because the inability to prove absence of actual bias is itself a good reason to doubt her judgment, she will have a conflict of interest even if she decides the case "correctly" and for all the right reasons.

This conflict of interest would not be "an apparent conflict of interest," a mere appearance. A conflict of interest is "merely apparent" if the relevant parties have available information capable of showing that the interest in question has, under the circumstances, no tendency to bias judgment. So, in our example, we could dispel the appearance of conflict by showing that the judge no longer owns the stock or, while owning it, cannot know that she does because her holdings are in a blind trust.

Responding to Conflict of Interest

A conflict of interest is like dirt in a sensitive gauge. For the same reason rational persons want reliable gauges, they want those on whose judgment they rely to avoid conflict of interest (insofar as practical). We would, for example, ordinarily want the judge to decline to hear the case (or to sell her stock before hearing it). We do not want her "bending over backward" to compensate for possible bias because we have no way to know how such bending will turn out. Will she bend over far enough? Will she bend over too far?

If that is what conflict of interest is, what can we do about it? Most conflicts of interest can be avoided. We can take care not to put ourselves in a position in which contrary influences or divided interests might undermine our ability to do what we are supposed to do. But, however much care we take, we will not always succeed in that. Our relations with one another are too many and too varied for us to keep track of them all. We cannot always foresee how they will affect one another and so cannot take the precautions necessary to prevent all conflicts of interest. Still, though conflicts of interest cannot always be avoided, they can always be escaped. We can end the association, divest ourselves of the interest, or otherwise get beyond the influence that might otherwise compromise our judgment.

But is it always practical to do that? Do we really want people never to act for us just because they have an interest that makes their judgment somewhat less reliable than it would otherwise be? Should there be an absolute prohibition on acting with a conflict of interest? These are not hard questions. Consider the judge again.

Suppose she retires. Some time later the two corporations have a similar dispute but this time agree to arbitrate rather than endure the expense of another trial. They come to the judge because of her reputation and the integrity she displayed in withdrawing during their previous dispute. She has not sold the stock. Would we want her either to refuse to arbitrate or to sell off the potentially biasing stock?

One might suppose that the answer is clearly yes, she should refuse or sell. After all, the ownership of the stock is still a consideration that could influence her judgment and an arbitratorlike a judgeis expected to provide unbiased judgment. On the other hand, the two corporations may be willing to run the risk of that influence to benefit from the judge's special insight into their problem (just as we might prefer to use a sensitive but slightly unreliable gauge rather than one which, though fully reliable, is too crude for the measurements we want to make). The general rule against conflict of interest protects the person who properly relies on the judgment of another. If such protection were sometimes to make people worse off *and* there were some other way to provide much the same protection without making the people involved worse off, would it not be reasonable to make an exception to the general prohibition? Would this not be like treating self-defense as an exception to the general prohibition of killing?

Consider the retired judge once more. *Suppose* she reasons in this way: "I could not have agreed to such an arrangement when I was a judge because the public as well as these two parties were relying on my judgment. My decision in the case would have been a precedent for others. Here there is no question of precedent; no one will rely on my judgment but these two corporations. They have come to me because they trust me and because they want to save money. They have not asked me whether I still own the stock. Obviously, they don't care. If I were to sell off the stock now, I would lose a lot of money, much more than they are willing to pay for this job. So, I must keep the stock. I can, however, do the job fairly even if I own the stock. I'm quite sure of that. So, there's no reason why I should not accept the arbitration without further ado."

Is there anything troubling about the judge reasoning in this way? Certainly there is. The judge seems to be taking too much on herself. She decided that the reason the corporations did not ask about the stock is that they did not care about it rather than, say, that they forgot about it or expected the judge to inform them if she still owned it. She also decided that she can arbitrate the case fairly even if she has a conflict of interest rather than leaving that decision to those whose agent or trustee she is to be. She decided what *they* will risk (and, however "sure" she is, there remains a reasonable chance that she is wrong). Her reasoning is, in a word, "paternalistic." She assumes that it is morally permissible for one rational person (without the other's informed consent) to decide significant aspects of the other's life because she believes herself at least as able to judge such things as the other is.

It is easy to see what is wrong with our judge's reasoning. Each rational person wants to live according to his own conception of the good (his own judgment of what his interests are and how they should be balanced), not according to someone else's. We do not want people deciding what is better for us simply because they believe they know better. That is true even when they may in fact know better and their decision does not impose any significant risk of harm. How much more true when, as usually happens, they lack the information about us that we ourselves have and the decision would impose significant risks on us! Because it is something all rational persons would generally oppose, imposing risks on another rational person for that other's good but without the other's informed consent must in general be morally wrong.

It seems, then, that before our retired judge agrees to arbitrate the case, she should disclose her conflict of interest. Indeed, she should disclose *any* information that might cast doubt on her ability to perform as the two parties would otherwise reasonably expect. She may advise them that she believes she can overcome the conflict (because she does believe that). But she must be sure that they are fully informed of what the conflict is and fully appreciate the risks of putting their case to an arbitrator laboring under such a disability. Only then can she be reasonably sure that if they go ahead with the arbitration, the decision to go ahead will be "theirs, not hers," that is, the result of their informed judgment, not in part the result of her not revealing information they would have found relevant. Disclosure has another benefit as well. It allows our judge to discuss with the two corporations ways to compensate for any tendency toward bias she might have.

To sum up: A conflict of interest exists if (1) an individual is in a relationship with another justifying that other's reliance on the proper exercise of her judgment in that other's interest and (2) the individual has an interest tending to interfere with the proper exercise of that judgment. In general, conflicts of interest should be avoided or, if unavoidable, ended as soon as possible. In special cases, however, a conflict may be tolerated if tolerating it will benefit the person who is relying on the judgment in question, but then only if there is full disclosure to that person and that person intelligently consents to the relationship nonetheless. Disclosure does not end a conflict of interest. What it ends is the passive deception of allowing an individual's judgment to appear more reliable than it in fact is. [39]

Judges, Hardin, and James

If all this makes sense, it should not be hard now to see what was wrong with what Hardin and James did. Let us begin with Hardin. Hardin initially gave his opinion on the interpretation of HG-605a in the friendly atmosphere of dinner with M&M executives. Such an atmosphere does not invite hard thought. We cannot know whether Hardin would have given a different opinion under other circumstances. Indeed, even he cannot know that. We can reasonably conclude, however, that his opinion *might* well have been different if, say, Hydrolevel executives had taken him to dinner first or had been present at the dinner with M&M executives. Having "gone on record" as accepting a certain interpretation of the code, Hardin would have found it embarrassing to change his mind once the inquiry was officially submitted in writing. His first response thus tended to undermine his ability to consider the written inquiry with the open mind he might otherwise have had. He had, in other words, a conflict of interest from the moment he first gave his opinion at dinner on a question likely to come before his committee. (Because giving one's opinion on a question tends to prejudice one's judgment thereafter, judges generally refuse to discuss any case that might come before them.) Hardin's helping to draft the inquiry may have strengthened further his feeling of owing M&M the opinion he gave at dinner. But, had he not given his opinion in advance, his part in drafting the inquiry would hardly have seemed important.

What should Hardin have done about the conflict of interest once it developed? He could have declined to respond to the inquiry when Hoyt referred it to him, passing it on to his subcommittee (minus James) and leaving it to them to decide what to do with it without his participation. Or he could have informed Hoyt that he had already committed himself on the question informally (and helped to draft the inquiry), leaving to Hoyt the decision whether Hardin should participate. Had Hardin done either, no one would have had reason to doubt his integrity (and his employer might have been saved $75,000).

Of these two alternatives, however, declining to participate seems much the better. Declining to participate resolves the problem altogether; while disclosing the problem to Hoyt simply makes it Hoyt's problem rather than Hardin's. Whenever there is a conflict of interest, there is someone ("the client") entitled to rely on the judgment in question. Conflict-of-interest problems cannot be resolved by disclosure unless the disclosure is made to the client. Sometimes it takes some thought to determine who the client is (or, more often, who *all* the clients are). This is such a case. Who is Hardin's client here? The answer is not ASMEor, at least, not only ASME. ASME holds itself out as an authority on boiler safety. It invites the general public to rely on its safety codes and on the interpretations its committees make of them. And the public does rely on them. ASME, though not a governmental body, is still a "public agency," that is, an agency that purports to serve the public interest. So, Hardin's client (or at least one of them) is ultimately the general public. Had Hardin made full disclosure to Hoyt and Hoyt told him to go ahead, Hardin would still not have made full disclosure to the public. He would have allowed Hoyt to act for his (and Hoyt's) client. He would have treated Hoyt as trustee or guardian of the public interest. That may sometimes be necessary, for example, when revealing information to one client would do serious harm to another and withdrawing would do similar harm. (Not all paternalism is morally wrong.) But, given the ease with which Hardin could have escaped the conflict altogether (without any risk of harm to the public interest), it does not seem necessary or even desirable for him to have, in effect, allowed Hoyt to act for the public without the public's informed consent.

Identifying Hardin's ultimate client as the general public, not ASME (or M&M), also helps to explain why Hardin should have revealed more to the Professional Practices Committee than he did. The Professional Practices Committee, like Hardin's own Heating Boiler Subcommittee, was acting as trustee of the public, not simply as an agent of ASME. (That is so because ASME implicitly guarantees the integrity of its procedures when it invites the public to rely on its codes and committees.) The standard of disclosure was, then, *not* what was *customary within ASME* but what the *public might reasonably think relevant* (or what it was in the interests of the public to know) should it wish to evaluate the reliability of the ASME interpretation in question. Hardin should have revealed his meeting with M&M executives because the meeting *might* reasonably have looked suspicious to members of the public. He should not have kept that information to himself just because *he*correctlybelieved ASME officers would agree there was nothing inappropriate about it. The decision whether to trust his judgment was the public's, not his, because he invited their trust by answering the M&M inquiry in his capacity as chair of the Heating Boiler Subcommittee. For the same reason, he should have revealed his part in helping to prepare the original inquiry.

I leave evaluation of James's conduct as an exercise for the reader. Consider in particular the following questions: What if anything was wrong with *not* signing the original inquiry? What if anything was wrong with reporting to the full Heating and Pressure Vessel Committee the recommendation of his subcommittee concerning the Hydrolevel objection to Hardin's original response? What if anything was wrong with helping to draft the letter of June 9, 1972? What if anything was wrong with failing to reveal those acts to the Professional Practices Committee? What part does mere appearance play in answering these questions? If there was anything wrong with any of these acts, what should James have done instead (while remaining a faithful employee of M&M)? Why?

8
Codes of Ethics, Professions, and Conflict of Interest

Chapter 7 used moral arguments to interpret provisions of the NSPE code of ethics. This may suggest that morality somehow determines what a profession should require of its members. This chapter uses an emerging field of engineering, clinical engineering, to show thatat least for conflict of interestmorality leaves professions a substantial range of choice concerning what should or should not be required of members. Morality, while limiting what professional ethics can be, does not determine what it is. This chapter also provides an opportunity to respond to some criticism of the book's general approach to engineering ethics.

What is Clinical Engineering?

Clinical engineering is part of another relatively new field, biomechanical engineering (barely twenty-five years old). Besides clinical engineering, biomechanical engineering includes rehabilitation engineering (the engineering that goes into, for example, the choice, attachment, and maintenance of artificial limbs) and biomechanical research (the engineering that goes into, for example, the design, building, and testing of those limbs). As in "bioethics," the "bio" in "biomechanical" signals a relation with medicine (rather than with "life" as such); the "mechanical," an *origin* in mechanical engineering. (Electrical engineers, especially, seem to prefer to call the field by the more informative "medical [or biomedical] engineering.")

Clinical engineers share with other biomechanical engineers a working relation with medicine. They differ from other biomechanical engineers in the relation they have. Working in hospitals (or other medical enterprises), clinical engineers oversee the vast technological structure that makes modern medicine possible. Because that technological structure is a complex mix of conventional mechanical systems and the newest in electronics, the typical clinical engineer may have a degree in either electrical or mechanical engineering. 1

Clinical engineers are engineers. They have degrees in engineering; employ much the same method, skills, and knowledge other engineers employ; and, like other engineers, are concerned with designing, developing, and operating safe and useful physical systems. Clinical engineers are, nonetheless, not ordinary engineers. Most engineers work in an organization where engineering is a central concern. Even in a finance-oriented company like General Motors, engineering is the mother tongue, the language of most of those with whom most engineers must deal. That is not true of a hospital. Medicine is the mother tongue there. A clinical engineer may be the only engineer the hospital employs. And even when (as often happens) he has a few colleagues, together they form only a small part of the organization. Most of their dealings are with physicians, nurses, medical administrators, and others to whom engineering is alien.

This alone suggests that the hospital may be an environment in which ordinary engineering ethics is not appropriate. There are other reasons to think so. For instance, engineers generally agree that the safety, health, and welfare *of the public*rather than that of the client (or employer)comes first. Yet, for physicians, nurses, and other health care professionals, the safety, health, and welfare of the *patient* comes first. The public interest, like the interests of colleagues or other third parties, is secondary.

Such differences in environment suggest questions such as these: How, if at all, should the obligations of clinical engineers differ from those of other engineers? What should be the paramount obligation of clinical engineers?

Such questions are not easy to answer. That is reason enough not to try to answer them here. But there is another reason. I am not a clinical engineer. Deciding what clinical engineers should profess is part of the profession in which they claim membership. Others can only advise. As a philosopher, I can best advise by clarifying the questions I have put so that clinical engineers, the members of the profession in question, find them easier to answer. I can, of course, give all sorts of other advice, too, but why do it? I lack the experience on which such advice should rest. And my theory of engineering will pass an important test even if it only helps clarify the questions I put.

But how can clinical engineers answer those questions, however clarified? Are not the questions ultimately philosophical? They are *not* (though they certainly can generate philosophical puzzles). They are, rather, much like other questions engineers routinely face, for example, questions of safety or reliability. They can be resolved in much the same way. Engineers will have to make educated guesses, test them, share results with peers, reassess their guesses based on the tests and peer response, make such modifications as seem appropriate, test again, and so on.2

At this point, some readers may be formulating objections. After all, I have suggested *both* that there is no Archimedean point from which to deduce a code of ethics for a profession *and* that the members of a profession have a privileged position with respect to determining what their code of ethics is (and should be). I even suggested that writing a code of ethics for engineers is much like other *engineering* tasks. Clearly, I went well beyond the claims of chapter 4. I have much to

explain. But, first, I want to examine an ethical problem typical in clinical engineering. That examination provides evidence crucial to my explanation.

A Problem of Professional Ethics

Consider this relatively simple problem: You are an engineer in charge of clinical engineering at Big Bill Hospital. Your work there introduced you to the products of Hi-Tec, mostly very expensive diagnostic equipment. Hi-Tec is a relatively large company, with good service as well as good equipment. You have been impressed by everything of theirs you have seen. Indeed, after some bad experiences with Hi-Tec's competitors, you have recommended some purchases from Hi-Tec even when the competitor's price was significantly lower. When your stockbroker lists Hi-Tec's stock as a good buy, you consider buying a few hundred shares at $14 each. Should you?

Some things are obvious. Big Bill's purchases are not large enough to affect the overall profitability of Hi-Tec. You will not be able to make money by giving business to Hi-Tec rather than to its competitors. You will not have what most people would think of as a clear conflict of interest. On the other hand, you will have a connection with Hi-Tec that *could* affect your professional judgment. [3] Hi-Tec will, as it were, be a member of your financial family. Although you may be sure that the connection will not influence you, you recognize that others cannot be so sure.[4] If they knew you owned Hi-Tec stock, they might wonder about your impartiality when you recommended a Hi-Tec product over some other. Your recommendation might carry less weight than it would otherwise.

Let us suppose that, like many employers, Big Bill does not require you to reveal ownership of publicly traded stock. So, you are not, as an employee, required to tell Big Bill if you buy the stock. Your employer leaves you free to choose between at least these three options: (1) passing up the stock, (2) buying the stock and saying nothing, and (3) buying the stock and informing your employer. Which should you choose?

A physician faced with such a question might profitably turn to section 8.06(1) of the Principles of Medical Ethics of the American Medical Association (AMA): "A physician should not be influenced in the prescribing of drugs, devices or appliances by a direct or indirect financial interest in a pharmaceutical firm or other supplier." Physicians are not forbidden to *have* financial interests that could influence their judgment in ways not in the best interest of their patient. They are only forbidden to *be influenced* by such interests. So, because you believe that owning the stock will not influence your judgment, you could if you were a physician rather than a clinical engineer, properly buy the stock.[5]

But you are a clinical engineer, not a physician. Where then can *you* go for guidance when your field has no code of ethics of its own? If you were a member of the Institute of Electrical and Electronic Engineers (IEEE), you might turn to its code of ethics. Clause 2 would tell you to "avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist."[6] For an electrical engineer, the crucial question is not whether the interest *will* influence her but whether she *has* such an interest ("real" or "perceived").

If, instead, you were trained as a mechanical engineer, you might turn to the Ethical Guidelines (4.a) of the American Society of Mechanical Engineers. You would get much the same answer: "Engineers . . . shall promptly inform their employers or clients of any business association, interests, or circumstances which *could* influence their judgment or the quality of their services." (ABET's code would answer in the same way.)

The American Association of Engineering Societies (AAES) sets an even higher standard. According to its Model Guide for Professional Conduct, "Engineers disclose to affected parties all known or potential conflicts of interest or circumstances which might influenceor *appear* to influencejudgment or impair fairness or quality of performance." Even if you were sure owning the stock could not affect your judgment, you would, according to the AAES, be obliged to inform the hospital because owning the stock might appear to influence your judgment (if ever anyone there came to know of the stock).

The similarity between the IEEE, ASME, and AAES codes suggests that engineers generally agree that they must be held to a higher standard than physicians. [7] No such agreement exists. If you were a licensed professional engineer, you might instead have turned to the Code of Ethics of the National Society of Professional Engineers. You would then find that article III, section 5 reads much like the AMA's code: "Engineers should not be influenced in their professional duties by conflicting interests." There is nothing about disclosure of what merely "could" influence your judgment.[8]

So, what are you, an ordinary clinical engineer, to do? You could, of course, hold yourself to the highest standard possible. But why do that if other engineers would not do the same and your doing so burdens you without benefit to your employer? Why should you not make a little extra money if you can do so properly?

Analyzing the Problem

Of course, the question is what exactly *is* proper here. Ordinarily, no matter what stock you bought, you would not want to notify your employer. Your investments are your own business. You have even more reason to keep any purchase of Hi-Tec from your employer. You want to avoid unjustified undermining of your professional authority. According to the NSPE, as an engineer you can properly keep that information confidential, as long as you don't allow ownership of Hi-Tec stock to influence your professional judgment. But, according to the IEEE, ASME, and AAES, if you own any Hi-Tec stock, you have a professional obligation to tell your employer. So what should you do?

You might call up other clinical engineers in the area and ask them what they would do. Engineers in specialized fields sometimes develop a consensus about certain ethical questions just as they do about the reliability of certain instruments. If the question comes up enough, you may get a relatively clear answer. If, however, the question does not come up enough, you are likely to get a range of half-thought-through opinions leaving you more or less where you began. Let us suppose you find no consensus. What then?

The way I set up the problem, the best you can do as a clinical engineer is muddle through. Without a standard governing clinical engineers as such, there are several *morally* permissible options. The choice among these is a personal, rather than a professional, matter (at least until you decide whether you are a professional engineer subject to the NSPE code, a mechanical engineer subject to the ASME code, or a member of IEEE subject to its code). You *can't* know what you should do *as a clinical engineer.*

This problem, though real enough for a practicing engineer, is, I admit, not "philosophically interesting" in the way those problems are that hold the attention of philosophers for generations. The problem is philosophically interesting in a more humble way however. Not being a hard problem, it is just the sort that any plausible theory of professional ethics should be able to handle easily. It is philosophically interesting as a test case, revealing something important about codes, something most theories of professional ethics miss.

If you, as clinical engineer, find "muddling through" an unsatisfying way to resolve the problem, you have at least one reason to want clinical engineering to have its own code of ethics. A code can turn a morally indeterminate question like this into a question of professional ethics with a relatively determinate answer. A code of ethics does that by creating a convention for all members of the profession to follow. If generally following the convention gives clinical engineers something they all wantwhether freedom to make money on the side, the greater trust of employers, or some combination of these or other goodseach clinical engineer has reason to want all others to follow the convention even if their following it means doing the same. If the others generally do follow the convention, realizing it in practice, each clinical engineer is morally obliged to do the same. Claiming to be a clinical engineer is a voluntary act. No engineer can fairly take the benefits flowing from that claim without doing her share to maintain the practice creating the benefits. A morally permissible code of professional ethics itself defines each member's fair share in helping to make possible the benefits the code generates. [9]

So, a code of ethics is, as such, not merely good advice or a statement of aspiration. It is a standard of conduct which, if generally realized in the practice of a profession, imposes a *moral* obligation on each member of the profession to act accordingly. A profession's code of ethics necessarily sets a standard below which no member of the profession can properly fall. Any document not intended to have that effect is not, strictly speaking, a code of ethics, whatever it may be called.[10]

A code of ethics sets a minimum standard, no matter how high the standard if, *but only if*, the standard set is generally realized in the practice of the profession. For that reason, a profession should not set its standard very high. For example, if the code set its standard so high that only a few could hope to survive in the profession, either all but a few saints would avoid the profession or most of those in the profession would ignore the standard. The code would either define a dying (or dead) profession or serve as a mere statement of aspiration in a profession defined in other terms. A living code of ethics is always a compromise between ideal and reality.

So, one reason clinical engineers might want to have a code of ethics of their own is to make it possible for them to tailor their professional obligations to the

special realities of hospitals. This may mean setting their standards higher or lower than those of other engineers (or just setting different standards). But, what it must mean is setting their standards higher than their employer's. A code is pointless when moralityincluding the morally permissible promise contained in the employment contractleaves only one option. In this respect, living by a professional code is necessarily "public service"that is, benefiting the public, those served, by giving them more than they would be entitled to but for the code.

Codes at Work

Adopting a realistic code is part of making an occupation a distinct profession. But it is only part. Let me now briefly describe some other aspects of professionalism, making clear how central a code is to them.

A code of ethics cannot actually guide conduct unless those to be guided know the code. Because a code necessarily sets a standard higher than ordinary morality, even a morally decent person is not likely to *do* what the code requires unless he knows what in particular it requires. The code must be learned in just the way other engineering standards are. The code can be taught as part of the profession's basic curriculum or its continuing education. 11 It can also be taught in less formal waysfor example, by publishing articles on particular questions of ethics in the profession's journals.

Education is probably the primary means by which a profession puts its code into practice. But every profession needs something more, some means of enforcement. The minimum is the informal enforcement that comes from one member of a profession saying to another, "But that would be unethical." Such a rebuke is barely distinguishable from education. Beyond this minimum are group pressure; peer review; reputation in the profession; formal certification of various sorts; disciplinary committees with the power to censure, suspend, or expel from the profession; and state licensing with the power to bar from employment.

Educational and enforcement activities almost define profession in the public mind. Without them a learned occupation is only a field of study and endeavor, a discipline, not a profession (strictly so called). These educational and enforcement activities all presuppose a code of ethics of some sort, that is, a minimum standard common to all members of the profession making improper what would otherwise be proper. The code need not be written, but the more that is in writing the easier it will be to teach the code, especially in a young profession. So, clinical engineering, though no longer a new discipline, is still only potentially a profession distinct from engineering. What it lacks is its own code of ethics.

Objections Answered

We come, then, to the objections. John Ladd represents the chief objection to my approach. For him, talk of "a code of ethics" rests on a confusion of morality and law:

> Ethics, sometimes called "critical morality," is logically prior to all these institutions and mechanisms of social control [like law or the "value system" of some group]. . . . The principles of ethics (or morals) are not the kind of thing that can be arbitrarily created, changed, or rescinded. . . . [T]hey are "discovered" rather than created by fiat. They are established through argument and persuasion, not by imposition of external social authority. 12

On my view, however, "ethics" as used in "code of professional ethics" does refer to a "value system of a group," the profession itself. It is a mechanism of social control, a way of coordinating the conduct of people engaged in a common occupation. Unlike morality, a code of professional ethics cannot be logically prior to all institutions of social control. A code of professional ethics *is* an institution of social control. However, a code of professional ethics can still be distinguished from law (and other forms of merely *external* authority). On my view, a code of professional ethics cannot, as such, be the work of external authority. To be a code of professional ethics, a code must be a morally permissible standard of conduct each member of the profession wants all others to follow even if their following it would mean he must do the same. Professional ethics thus resembles morality in having an "internal" aspect (being something each wants). Argument and persuasion are essential to developing and maintaining a code as a living practice.13 Professional ethics is "social" because it involves coordinating the conduct of a group, the profession. But it is "control" not by external authority but in part at least by the conviction of those subject to it that claiming membership in the profession is voluntary; that the profession prescribes certain ways of acting for its members; that acting in the prescribed ways will, on balance, serve the interests of all members of the profession;

and that therefore none can fairly claim membership while failing to act as prescribed.

Though ethics resembles morality in this internal aspect, it is not just ordinary morality, something that is or should be common to all rational persons, to all rational persons in this society, or even to all rational persons in a particular occupation. Groups like clinical engineers actually "create" their ethics; they do not simply "discover" them in the larger society. Or, at least, they do not discover them in the larger society in a sense different from the way a legislature "discovers" the law.

We must make a distinction Ladd does not. There is a sense in which law, like ethics, must be discovered. We do not make law arbitrarily. That would ordinarily be irrational. We look for reasons. We try to choose wisely. Still, what the law is is determined in part by what we actually decide. It cannot be deduced from any (interesting) general principles (even combined with a description of circumstances). So, for example, no principles settle which side of the road Japanese law will require vehicles to drive on in the year 2101, or how much I should pay in taxes next year, or even how much sulfur dioxide steel plants along Lake Michigan's Indiana shore should put into the air tomorrow. Legislators must make law to decide such questions. And the laws they make will be the law even if they do not in fact choose wisely (as long as they satisfy procedural requirements, substantive constitutional restraints, and the minimum requirements of ordinary morality).

Members of a profession make professional ethics in the same way. Clinical engineers need have no special rules about conflict of interest. They can continue to allow those practicing in their field to follow ordinary moral standards, the standards set by their employers, or the standards of their respective professions. They are free to "legislate" or not, as they choose. They do, however, have reason to "legislate." If they want clinical engineers to be known as people who handle conflict of interest in a specific way, they have to determine what way that is. If they want clinical engineers to be respected for the way they handle conflict of interest, they have to set a standard higher than would otherwise prevail. Such reasons certainly do not leave clinical engineers free to set any standard whatever. They do, however, leave them free to choose among a fair number. Each clinical engineer has to balance individual convenience in complying with this or that standard against the benefit to everyone of a common standard. Reasonable people may disagree about where the balance is to be struck. For example, the choice between the AAES and the ASME treatment of conflict of interest is neither a choice between right and wrong nor a choice without a difference. Clinical engineers cannot "discover" what their profession's ethics are; they have to decide what they will be.

By now it should be obvious that writing a code of ethics is like other engineering tasks in one way: Writing a code of ethics has (as Caroline Whitbeck might say) the structure of a design problem. [14] Ordinary morality, licensing laws, the interests of clinical engineers, and the like correspond to the specifications with which engineers usually begin a project. Specifications constrain outcome but seldom determine it. Engineers are free to invent new options or cull old ones from current or past practice. Having developed a list of options, they try to choose the best one. There is often no standard decision procedure yielding a unique answer. Consideration may weigh against consideration. Different engineers may initially choose differently. The engineers involved then discuss the problem until a consensus emerges (perhaps doing additional tests or drawing on other sources for relevant information).[15] Perhaps no one gets his first choice, but each gets a choice he considers better than stalemate.

That is one way in which writing a code of ethics for clinical engineering is like other engineering work. There is another. The history of engineering is, in part, a history of standardizationthat is, a history of constructing tables, formulas, or procedures defining safety, reliability, convenience, or other elements of good practice. These standards cover everything from strength of beams to be used in highrise buildings to the distance between threads on a screw. The boiler codes described in chapter 7 constitute just one example. Every such standard lays down a rule of conduct for engineers. Engineers develop these standards because all engineers doing things the same good way is better than each engineer choosing a way she considers best. Coordinating conduct pays in such cases.

The standards so defined are not, however, likely to freeze in the way pure conventions tend to. Most change from time to time as experience generates new options or shifts the weight of evidence favoring this or that old one. But change cannot be justified simply by the fact that a new standard would beat the old one in a "fair fight." "Ideally best," "best in the original position," or best in some other timeless way is not good enough. The proposed standard must be so much better than the

present one that the benefits of changing to the new one at least pay the costs of changing over. Engineers must give history its due.

Indeed, history has much to do with maintaining consensus on engineering standards, ethical as well as technical. Individual engineers may have strong views about which standard would be bestfor example, the best layout for keys on a typewriter or computer (almost anything but the present one). Yet, for most standards, there is also agreement that the present standard, whatever its faults, is better than none at all. And, for most standards, there is no consensus on which alternative is better. When standardization is important, that is enough to justify following the present standard until a new consensus emerges. Like the rest of the world's work, the work of engineers cannot wait for perfection.

Engineering standards are, of course, not necessarily what any engineer or set of them intends them to be. They are public facts, usually words, numbers, or symbols on paper. They are always vague or incomplete to some degree. 16 They require "interpretation" (or, as engineers might say, "interpolation"). A code of ethics is no different from other engineering standards in this respect, either. Just as ASME has a committee to interpret its boiler code, so the NSPE has a committee to interpret its code of ethics. Each profession is a continuing discussion, fundamentally political in the good sense the ancient Athenians used to distinguish government by persuasion from tyranny. To join a profession is, in part, to enter that discussion, gaining some control over a common enterprise by giving up the right to act as a mere individual (what the Athenians called an "idiot"). To claim to be an engineer is not simply to claim to know what engineers know; it is to claim to act as engineers act. To claim to be a mechanical engineer, for example, is to claim a share in a specific historical enterprise carried on according to certain standards of conduct from technical codes like ASME's boiler code to ASME's ethical guidelines. Anyone who wants to be a mechanical engineer but not to act according to those standards has some explaining to do, especially to his employer and those who might otherwise rely on him for engineering judgment.

Indeed, insofar as the distinction between "ethical standard" and "technical standard" suggests that technical standards have nothing to do with ethics, the distinction is misleading. For any profession, part of acting ethically is satisfying technical standards. What we call a code of ethics can equally well be thought of as the most general of technical standards, the framework into which the more detailed ones may be sorted. So, clinical engineering is a mere field of engineering insofar as clinical engineers are "standardized" in the way mechanical or electrical engineers are. They are an emerging profession in part because they have already developed some distinctive technical standards. But they will not achieve full status as a distinct profession until they adopt their own code of ethics. And nothing requires them to do that. They may instead (properly) choose to remain a part of the engineering profession.

PART IV
EMPIRICAL RESEARCH

The first three parts of this book drew irregularly but often on history for insight into engineering. Though this part again begins with history, including an already familiar example, the Challenger disaster, its focus is on the social sciences. Chapter 9, a report of empirical research, reveals something of the day-to-day work of engineers, their place in business, and their relationship to management. It is also, like chapter 5, an attempt to use what we learn about engineers to protect them from some hard ethical choices.

Chapter 10 tries to convert the abstract claim that most engineers cannot be professionals because, as employees, they lack autonomy into a set of concrete claims capable of empirical testing, but it leaves the testing to social scientists. Chapter 10 thus suggests the useful cooperation possible between philosophers and social scientists interested in professions.

The book's epilogue is an invitation to the social sciences (and history) to contribute more to engineering ethics. It formulates four questions about engineering, the answers to which would be useful to those of us who work in engineering ethicsfour questions the social sciences seem admirably suited to answer. The epilogue underscores the preliminary character of the book as a whole: its attempt to open up a field of study, to suggest hypotheses and lines of research, and, perhaps, to offer a target for those who think differently.

9
Ordinary Technical Decision Making: An Empirical Investigation

For Canada's engineers, part of belonging to the profession is wearing a finger ring, originally a plain band of iron, now generally steel, in memory of the collapse of a great "iron" bridge across the St. Lawrence at Quebec in 1907. [1] Remembering that disaster, in which more than seventy workers died because of an engineer's error, is supposed to help today's engineers avoid similar errors. No other engineering society I know of has anything quite like this physical momento, but there is in it something characteristic of engineering. Engineers do not bury their mistakes. They record them, study them, and put into practice what they learn from them. Engineering handbooks, with their tables of tolerances, safety factors, standard methods, and so on, are in part the intellectual equivalents of Canada's iron ring, an attempt to use failure.

This chapter is also an attempt to use engineering failure; it differs from most such attempts in being concerned with ethical rather than technical failure. I begin with the assumption that whenever an engineer faces an ethical problem, something went wrong. There are at least three possible ways to explain what went wrong: (1) the individualsomeone (the engineer or someone else) acted inappropriately; (2) the organizationalthe organization lacks a satisfactory policy or procedure to prevent the problem or at least to make it a "no brainer"; or (3) the technicalthe absence of some device that would prevent the problem from arising (for example, a testing device eliminating the uncertainties that leave a decision to "engineering judgment").

These three ways of explaining an ethical problem are not mutually exclusive. Indeed, often, each sheds some light. What we identify as "the explanation" of a problem probably has more to do with the solution we think best than with how the problem arose. When we think the problem best handled by an individual, we emphasize individual conduct. When we think the problem best handled by changing the organization, we emphasize the role of practice or policy. When we think the problem best handled by bringing in a new machine, changing the physical layout of a building, or otherwise rearranging things, we emphasize the technical (usually without acknowledging the ethical dimension in any technical choice). And, when no one approach seems adequate, we are likely to describe the problem as "complex."

This chapter approaches certain problems of engineering ethics organizationally. We can identify policies or practices that, by improving communication between engineers and managers, will avoid some of the ethical problems engineers would otherwise have to resolve as individuals. This is a work in "preventive ethics."

The Problem

What engineers do is important. A defect in the design of an airplane, a failure to maintain quality in the manufacture of a chemical, or even a mistake in operating a power plant can ruin a company, undermine trust in government, or kill hundreds of innocent people. Our comfort, prosperity, and safety depend on feats of engineering which, because of their scale and complexity, are necessarily feats of management, too. Anything in the relationship between engineers and managers that can threaten the integrity of their work also threatens our common well-being. The tendency for technical communication between managers and engineers to break down is certainly such a threat. The Challenger disaster provides two stories that illustrate how serious a threatand suggest the potential significance of this chapter.

Acting as a member of the Presidential Commission investigating the Challenger disaster, Richard Feynman, a Nobel Prize-winning physicist, interviewed managers and engineers in the shuttle program. He soon found that managers could differ substantially from engineers even about what seem readily determinable facts. [2] For example, Feynman asked both a middle-level manager and three engineers working for him on the shuttle's engines "what the probability of failure for a flight is, due to failure in the engines." The engineers all said about one in two hundred. Feynman's description of the manager's answer is too good to paraphrase:

> [The manager] says, "100 percent." The engineers' jaws drop. My jaw drops. I look at him, everybody looks at him and he says, "uh . . . uh, minus epsilon?"
>
> "OK. Now the only problem left is what is epsilon?"
>
> He says, "1 in 100,000." So I showed [him] the other answers and said, "I see there *is* a difference between engineers and management in their information and knowledge here."[3]

The disagreement Feynman thus uncovered had nothing directly to do with the Challenger disaster. Failure of a *booster* O-ring, not the *shuttle's* engines, caused the disaster. The company responsible for the boosters, Morton Thiokol, had nothing to do with the shuttle from which the boosters would have detached after the first few minutes of flight. Neither these shuttle engineers nor their manager was an employee of Morton Thiokol.

Yet, the disagreement is relevant. Feynman asked his questions of these engineers and their managers only after finding that the managers and engineers working on the booster differed substantially in their assessment of the probability of the booster's failure. The differences there had come as a surprise. The probabilities were easily calculated (or, at least, everyone agreed on how to do the calculations). Once Feynman realized such differences existed, he wondered how widespread they were.

He began his interview with the shuttle engineers by asking about any disagreement between the engineers and their manager. The manager assured him there were none, explaining why by pointing out that he, too, had been trained as an engineer. [4]

Feynman did not ask the manager why training as an engineer should guarantee agreement with the engineers he managed. No doubt the manager assumed that being able to understand technical information is enough to ensure that he would understand it in the way others with the same technical training did. This assumption certainly seems plausible. What, then, explains the disagreement? Feynman suggests that the manager's misunderstanding was produced by a work environment, "a game, just as in the case of the solid rocket boosters, of reducing criteria and accepting more and more errors that weren't designed into the device."[5] Feynman does not explain *how* this process could lead managers to get simple facts wrong or *why* ordinary engineers were not affected in the same way. In truth, Feynman's suggestion does not so much answer a difficult question as identify the difficulty. We may get a better sense of the difficulty by considering an event crucial to the disastrous decision to launch, one already described in chapter 4.[6]

The night before the Challenger blew up, one manager advised another to "take off [his] engineering hat and put on [his] management hat." This advice apparently led the manager, a vice president at Morton Thiokol, to *change* his evaluation of the risk of O-ring failure and approve the launch (knowing that the launch would not occur without his approval). The manager was himself an engineer who, earlier that day, had decided against the launch after receiving the unanimous recommendation of his engineering staff. The night-time reversal occurred under pressure from NASA but without any new information about the risks involved. "Putting on [his] management hat" seems to have changed the way he thought about the data before him. Here the gap between engineers and managers seems to have existed within one individual, an engineer-manager.

Feynman did not find this gap between engineers and managers everywhere in the shuttle program. For example, in avionics, "everything was good: the engineers and managers communicated well with each other."7 So, the gap is not inherent in relations between engineers and managers. It must open as a result of specific practices. Once it opens, management may (like Feynman's NASA manager) make decisions on the basis of something less than all information readily available. Insofar as full information tends to make decisions better (better by almost any reasonable criterion), management has reduced its chances of making a good decision.

Good managers want to avoid making decisions on less than the best information available of course. The research reported here is intended to contribute to that end. Our research group began with four related questions:

1. Can the communications gap Feynman discovered occur in other organizations that employ engineers and managers?

2. Is there a readily usable procedure for identifying the communications gap before disaster strikes?

3. What can be done by engineers or managers in an organization to help prevent the communications gap from opening or help close it once it has opened?

4. What can be done by colleges and universities training future engineers or managers to help prevent the gap from opening or to help close it once it has opened?

Relevant Literature

Descriptions of the manager's life in large organizations are common. Many touch on ethical problems a manager may face. Few do more than touch on them. An important exception is Robert Jackall's *Moral Mazes*, a particularly grim evocation of corporate life. His managers work in a largely amoral environment in which technical knowledge seems largely irrelevant and satisfying the boss is the only criterion of success. Jackall discusses engineers only in the context of whistleblowing and without giving any indication that engineers might differ in any significant way from managers or other employees. [8] Still, if the managers he describes are even a rough approximation of the managers with whom engineers work, the communications gap between managers and engineers would be both common and difficult to eliminate.

Engineering is a profession. What does the literature explicitly discussing relations between managers and professionals have to offer? That literature is surprisingly small. Most of it seems designed for the personnel department (or, perhaps, for a generic MBA program). Albert Shapero's *Managing Professional People* is typical. Much is said about how to recruit creative professionals, how to keep them creative, and how to evaluate them. Shapero is especially good on such personnel questions as whether to keep salaries confidential and how to break in a new hire. He even provides some useful advice about encouraging communications *between* professionals. But he says virtually nothing about what happens to the information, designs, and recommendations professionals generate. Shapero gives no hint that professionals and managers might disagree in the way those working on the Challenger did.[9]

The one significant exception we found to this personnel-department orientation in the literature concerned with managing professionals is the work of Joseph Raelin, especially *The Clash of Cultures: Managers and Professionals.* The title itself suggests the important difference between Raelin's work and that of others writing about relations between professionals and managers. For Raelin, there can indeed be a "clash" between managers and professionals. Raelin explains this clash by the difference in culture between professionals and managers. Professionals have a code of ethics setting standards they must satisfy whatever their employer may think. Professionals, as such, always have loyalties beyond their employer. Managers, on the other hand, have no such divided loyalty. They are therefore much more susceptible to organizational pressures. Raelin therefore urges managers to rely on their professionals for guidance in decisions with an important ethical component. [10]

Yet, even Raelin's work does not help us understand the gap between managers and engineers. Raelin's own discussion of the Challenger disaster ignores the fact that virtually all the managers involved in the Challenger disaster *were* engineers.[11] His emphasis on the ethical also seems misplaced. The disagreement between managers and engineers on the night before the shuttle exploded was not explicitly ethical. And the disagreement Feynman reports is over an easily calculable *fact*, the probability of failure.

Chapter 5 (in this volume) takes a different tack, one closer to Feynman's.[12] It stresses the close relation between the work we do and the way we think. Because the work engineers do is different from that of managers, engineers may be expected to think somewhat differently. However, the exact differences depend on the specific working environment. Chapter 5 suggests that the working environment at Morton Thiokol (Feynman's "game") would have made a certain "tunnel vision" part of how managers normally thought about risk. Thinking like a manager rather than an engineer there would, then, mean giving less weight to engineering considerations than an outsider might think justified. The managers, in effect, went blind.

Chapter 5 (like Raelin's work) is a contribution to the literature on the relation between organizational structure and ethics. James Waters makes another suggestive contribution to this literature. Though Waters's chief example, GE's price fixing in the 1950s, does not involve a breakdown of *technical* communications, there was a communications breakdown. Waters argues that seemingly unproblematic aspects of the organization blocked the normal tendency of people to oppose conduct they judged illegal, unethical, or unwise.[13]

Technical communications seem far from ethics. Why, then, are we drawn to the ethics literature? The answer is that technical communications are often the vehicle for making ethics practical.

Consider that the cases commonly used to teach business ethics include a surprising number that seem to involve a breakdown in communications between managers and engineers of just the sort that concerns us. Among these cases are the Ford Pinto's exploding gas tank, the DC-10's cargo door, Three Mile Island, and BART. Though Waters's 1978 article focuses on GE's price fixing, he briefly discusses another workhorse of business ethicsthe scandal over brakes Goodrich developed for the Air Force's A-7D project. Waters notes what is a common feature of the other scandals as well: the great difference between the way the senior managers and the engineers directly involved interpreted crucial events, an apparent failure of middle managers to pass along important information, a failure in principle avoidable because it arose predictably from procedure or organizational structure rather than by accident.[14] Engineers saw serious problems where, apparently, management, especially upper management, saw nothing significant.

Our problem is connected with engineering ethics in the same way. Most of the scandals cited here can (and frequently do) appear in a course in engineering ethics. Our problem is more than a problem for business and engineering, however. There is evidence of a similar gap between government managers and their engineers.[15] There also seem to be analogous communications breakdowns where no engineers

are involvedfor example, between army generals and their technical staff and between airline mechanics and their managers. 16

Our problem's connection with business ethics is nonetheless important. Unlike the literature on professional ethics, the literature on business ethics is relatively rich in suggestions for preventing or eliminating the sort of communications gap that concerns us. For example, Waters makes five suggestions:17

1. Remove ambiguity concerning organizational priorities (e.g. by a corporate code of ethics)

2. Include concrete examples in directives concerning what is permitted or forbidden

3. Provide concrete steps for internal whistleblowers (e.g., ombudsman)

4. Develop an appropriate organizational vocabulary (e.g., by organizationwide ethics training that includes discussion of specific cases likely to arise in the organization)

5. Launch regular ethical investigations similar to the annual audit.

Waters also remarks that the problems that concern him seem to arise in relatively hierarchical organizationsthat is, highly compartmentalized organizations with a strict chain of command that makes it difficult for information to flow "horizontally" (from department to department) or "vertically" (around a particular manager).

Raelin's recommendations are similar to Waters's. The only important additions are:

6. Mentorship to help socialize new engineers professionally

7. Rewards for those who bring in bad news the organization is better off having (as well as the usual rewards that go to those who bring in good news)[18]

Similar recommendations abound.[19] But virtually missing from the literature is the suggestion that the *organization* should explicitly encourage professionals to adhere to their *profession's* code of ethics, provide in-house training in that code, or otherwise encourage loyalty to the profession.[20] Even studies of *professional* diversity in the workplace are rare.[21]

We have so far omitted mention of two more categories of relevant literature. One is the literature on managing innovation, especially the classic study by Burns and Stalker.[22] That literature seems to confirm the connection already suggested, between good ethics and good management, while offering another perspective on it.

The other category of relevant literature so far omitted should have been obvious to us from the beginning. The *Challenger* explosion was a man-made disaster. It was, however, very late when we discovered Barry Turner's classic work on manmade distasters. Much of his analysis focuses on breakdowns of communication, some quite subtle. Unfortunately, he says little about prevention.[23]

Hypotheses

We began this study with the assumption that business and government tend to treat engineering as a "staff function" and management as a "line function." That seemed safe. The staff-line distinction has been a relatively stable feature of American business ever since the middle of the last century when America's first big businesses, the railroads, organized on the model of the U.S. Army, America's first big organization. [24]

In its pure form, the division between staff and line works like this: Engineers (and other professionals) are regarded as having special knowledge of how to do certain work (drafting, designing, checking, evaluating safety, and so on). They answer to a manager, but no matter how high they stand in the organization, no one (except perhaps a few assistants) answers directly to them. The engineers are not "in the chain of command." Managers, on the other hand, whether or not they have technical knowledge, are regarded as having special responsibility for deciding what to do and how to do it. Managers answer to those "above" and command those "below." Engineers on the staff of a particular manager provide information, advice, and technical assistance.[25] Engineers are concerned with facts; manager, with decisions. A historian of technology recently summed up this "military model" of engineer-manager relations rather nicely (while assuming it to be an accurate description of engineer-manager relations today): "The organizational structure of engineering today does not encourage practitioners to ask questions beyond narrowly technical onesmuch less to raise objections."[26]

While recognizing that practice is seldom pure, we assumed that the staff-line distinction would nonetheless produce a division of labor in which engineers tended to think about questions one way while managers tended to think about them another. In particular, we expected engineers generally to defer to managers, to present options and let the managers decide. We also assumed that engineers and managers would bring somewhat different standards of evaluation to their work. For example, engineers, adhering to professional standards of success, would want to "do things right," even if the added expense or time required was substantial. The managers would instead adhere to company standards of success; they would want to "get things done"in time and within budgeteven if that meant cutting corners or taking substantial risks. We expected this difference in perspective to make the perspective of managers at least partially opaque to engineers and the perspective of engineers partially opaque to managers.

Finally, we began with the assumption that the current literature on improving communications between managers and engineers was probably inadequate. The shuttle program had a complex system of consultation to ensure engineering "input" at every step in making any important decision. That system included much of what the literature recommended. Information (or, at least, the paper it was printed on) moved upward relatively freely, with no one in a position to block it. Communications between engineers and managers still broke down on a grand scale, however, and the result was a disaster no one wanted. Because the shuttle program did not seem to differ in any fundamental way from other undertakings that employ large numbers of engineers, we assumed that the same thing could happen in any other undertaking of that sort. Clearly, then, something more than NASA's complex system of consultation was needed.

These assumptions lead naturally to the following hypotheses:

1. That the boundary between engineer and manager would be relatively clear in most organizationsso that, for example, an engineer would know whether or not she had become a manager

2. That engineers would be primarily concerned with safety and quality while managers would be primarily concerned with costs and customer satisfaction

3. That engineers would tend to defer to management judgment, because management had ultimate responsibility for decisions (so that, for example, one way to improve communications between managers and engineers would be to find ways to encourage engineers to be more assertive in their dealings with managers)

4. That the more hierarchical an organization, the more difficult communications between managers and engineers would be and the more likely that a communications gap would open

5. That we could develop a procedure for identifying a gap between engineers and managers if one existed

6. That we could add to the stock of procedures to prevent a gap from appearing or to help close it once it appeared

Method

We early recognized that the empirical literature was inadequate for our purposes in three respects.

First, little of the literature specifically discussed engineers. Most of what did discuss engineers was too abstract to give any feel for how managers and engineers deal with each other day to day.

Second, the only works that did give such a feel were the congressional hearings, court cases, and investigative reporting that scandals generate. Engineers were, we assumed, likely to err on the side of safety and quality. Such errors may hurt corporate profits or even ruin a company, but they do not produce a public scandal. Managers, on the other hand, seemed likely to err on the side of profit or consumer satisfaction. Because such errors tend to threaten safety or quality, they are likely to create just the sort of disaster the public would be interested in. Thus, the scandal literature, standing alone, seemed likely to be skewed against managers.

Third, engineers are seldom in a position to produce an interesting disaster by themselves. Managers have to be involved. When managers are involved, they have to take the blame, whether or not they relied on their engineers. It would be their decision, however poorly they were advised. Engineering advice thus tends to be invisiblewith one exception. When the disaster happens because the manager did *not* take the engineers' advice, the engineers' advice suddenly becomes visible. Why, everyone wants to know, did the manager not take *that* advice? It is, then, not surprising that the scandals getting the most attention are those where communications between managers and engineers broke down. When a manager correctly overrules an engineer, nothing newsworthy happens.

So, we could not rely solely on the scandals literature for an understanding of how managers and engineers *normally* work together. We needed to investigate directly how engineers and managers work together under more or less normal conditions (that is, without the selective hindsight disaster gives).

We developed one questionnaire for engineers and another for managers (see Appendixes 1 and 2). We then tested the questionnaires at one company and made minor revisions, mostly clarifications in wording so that, for example, it was clear that we were interested in disagreements on "technical" rather than "personnel" matters. We then interviewed at three more companies. Only then did we add the starred questions, preserving the original numbering to make reference easier.

The questionnaire had four functions: (1) to tell us what the engineer or manager did, his daily routine and place in the organization's work; (2) to tell us what his relations were with management (if he was an engineer) or with engineers (if he was a manager); (3) to help us identify those practices that contributed to good communications and those that did not; and (4) to see whether we could identify a breakdown in communications of the sort Feynman found in the shuttle program. The questionnaire was designed to structure an open-ended interview lasting about ninety minutes.

After developing the questionnaire, we contacted companies that employed engineers. The smallest employed four engineers (two without degrees); the largest, more than ten thousand. Except for one construction company, all were engaged in manufacturing. They ranged from companies with relatively benign technologies such as electronics to a company with a relatively dangerous technology (manufacture of petroleum-based chemicals); from companies that are primarily parts suppliers to companies that produce primarily for end markets; from a company with one location to several large multinationals (one of which was closely held).

These companies were not chosen by chance. Our original budget kept interviewing within the Chicago metropolitan area. Even after the budget was revised to allow interviews at two locations beyond an hour's drive of Chicago, we were selective. We assumed that few companies would be willing to let just anyone interview their employees on company time. We therefore limited our contacts to companies at which one of the research group had an "in." [27] The result of this mode of selection may be a bias in favor of "good companies."

Perhaps for this reason, one sort of bias we expected did not occur. We expected some self-selection (even though we promised that our report would name the company only to acknowledge its help or to recommend one of its procedures). Agreeing to participate meant that the company had to think what we were doing was important enough to be worth the time we would take out of the working day of its managers and engineers. The company also had to feel comfortable having outsiders probe into day-to-day operations. Every company we asked to participate wanted to know what we were going to do before they agreed. Management saw our project proposal and both versions of the questionnaire. We made no effort to conceal our interest in ethics. Any company without a sense of social responsibility or without a clear conscience would, we thought, refuse. To our surprise, not one of the ten companies we contacted refused, insisted on control over what we published, or even suggested that the company be allowed to comment before we published. All did, however, ask for a copy of the final report. (We gave each a chance to comment on a draftto see whether our sense of their technical decision making fit theirs.)

Once a company agreed to cooperate, we (the research group) indicated that we were not interested in interviewing just any manager or engineer. We were interested in the "interface between management and engineering functions." We wanted engineers who dealt with managers and managers who dealt with engineers. We left it to the company to choose the managers and engineers to be interviewed. Their choice seemed determined primarily by who, among those who would be appropriate, could be available on the day we were to interview. Generally, we got to interview a manager and one or more engineers who worked together rather than two unconnected individuals. In a significant number of cases, there were lastminute substitutions because "something came up" (for example, an emergency at a distant plant or a meeting date had changed). Often, it seems, a company simply asked for volunteers from among those in the appropriate category. We never had a sense that we were interviewing from a "stacked deck."

Small companies had no trouble understanding what we meant by "manager" and "engineer." But, to our initial surprise, companies with large numbers of engineers did. In these companies, there was no single interface between the engineering and management functions. Two, three, or even four levels of organization might stand between employees regarded as "just engineers" and others regarded as "just managers." In such companies, we said we wanted to interview some from each level, beginning with "bench engineers" and ending with the first level of "just managers." For this reason, we conducted more interviews in large companies than in small.

All interviews were conducted at the company on company time and usually within a few feet of where the engineer or manager worked, either in a conference room or in a private office. The only people present during an interview were the interviewers and the interviewee. We did not use a tape recorder. Generally, we had two interviewersone to ask questions and one to take notes. 28 Occasionally, the note taker would ask a clarifying question. The interviews began with introductions, an explanation of the interview's purpose, an assurance of anonymity for the interviewee, and a promise to identify the company only to thank it for its cooperation or to point out a procedure others might want to copy.

The interviewer then asked, "Manager or engineer?" This often occasioned a brief discussion useful in understanding how the organization thought about engineering. We abided by the individual's decision. This method had one troubling consequence. Some "group leaders" (those who look after the work of four to six bench engineers) are treated as engineers, while others with the same responsibilities in the same company are treated as managers. This is less troubling than it may seem. We were, after all, concerned with understanding our interviewees' work from *their* perspective. However, we have taken one precaution against any bias this method might introduce. Whenever we quote a group leader while contrasting the perspective of manager with that of engineer, we indicate that the person quoted is not only an engineer or manager but also a group leader.

Once the interviewee decided that he was a manager or an engineer, the interviewers worked from the appropriate questionnaire (adding a spontaneous question now and then). Though we tried to get a copy of the questionnaire to each interviewee at least a week before the interview, about half the interviewees did not see

the questionnaire in advance. Those who received a copy in advance indicated that they had read it and given it some thought. A few had even made notes. Our impression is that those who had the questionnaire in advance tended to give fuller answers. Otherwise, the answers given by those who had the questionnaire in advance did not seem to differ from the answers of those who did not. No interviewee gave any indication that he had discussed his answers with a superior.

We interviewed a total of sixty engineers and managers. All but one were male (indicating, we think, how few women these companies employ in engineering work). These sixty represented all the major fields of engineering: mechanical, electrical, chemical, civil, and metallurgical. They included engineers in design, testing, and operations (both manufacturing and construction). Not all were trained in the United States. At least one was trained in each of the following countries: Canada, Netherlands, what was then West Germany, what was then East Germany, Poland, India, and Japan. Most of the foreign-trained respondents had worked as engineers before coming to the United States. In the large companies, the most senior managers interviewed were middle level; in the smaller companies, they were close to the top of the company.

Initially we expected that engineers would have engineering degrees and managers would have management degrees. Although most engineers in most companies were in fact "degreed," we occasionally came across an older "engineer" who had been "promoted from the shop floor." In one company, however, promotion from the floor was still common. That was also the one company in which we interviewed three managers who had neither been trained as engineers nor worked as engineers. We sought out that company when we realized our initial sample of managers consisted entirely of former engineers (most with a baccalaureate in engineering, whether or not they held an MBA or other management degree). Because the common wisdom is that "business schools, not engineering staffs, are [now] the favored sources of managerial expertise," 29 we were surprised at how hard it was to find a company with a significant number of managers of engineers who were not themselves engineers. We now doubt the common wisdom on this matterat least for the management of engineers.

Our interviews cannot provide a complete picture of the way managers and engineers work together. What they provide is a part of the picture different from that given by the scandals or the existing management literature. Ours is a study of *technical* decision making under *normal* conditions (or, at least, without the benefit of hindsight that a disaster brings).

The picture is somewhat fuller than our method of selecting companies and their absolute number suggests. Just over a third of our interviewees (ten managers and eleven engineers) had worked for at least one other employer first. Several others had worked for another branch of the same corporate family (in Germany, Japan, or India). We encouraged these interviewees to compare their present employer with their previous one or their employer's practices here with its practices abroad. This gave us some insight into a kind of company not officially represented.

Some of the interviewees had worked for their present employer for several decades, long enough to see important changes in relations between managers and engineers. We encouraged those interviewees to compare past and present. These comparisions imparted some sense of history to what would otherwise have been a snapshot of the present. [30]

Evidence

My discussion of evidence has five parts. The first compares the perspectives of engineers and their managers. The second distinguishes three kinds of company according to the criteria emphasized in engineering decisions. The third describes how engineering decisions are normally made, noting differences related to kind of company. The fourth considers the effect of an open-door policy, a code of ethics, and other devices (including some not in the literature) on how engineering decisions are made. The fifth describes a breakdown in the normal decision process that our questionnaire uncovered, an undramatic form of what led to the Challenger disaster.

Engineers and Managers: Some Differences

Question 11 on the manager's questionnaire ("Are engineers good management material?") and the identical question 12 on the engineer's were designed to encourage interviewees to compare and contrast managers' and engineers' ways of doing things. We also expected answers to question 5 on both questionnaires ("Is the company's management trained or versed in the company's technology?"), question 12* on the manager's questionnaire ("What questions should an engineer ask you to get the information he needs . . .?"), and question 13* on the engineer's ("What questions should a manager ask you to get the information he needs . . .?") to provide useful information about differences between engineers and managers.

What we found was that the engineers and managers interviewed were virtually unanimous in the way they distinguished the engineer's perspective from the manager's. Both engineers and managers agreed that some engineers could be good managers, but they also believed that engineers had to change (and that those who could not would not make good managers). Three sorts of change seemed to be involved (apart from learning how to do budgets, fill out personnel reports, and the like).

First, an engineer must pay less attention to engineering to be a good manager. "Letting go of the hands-on-the-bench engineering was," for one manager, "the most difficult part for me." Another in a different company made the same point: "An engineer [when he becomes a manager] must look at the picture differently and detach himself from the details of the job." An engineer (in that company) made the same point: "Engineers that can't wean themselves from the engineering work make bad managers. . . . You have to learn to let engineers do the engineering." The most negative comment about engineer-managers came from an engineer in another company: "No, engineers aren't good management materialunless given specific training. Engineers have trouble giving up control over every detail."

Second, not only must engineers give up control of engineering details, they must, as one manager put it, "develop a broader horizon and look at the big picture." For another manager (at another company), that broader horizon included learning "to think forward, think about others, think in terms of human resources." Connecting the first change to the second, another manager put it this way: "We have to move from reaching the conclusions to guiding the process which reaches the conclusions."

The engineers could not have agreed more. One suggested, "The engineer turned manager needs to appreciate what it takes to implement his project . . ., to take cost into account and . . . to track performance on a weekly basis." Another in a different company made the same point: "He must learn to handle responsibility and learn to get things done through his people. He can't do it all himself."

Third and more fundamental, the manager must not only widen his horizon but also change the character of what he does. "Engineers like to work with things," as one engineer noted, "[but] managing is more a matter of people than things." Or, as another engineer expressed it, "Socially adept engineers make good managers. Others should stay away from management." Managers made the same point. One recalled, "I had to become much more people sensitive." Another observed, "You have to build effective working relations with your people."

Unfortunately, we did not ask in what ways an engineer turned manager should *not* change. Nonetheless, we did receive some relevant responses, most from managers. Here again, there seemed to be a consensus. "[The manager] shouldn't lose his technical touch," said one manager. If he does, observed another in a different company, he will become "too superficial" and "no engineer goes to this type of manager for help." "Technical understanding," according to one engineer, "is crucial at times. What's needed is a fine balance [between technical understanding and holding on to one's engineering loves], and it is seldom found."

Although most companies at which we interviewed provide some formal training for an engineer turned manager, either in-house or more often by paying tuition, the general opinion was that the training was not much help (except in handling personnel and technical business matters). A surprising number of both engineers and managers answered question 11a (for managers) or 12a (for engineers), "None" or "None, really," while others in the same company (often in the same department) reported such training. One engineer answered in a way that may explain this apparent disagreement. Having answered, "None to my knowledge," he added, "We have a management training program, but it seems pretty hokey, so I don't go to it." A manager in the same company gave an answer that at once suggests the vast scale of the company's efforts and the great difficulty of the undertaking. Having answered "No transition training," he went on, "Well, we do have some supervisor development courses. And an MBA program. Role models. But that's about it. Nothing that really prepares an engineer for the transition." Perhaps an engineer in another company best expressed the underlying difficulty: "Engineers know their products but management is a trait."

For most managers we interviewed, the most helpful preparation for managing was early experience at the edge of management, for example, as group leader, together with a certain amount of informal coaching. Most managers seem to be trained "on the job." Those engineers who can't change enough (or don't want to)what one manager called "the scholar type"never get beyond group leader. The rest get more and more management responsibility (and less time for engineering) until they become full-fledged managers.

The transition from engineer to manager then, is not primarily thought of as the acquisition of technical knowledge an engineer can't expect to understand. 31 A manager may indeed know about matters an engineer does not because the manager gives his attention to matters an engineer does not (just as the engineer gives his attention to matters the manager does not). But the manager's knowledge is in principle as easy for the engineer to understand as it is for the technically trained manager to understand what the engineer knows. The good engineering manager differs from the bench engineer primarily in being able to do his engineering *through* other engineers. So, according to this common understanding of management, an engineer and an engineer turned manager should have no more trouble communicating their respective (technical) concerns to each other than one engineer or manager has communicating them to another.

This common understanding may explain both why we found so few nonengineers to be managing engineers and why those few were concentrated in production. According to our interviewees, production is that part of engineering where experience, rather than technical training, is most likely to be the decisive factor. Even so, we noticed unusual friction between production engineers and their nonengineer managers. At the one company that did have nonengineers managing engineers, one college-trained engineer told us, "I have to explain to my own manager in `baby talk' since he is not an engineer. This is frustrating. I pull my hair out when he repeats my recommendation to his manager since he presents the recommendation incorrectly." One college-trained nonengineer manager confirmed this description (while giving the manager's side): "Sometimes engineers will spoon feed me. Then I'll tell them to hurry up. Or they'll water the information downyou know, talk about apples and bucketsthen I'll tell them to talk about engines. Engineers often don't know how to talk to nonengineers."

What we derived from these interviews was not so much an impression of a breakdown of communications between engineers and their nonengineer managers as of an inauspicious thinning out of communication. A lot of important information seemed to be "lost in translation." We found something similar in the one company at which many of the managers were foreigners struggling to perfect their English. Thus, one American engineer gave us this example (after making clear that he thought his manager was a good engineer): "Let's say we discover a design change is needed on a local part. I might make the change myself and put it into operation and then tell my manager. This is just a simpler way to go. If I had an American manager, it would be easier to explain the fine details and involve him." Good technical communication is surprisingly fragile.

Three Kinds of Company

The companies at which we interviewed seem to be of two kinds: "engineer oriented" and "customer oriented." To these two kinds must be added a third, "finance oriented." Although none of the companies at which we interviewed was finance oriented, we did hear about finance-oriented companies from several interviewees when they contrasted their present employer with a previous employer or the way their employer does things now with the way it used to do them. Finance-oriented companies seem to be different enough from engineer- and customer-oriented companies to be treated separately. 32

An *engineer-oriented* company is distinguished by general agreement that quality is the primary consideration (or, rather, the primary consideration after safety). So, for example, in one such company, an engineer volunteered, "It is company religion to seek perfection." A manager in the same company was equally definite: "We have overdesigned our products and would rather lose money than diminish our reputation."

Such companies do not ignore cost but, as one engineer put it, "Cost comes in only after quality standards are met." They also do not ignore their customers, but they are likely to take pride in how often they say no to them. So, for example, one manager at such a company told us, "If a customer wants to take a chance, we won't go along." An engineer at the same company told us: "We do actually say no to customers. . . . We refuse customer applications to exceed our ratings in spite of these often being big-ticket items where money losses can be significant. We will negotiate with customers to move them within our specifications. We very rarely budge from this posture."

Such a company is not likely to maximize return on investmentin the short term at least. But it can be successful by another measure. Each of the four companies we identified as engineer oriented told us it had a large and growing share of the markets in which it competed. Two were closely held; three (including one of the closely held) were large multinationals.

We do not call a company "engineer oriented" because engineers in fact run it. Like Morton Thiokol, all the companies at which we interviewed had engineers (or "former engineers") at all levels up to (and sometimes including) executive officers. Rather, what led us to call some companies engineer oriented is that their way of doing business closely fit the stereotype of engineers as concerned primarily with safety and quality (and of managers as differing from engineers in their greater concern with customer satisfaction and finance). The companies we call engineer oriented were therefore ones in which the engineers felt at home. What was surprising was that the managers in these companies seemed to feel exactly the same way.

Still, even in such a company, the expression "take off your engineering hat and put on your management hat" would not have been meaningless (even ignoring personnel matters). The engineers were likely to think the managers "more cost oriented." Managers, on the other hand, could still contrast the engineer's tendency "to go into too much detail" with the manager's tendency to be "too superficial[to] want only a `go or no go' decision."

The contrast with *customer-oriented* companies is nonetheless substantial. For customer-oriented companies, customer satisfaction is the primary consideration (or, rather, the primary consideration after safety). "The main objective," as one engineer in such a company put it, "is meeting the customer's requirements." A manager in the same company gave this example: "If a particular batch can't meet specs, we might call the customer, tell him what we have and ask whether we should ship anyway." In place of the engineer-oriented company's *internal* standard of quality is the *external* standard of what the customer wants or is willing to accept.

In such a company, the engineer's concern with quality *regularly* comes into conflict with management's concern to satisfy the customer. Consider, for example, the question: Should we substitute a cheaper material for a more expensive one, making a part significantly less durable, if the part's probable life is still significantly longer than that of the machine into which it will be put? Both engineer-oriented and customer-oriented companies have to answer such questions. In an engineer-oriented company, it will probably be understood as an engineering question, that is, as a question about how to define quality. In a customer-oriented company, however, it will probably be understood as a choice *between* engineering standards and management standards, that is, as a choice *between* quality ("lowering standards") *and* giving the customer what he wants ("a cost-effective solution" to his problem). So, even if the decision is ultimately the same, the dynamics of deciding will be different (in this respect at least).

The *finance-oriented* company resembles the engineer-oriented company in having an internal standard of success but resembles the customer-oriented company insofar as that standard is distinct from quality. For a finance-oriented company, certain business numbers (for example, gross profit or return on investment) are the primary considerations. Customer satisfaction and quality are relevant only as means of maximizing those numbers. As one former employee of a finance-oriented company put it, "[The] attitude [there] was `we get by with what the customer cannot detect.'"

Finance-oriented companies tend to measure success in tons produced, units out the door, or other *quantities* rather than in ways explicitly acknowledging quality or customer satisfaction. Although we might expect engineers to prefer such hard measures to quality or customer satisfaction, all references to finance-oriented companies were negative or at best neutral. One manager recalled that "the production process [there] was driven by a `units out the door' mentality which often inhibits quality and cost-effectiveness." Another manager recalled with obvious pain being asked to make small adjustments in test results (that is, as he saw it, falsifying the data) so that a product could be said to meet customer specifications and be shipped. The standard of success in a finance-oriented company seems to be much more foreign to engineers than that of a customer-oriented company.

Being a finance-, customer-, or engineer-oriented company is not, like being male or female in humans, a matter of being more or less permanently one or the other. We interviewed at one customer-oriented company that seemed to be consciously trying to become engineer oriented. (The engineers reported these efforts with a tone of "at last," while the managers were plainly having difficulty adjusting to the new demand for quality.) We also interviewed at several companies that seemed to have gone from finance oriented to customer oriented within the last decade or so. We even interviewed at two companies which we assigned to the customer-oriented (rather than to the engineer-oriented) category only after considerable discussion. What made these companies difficult to classify was that one of their largest customers was pressing them so hard for quality that they themselves seemed to be

uncertain whether they thought quality a mere means to satisfy a major customer or something good in itself.

The distinction between engineer-, customer-, and finance-oriented company is probably best thought of as a rough topology useful for organizing the data presented here or as specifying "ideal types" actual companies only approximate to varying degrees (with perhaps some departments or divisions in the same company belonging to one type while others belong to others). The distinction has no obvious connection with that other ideal type, "the technology-driven company." Most of the companies in our sample probably qualify as technology driven.

Normal Decisions

Questions 3, 4, and 7 on the manager's questionnaire and questions 3, 4, and 6 on the engineer's questionnaire were designed to tell us who made the decisions and how they were made. Question 8 on the manager's questionnaire and question 10 on the engineer's questionnaire were designed to tell us whether the interviewee approved of existing practice. In fact, questions 8 and 10 (about how decisions *should* be made) often led interviewees to modify their description of how decisions *were* made. Occasionally, questions 12 and 12* (for managers) and 13 and 13* (for engineers) also led to such modifications.

Engineer-Oriented Companies

Some of our interviewees initially described what sounded like a modern version of the staff-line division between managers and engineers. For example, one manager told us, "Managers nearly always make the decisions"; another, "Managers have the most weight." One engineer put it this way: "[The engineer] gives the best advice he can but it's their money." Another told us that, in case of disagreement, "The boss typically wins."

However, such comments were largely contradicted by what even these interviewees went on to tell us about decision making in their company. For example, the same manager who told us managers nearly always make the decision also told us: "If an engineer has a good case, a manager seldom, if ever, would overrulethat is, if the engineer really feels it won't work. However, a manager might step in regarding costs, customer preferences, or some life cycle strategythat is, something that is not absolutely engineering in nature." In the same vein, the engineer who told us the boss typically wins added, "I haven't experienced this."

What in fact emerged from our interviews was a process of "negotiation" (as one manager called it) much more reminiscent of an academic department than an army barracks. Engineers' "recommendations" were often indistinguishable from decisions. Managers generally "overruled" engineers' recommendations only when nonengineering reasons (such as cost or schedule) seemed to outweigh engineering considerations. Managers generally let the engineer do the engineering. And even when they "overruled" an engineering recommendation for nonengineering reasons, they did not literally overrule it. Instead, they presented the additional reasons to the engineer and sought the engineer's concurrence, either by winning him over with the new information or by seeking some compromise. Consensus seemed to be the mark of a good decision; outright overruling, something to be avoided at almost any cost.

This process of seeking consensus (a better term than "negotiation") seemed to rest on three assumptions: (1) that disagreement about any engineering or related management question is ultimately factual; (2) that when reasonable technically trained people with the *same* information cannot reach consensus on a factual question, there is not enough information for a good decision; and (3) that, except in an emergency, putting off the decision until there is enough information (or a better understanding of the information available) is better than making a bad decision. Our interviews suggest that these assumptions are shared by engineers (and engineer-managers) at whatever kind of company they work. These assumptions, however, are likely to be more potent in an engineer-oriented company. There the priority given quality gives engineering considerations a force they cannot have when customer satisfaction or "the numbers" carry more weight than quality.

Whether such considerations as quality or customer satisfaction are literally factual is a philosophical question we may ignore here. What we mean by calling such considerations "factual" is simply that experience teaches those who disagree about such matters to expect to settle their disagreements by further testing, other new information, or reconsidering information already available. For our purposes, what is important is that engineers and managers *do* expect to agree on questions of safety, quality, customer satisfaction, and cost even if they do not expect agreement on anything else.

The power of these assumptions can be seen in comments like the following. Asked whether he and his engineers always see eye to eye, one manager, having answered no, went on to explain: "There are different ways to approach a problem. Young engineers are often inexperienced and need to learn from their mistakes. There are no real differences, though, on matters of safety and qualitythese are pretty much black and white." Asked how much weight an engineer's recommendation should have, he responded 100% and added, "I've always reached agreement with my engineers." Another manager informed us that if a manager and engineer disagree over a major technical decision "engineers and managers go to a boss together . . . The boss then decides. But we haven't had major problems here."

Engineers sketched a similar picture. Asked how engineering decisions were made in his company, one engineer responded, "I'm handed a design and asked, `How do we produce this?' Eventually I make a recommendation. My boss, a supervising engineer, says yes or no. If he says no, he gives reasons. If I'm not convinced, there's no standoff; we just go out and test." The boss seems to have no more weight in the decision than the engineer. The ultimate arbiter is another test. Another engineer, the one who said he gave the best advice he could "but it's their money," nonetheless reported that he and management "*always* see eye to eye *in the end*." In fact, he had never been overruled.

This process of reaching consensus seems to presuppose that engineers and managers have the same information. Because openness about technical and related business matters would seem to be crucial to reaching such a consensus, what engineers and managers at these companies report about technical communications is important. Questions 9 and 10 (on the manager's questionnaire) and question 8 (on the engineer's questionnaire) were intended to tell us how open communication of technical information was.

Managers at engineer-oriented companies were unanimous that *they* never withheld technical information from their engineers. Though evenly divided about whether their engineers ever withheld information from them, managers never indicated they thought their engineers' conduct a problem. One manager's answer may explain why. Having said that his engineers do sometimes withhold information "to cover up a mistake," he added: "Sometimes I need to ask questions to determine who made a mistake." Another manager put the point more gently: "I believe that engineers never intentionally withhold information, [but every] person tries to put his best foot forward." In an engineer-oriented company, the natural tendency of engineers to withhold embarrassing information seems a small impediment an experienced manager can overcome with a few probing questions, not anything likely to affect significantly the free flow of information.

The engineers saw things a bit differently. They generally agreed that their managers were open with them. Only one thought there "have been cases when the boss had information and did not give itbut never knowingly." On the other hand, *none* reported knowingly withholding informationexcept, significantly, in the company with foreign managers and American engineers. For one engineer, the problem was "the other way": "Usually . . . I provide too much detail to my superiors. I have had to learn brevity. But there is a fine line between too much and too little. I believe in open communications, and for that reason I don't hold back."

Another engineer, while denying that he ever withheld information, did admit that "lots gets lost in translation."

In any organization, the ultimate test of openness is bad news. Our interviews at one engineer-oriented company provided an example of how bad news was handled. The example gives some insight into how such a company remains engineer oriented even under the market's constant pressure to pay more attention to customers.

A manufacturer of motors for pleasure boats asked the company to make a part for the manufacturer's engine that would outlast the engine under normal operating conditions but would quickly wear out if the engine operated at full power for very long. A part adequate for extended operation at full power would have been much more expensive. Company policy was to make parts so that they would outlast the engine, however it was used. So, the engineer in charge recommended against making the part. After much back and forth along the chain of command, the engineer's superior decided to go ahead, explaining the decision this way: "There is no safety issue even if the motor fails. There is no real quality issue, either. Pleasure boats are *never* run at full power long enough for the part to fail. Hence, the part will be cost-effective for the use it will serve. I do, however, agree there is at least the possibility of legal liability here should the engine be misused. So, we must take care to inform the customer of our concerns in writing and require him to take full legal responsibility for the part."

A few years later, the customer sold out to someone who made towboats, as well as pleasure boats. The new owner promptly put the engine on its towboats. The part would fail after only a few hundred hours of towing. Legally, the

company was in the clear. But, because its name was on the part, it received some complaints.

We heard this story from both managers and engineers. We heard it not only in the department involved but also in other departments. Each person who told the story treated it as a cautionary tale. The company had taken a risk it should not have. No one wondered whether the profit from the deal might have justified the risk or argued that satisfying the original customer excused it. The bottom line was that the decision had harmed the company's reputation. What could be worse than that? Here was an experience to learn from, not a skeleton to be locked away in a closet and forgotten. As one engineer predicted with evident pride, "We probably won't do anything like that again."

Customer-Oriented Companies

Decision making in customer-oriented companies is similar to decision making in engineer-oriented companies. Once again we heard echoes of the staff-line division in interviews that eventually revealed a quite different process. For example, a manager who first told us that "engineers lay out options; managers choose," immediately corrected himself: "Well, managers choose when the decision involves risks or resources. Other decisions, purely technical ones, are really for engineers." Similarly, the same engineer who initially told us "The manager decides," later told us, "If I don't like a decision, I would go to my boss. I could go to my boss's boss, too, but I never had to. . . . Technical questions are talked out."

The search for consensus was again central to decision making.

One engineer at a small company described decision making quite simply: "We operate by consensus." A manager in a large company described the process in greater detail: "Engineers have high weight on technical issues. The problem is integrating technical recommendations into company interest. Cost. Marketing strategy. Change in technology. Etc. It's important that the engineer's recommendation get out beyond the immediate group. When he sees how his decision does not fit into the large picture, he's likely to rethink it."

Despite the basic similarity between decision making in engineer-oriented and customer-oriented companies, we did notice four significant differences. Customer-oriented companies seemed to (1) assign greater importance to the engineer's role as *advocate*; (2) place more emphasis on nonengineering considerations in decision making; (3) be more explicitly concerned with safety (even though the technology seemed no riskier); and (4) have more difficulty maintaining open communications. Let's consider these in order.

1. In most of the customer-oriented companies at which we interviewed, relations between individual engineers and managers seemed as good as at the engineer-oriented companies. Yet, the managers repeatedly stressed the need for engineers to "hammer" on their recommendations. One manager at a small company thought that "an engineer should be willing to go to the mat if he feels strongly that quality is violated." A manager at a large company agreed: "Engineers should never be content to see their professional judgment superseded. If there's a good reason for

the manager's decision, the engineer should agree. If the engineer doesn't agree, something must be wrong. Everyone should keep talking."

The managers clearly thought of their engineers as advocates of a point of view which, though different from their own, had to be weighed against their ownor rather, integrated with it. There was no mystery about how the two points of view differed. According to one manager, "[satisfying] the customer's needs [involves] three factors . . .: quality (which is a technical matter), timing (which is a concern of sales); and specs/cost." The engineers spoke for the "technical." A manager at another company contrasted his role with the engineers' this way: "It has to be decided where the line is on a specification. For example, how `perfect' does something have to be. I occasionally have to explain, `Hey guys! It doesn't have to be absolutely perfect.' . . . The customer's needs are the most basic consideration." Another manager at this company gave the same picture but in a phrase familiar from the Challenger disaster: "The most important factors in company decisions are business issues: What does the customer want? What are his expectations? What can we do to optimize given time and quality requirements? Often, it's time *versus* quality. And then you have to decide which hat to wearengineer's or manager's."

2. Engineers in most customer-oriented companies seemed to acceptor at least be resigned tothe conflict between technical and business considerations. As one engineer put it, "Cost issues are constraints I can understand." There was, however, one company in which the engineers showed no such resignation. This was the customer-oriented company that seemed to be trying to become

engineer oriented. Here, for example, one engineer told us: "Technical questions get short-changed to make schedule. `We can do it better,' I say, but my manager says, `No time.'" Another engineer said with evident disgust, "They'll sacrifice quality to get it out the door," adding, "Why not do it right the first time rather than taking a lot of time later to patch up a system?"

3. In engineer-oriented companies, "safety" and "quality" were mentioned in the same breath (when "safety" was mentioned at all). That, however, was not true in customer-oriented companies. In customer-oriented companies, safety had the same absolute priority it had in engineer-oriented companies, but it was mentioned much more often. So, for example, the same engineer who said quality was sacrificed to get products "out the door" stressed that he "never felt safety was being sacrificed." Many engineers also told us that they should have the "last word" on safety (even though they did not claim the last word on anything else). Managers agreed, "It's okay to overrule an engineer's recommendation on a business issue. But on safety, exposure to dangerous materials, etc., the engineer should have the last word."

4. Given the importance assigned consensus in customer-oriented companies, open communications should be as important in such companies as in engineer-oriented ones. Many of the managers seemed to believe so. Indeed, generally, they were more emphatic about being open with engineers than the managers at the engineer-oriented companies. Thus, one manager observed (in response to question 9), "I never withhold technical information. That's dumb." Another (at another company), "Never. That's dangerous." A third, "There's no need . . . We've got strict rules on use of information."

Yet, in each customer-oriented company at which some managers answered in this way, others reported withholding information relevant to technical decisions. For example, one manager admitted: "I have withheld proprietary information, for example, relating to preparations for a joint venture that might mean using a different technology." Others, while denying that they had withheld information, reported superiors withholding information from them: "I should add," said one, "that engineers are often in the dark and are subject to last-minute surprises. Our department last year was working on existing products, things that were familiar. We were not told about any new possibilities or any new product challenges. We were provided only with vague clues. I don't know why."

These managers also seemed more concerned about engineers withholding information from them than were their counterparts at engineer-oriented companies. Thus, one manager reported, "Engineers tend to give me a rosier picture than is factual just to continue getting my support. I try to counteract that by MBWA [management by wandering around]. This is a lot more effective than formal performance reviews." Another manager at the same company stressed the dark side of such withholding: "Yes, but it only happens when they don't know enough to know what to tell. For example, now and then, a guy gets into trouble and thinks he can fix it himself. The result is I find out when it's too late to helpand I get burned, too. That's happened a couple of times in my career." A manager at another company put it more succinctly: "Do they withhold information from me? When they screw up, yes."

Yet, other managers at these same companies denied that their engineers ever withheld technical information from them. One manager was more cautious: "This is the toughest question on the list. I've occasionally had the feeling there was more there than I could see in the engineer's report."

Engineers gave an equally mixed report on communications. For example, one engineer told us of a "recent survey" that indicated that "people believe upper management holds back information from the company," adding, "My current manager does not withhold information from me." An engineer at another customer-oriented company admitted to the "feeling" his superior was withholding technical information. Yet, most engineers reported that they did not think their managers withheld technical information from them.

Interestingly, unlike engineers at engineer-oriented companies, engineers in some customer-oriented companies did report withholding information from managers. One observed, "I have, but I'm not sure it was necessary. I have withheld a theory or brainstorm until it was tested to verify it positively. I have delayed bad news in order to retest first." A group leader at another company admitted, "I sometimes don't tell my manager about a decision, if I am already quite comfortable with it."

Technical communication in customer-oriented companies thus seems to be somewhat less open than in engineer-oriented companies. Given how much these companies differed, the cause of that tendency is probably complex. Still, two factors are clearly relevant. First, the relatively greater importance of business information in decisions of customer-oriented companies seems likely to change the nature of withholding such information. Even if the same amount of business information were withheld in a customer-oriented as in an engineer-oriented company, its with-

holding would be more likely to threaten consensus in a customer-oriented company (where it would be a more important part of the big picture). Second, the greater emphasis on the engineer as advocate in customer-oriented companies may itself tempt engineers to engage in lawyerly tactics. But, whatever the cause, a customer-oriented company that wants to decide by consensus will, it seems, have to take more care to keep information flowing than an otherwise similar engineer-oriented one.

Perhaps this is the place to note that we found little in relations between managers and engineers that resembled the ruthless gang culture Jackall reported. What explains that? At least two factors may help explain the apparent difference between what Jackall reports and what we report. One factor is that Jackall's description may be true only of companies against which our method of selection was biased. Our method of obtaining interviews seems to have selected in favor of "good companies"; Jackall's method probably did not. Another factor may be that what Jackall describes begins *above* the engineering departments in the companies at which we interviewed. Interestingly, we did find one manager supporting this explanation (but without any example from his experience). A group leader responded to question 12* (in part): "Higher managers often become involved in company politics, however, and may compromise our engineering values. As managers go higher up [here], their engineering values become corrupted, in my opinion. No, I cannot think of any precise example, I am a blank right now. But, managers can become selfish. They want to be promoted and will enhance this prospect by focusing on high-visibility projects that look good."

Finance-Oriented Companies

We do not have enough information in our interviews to conclude anything about the normal decision making process in finance-oriented companies. We do, however, have enough to offer four related hypotheses:

1. Because finance-related information tends to be centralized in a way customer-related information is not, engineers in a finance-oriented company normally receive less information crucial to company decisions than in a customer-oriented company.

2. Because engineers receive less crucial information, their recommendations will carry less weight in finance-oriented than in customer-oriented companies.

3. Because their recommendations carry less weight in finance-oriented companies than in customer-oriented companies, finance-oriented companies are less likely to try to reach consensus with their engineers.

4. Because finance-oriented companies are less likely to try to reach consensus with their engineers than customer-oriented companies are, they are more likely both to compartmentalize decision making and to treat engineering as a staff function. As one manager remembered: "[At his old finance-oriented employer], a report couldn't leave the department without the co-signature of a manager. . . . The engineering function can be muzzled by a heavy-handed management. . . . Management's pressure on engineers sometimes results in low quality."

The Effect of Various Devices

The literature surveyed in the section "Relevant Literature" recommended a number of devices to improve communications within an organization to reduce the chance that the organization would do something wrong. What do our interviews tell us about those devices? We found nothing like Waters's "ethical audit" or Raelin's awards for bringing bad news. Though one company had a mentoring program for engineers of the sort Raelin suggests, no interviewee mentioned it. Our interviewees did mention the following devices however: a code of ethics, ethics training, open-door policy, ombudsman, and reduced compartmentalization (including such things as a technical promotion ladder paralleling the management ladder). Except for reduced compartmentalization, none of these devices was common to more than a few companies. Some occurred at only one. In general, the large companies were more likely to have adopted some of these devices than the small were; the customer-oriented companies more likely to have done so than the engineer-oriented companies. I have organized evidence concerning these devices under three headingscodes, appeals, and reduced compartmentalization. Except for reduced compartmentalization, none of these devices seems to have had much effect on technical decision making. We also came across one informal procedure, "bringing others in," and one formal procedure, "independent technical review," neither of which was mentioned in the literature. I discuss them as well.

Codes

At four of the six customer-oriented companies we interviewed, some of our interviewees answered yes to question 4.b on both questionnaires: "Does your company have a code of ethics?" Most of those so answering were managers. Their answers were often qualified. And they often disagreed in important details. Consider, for example, these two answers from managers in the same company. "We have a *business* code of ethicsno gifts, etc." one told us, "but we have nothing called a `code of ethics' for engineers, nothing that would, for example, provide guidance if someone orders an engineer to change test results." Yet, another manager at the same company thought not: "Well, there are policies on . . . e.g. entertainment. But no formal codeexcept [the CEO's] letters. Nothing written, for example, on how a technical rep should act in a customer's plant." In another company, one manager informed us, "Yes, we have a code of ethics. We're even going to get a lecture on it from the legal department tomorrow. But it doesn't affect engineering work. What matters is the `spec book.'" Yet, another manager there (a group leader) answered, "I think we have one, but I'm not sure. I vaguely remember being given a pamphlet when I was hired that said something about all this."

If that is how managers described their company's code of ethics, what did the engineers say? Most either told us that their company had no code or responded in some such way as this: "No real corporate code, just individual standards. Maybe there's a code of ethics somewhere . . . but I don't know of it."

Because the corporate codes apparently have little to say about engineering decisions, any training in those codes could have little effect on those decisions. We are then in no position to judge the effect of appropriate ethics training on the way engineers and their managers make technical decisions. As far as we could tell, no company has a code appropriate for engineers.

No one at any company at which we interviewed mentioned a *professional* code as a guide to decisions, and, as far as we can tell, no company at which we interviewed had ever circulated or endorsed the code of any professional society. Our interviews gave us no insight into why that was so. Our interviews did, however, suggest that one explanation should be ruled out. Engineers, it might be thought, did not mention professional codes because they had no sense of themselves as professionals. Yet, some of the engineers we interviewed clearly did think of themselves as professionals. For example, one engineer (a group leader at a customer-oriented company) answered question 12: "Managers of engineers should provide support, not control. Engineers work on their own. They like their work. They're professionals. Look at the engineers here. They work forty-five hours a week, even though they are paid a forty-hour salary. They'll sacrifice to get the job done right. Where they work is too cramped, overcrowded, and dingy."

We may be left with a mystery, it seems. If the corporate code of ethics has little to say to engineers about their technical decisions, and few seem aware of their profession's code of ethics, why do engineers so uniformly become advocates for safety and quality? The traditional answer of sociology is "socialization" (in professional school or on the job). Our interviews tend to confirm this answer. For example, one engineer at an engineer-oriented company explained his commitment to safety and quality this way, "I learned that attitude as part of my professional training." He then added, "But . . . it is [the company's] attitude too." In fact, most interviewees who had an explanation for the emphasis on safety and quality referred only to company "norms," "spec book," or other detailed engineering standards developed within the company. And this was true even of engineers who made it clear that they had to contend with managers who routinely wanted to put customer satisfaction ahead of quality.

Our impression is that the engineers' concern with safety and quality is too ingrained for most of them to have a good sense of its origin. What they do have a good sense of is how pervasive such concern is in the company in which they work. This does not mean that, for example, managers are not more concerned with other things but that even managers recognize safety and quality as central considerations. The company demonstrates this concern not so much through general pronouncements as through relatively strict adherence to thousands of minute specifications.

Appeals

The small companies were so informal that recourse to the "top" seemed routine. As one engineer in an engineer-oriented company put it, "What would be the point of such a policy [an open-door policy]? I walk into the office of the president and vice president every day." But even this engineer thought it important to tell his immediate supervisor first: "A manager doesn't like to hear bad news from outside. So, I first tell him and get advice." Yet, even in the small companies, our interviewees could not recall taking a technical question directly to the top.

Given their informality, it is not surprising that the small companies seemed to have no formal appeals procedure of the sort discussed in the literature. The informality was enough. The formal procedures were available only in larger companies (and not always there). The most common of these formal appeals was the open-door policy. A subordinate dissatisfied with his superior's decision could take it to his superior's immediate superior who would hear him out, might make subtle inquiries, and might even change the decision if that seemed justified, all things considered.

Though this procedure could in principle be used for any problem, it was in fact much more likely to be used for "personnel" than for "engineering" problems. One manager in a customer-oriented company described his company's open-door policy in this way: "Engineers can go to my boss and complain. This happens sometimes, on personnel matters, primarily. It's never happened on an engineering question." An engineer gave a strikingly similar description of the appeal procedure at another customer-oriented company: "You can go to his superior. I've only done this once or twice, but more on personnel than on technical matters."

Only one company had something like a formal ombudsman. A group leader explained the procedure: "There is a formal path to use in such cases. . . . It is a strong way to express your disagreement. It has not been used very often in my recollection. I can think of just one case in which an engineer used it. This was a case where a product was being tested. The engineer thought that the performance problem was due to a screw that was not tightened all the way to ground contact. I hadn't responded quickly enough to his recommendation, he thought. So, he used [this procedure] and I had to respond." The procedure involved filling out a form and placing it in a special box emptied once a day. The form is delivered directly to someone in the general manager's office. The person against whom the complaint is made is then notified and has a certain number of days to respond.

Few engineers or managers at this company mentioned this procedure as a way to appeal engineering decisions (just as few engineers or managers made much use of any other formal appeal procedure). Why? Fear of reprisal may seem the most likely explanation. As one manager put it: "Most managers don't mind. But there are some around here who would do a guy in for going over his head." There are, however, two reasons to doubt this explanation. First, personnel appeals are *less* rare even though they seem at least as likely to lead to reprisals. Second, few engineers we interviewed expressed any fear of reprisals. As one group leader at the same company explained, "Yes, this can ruffle some feathers. But a manager who indulges in reprisals doesn't last long."

Perhaps, then, a better explanation for the relative rarity of appeals is simply that both engineers and managers work harder to reach agreement on engineering questions than on personnel questions. They work harder because they *expect* to reach agreement. Engineering questions are, as explained earlier, supposed to be "factual" in a way personnel questions often are not. As one manager explained why his engineer-oriented company did not need a formal procedure for technical appeals: "There's no appeal process. I can't imagine an engineer and manager not being able to come away with a solution." Given such expectations, going over a manager's head is likely to suggest a criticism of the manager's technical judgment, something

much more likely to ruffle the feathers of an engineer-manager than a disagreement over a personnel matter.

There is other evidence for this explanation. Some interviewees reported an informal procedure easily mistaken for an open-door policy. The procedure had no name (and may in fact be no more than a natural by-product of reduced compartmentalization). One engineer, at an engineer-oriented company, described it this way: "Policy is to discuss the [technical] problem with your boss. If you can't agree, the two go up to the next level or bring in more people who know about the problem. There's no written policy as far as I know. That's just how we do it." We found this procedure of "bringing in more people" in customer-oriented companies as well. For example, one engineer in such a company told us, "If I had a [technical] concern I didn't think was properly resolved, I would write a note to my boss restating itwith copies to lots of people, including [his boss's equivalent in the next department over]. Writing such notes is not all that uncommon."

This procedure of "bringing others in" seems to differ from an open-door policy in at least three important ways. First, it does not seem to be a formal policy in any company at which we interviewed. No one knew its origin. It was, as one engineer said, "just how we do it." Second, no interviewee suggested that bringing others in would "ruffle feathers" (although several suggested that using an open door would). No one, it seemed, doubted the benefits of another perspective. Third, and perhaps most interesting, bringing others in seems to be a procedure even managers can use, for example, when their own arguments cannot budge an engineer from a recommendation they don't like. Asked when an engineer should have the last word, one manager (a group leader) responded, "Last word? You can always get a second opinion."

Reduced Compartmentalization

For a century at least, one characteristic of engineering has been the large number of engineers involved in any significant project. The traditional way to approach an engineering project was for a senior engineer, the project manager, to divide the project into small parts, assign each part to a particular engineer (or engineering group), send them off, and then assemble the results as they became available. The engineers would not be encouraged to coordinate their work with one another. Coordination would be the manager's job. Engineers might not even know who else was working on their project. In fact, they might have little idea how their small project fit into the overall work. Especially in a large company, very little information could flow directly between engineers. The project manager alone would know more than a small part of the overall work. Engineers would have no choice but to defer to the manager's judgment.

Burns and Stalker called this form of organizing work "mechanical." They found many instances of it in the British companies they studied in the late 1950s and early 1960s. That highly compartmentalized way of managing engineering was also practiced in the United States. One engineer we interviewed recalled work at a previous employer (more than ten years earlier): "There I would often be assigned a job by a P.E. I never saw and sent him a written report. Occasionally the report came back with written comments. Usually I had no idea what happened to it." Though this way of managing engineering may continue in the United States, we found little evidence of it in our interviews.

We may distinguish two aspects of compartmentalization: vertical and horizontal. Vertical compartmentalization produces a strict hierarchy, with one manager having a certain number of subordinates, each of whom answers only to her. They cannot go over her head without her consent. Horizontal compartmentalization puts up barriers between individuals, groups, and departments on the same level. For example, an engineer might have to ask his manager's permission before talking to an engineer in another department about a technical matter, or he might simply have no way to know who else is doing work he should know about.

As our discussion of appeals suggests, we found relatively little vertical compartmentalization. We did find significant horizontal compartmentalization, however, between major functions such as sales and design or development and manufacturing, primarily in the large companies. So, for example, one engineer in manufacturing complained that the engineers in development still "throw things over the wall to us"that is, develop a product without consulting the manufacturing people about how it is to be manufactured. Sometimes the technically neat solution causes trouble in manufacturing.

Although we found significant horizontal compartmentalization, we also found that every company at which we interviewed was trying to reduce it. Answers to questions 12* (for managers) and 13* (for engineers) suggest that managers, rather than engineers, are generally leading this effort. For example, one manager complained: "I want my engineers to see their job as involving more than technology. How should mills relate? Where does what we're doing fit into the [company's] future? They need to ask more integrative questionse.g., `Who reports to whom?' or `Who can hold their feet to the fire?'" A manager at another company gave a different list in the same spirit: "What don't engineers ask that they should? Cost? Quality? Time? Cycle time? Design for assembly? They are ready to run as soon as they see the specs."

The engineers, in contrast, tended to think their managers more likely to fail to look into the engineer's own compartment. For example, one engineer wanted his manager to ask, "How thoroughly did you analyze the problem? Did you shoot from the hip? How much data and factual evidence did you collect? Is it repeatable? If you had more time, what would you do differently? If you're wrong, what are the ramifications? What's your second best answer?" An engineer at another company gave a similar list: "Managers need to ask, How did you reach that decision? What information did you use? Did you cover all the bases? Substantiate. The question managers are least likely to ask is, Is this date realistic? Usually, I'm told a date to be done by, not asked when I can be done. Often the date isn't realistic. But no one seems to know thatuntil the deadline is close."

Overall, what we found was a highly fluid decision process depending heavily on meetings and less formal exchange of information across even department boundaries. Managers seemed to have little control over what information would reach their engineers. Indeed, they seemed anxious to get their engineers to hook up with others on their own. Their only complaints were about remaining compartmentalization, especially the parochialism of their own engineers.

Although we heard many complaints about remaining compartmentalization, we also heard a few arising from attempts to reduce compartmentalization. For example, an engineer at an engineer-oriented company answered question 13 ("If you had full control . . ., what would you do differently") as follows: "I wouldn't show up at a field meeting with so many engineers we outnumber the customer." Such outnumbering was, it seemed, a common consequence of sending one engineer from each department likely to be involved in a particular project. The most common complaint of this sort was simply "too many meetings."

Independent Review

Several companies at which we interviewed had a "technical review" in which a project group, section, or department had to defend its proposal to a committee of experienced engineers (and managers) from elsewhere in the organization. These reviews seemed to vary considerably in formality (as well as in other respects). The most elaborate we found was the HAZOP (hazard and operability) study used by Amoco Chemical. Designed for a particularly unforgiving technology, HAZOP is probably too elaborate for most engineering undertakings. Even so, it provides a standard against which other companies can measure their own review procedures.

Amoco uses HAZOP to evaluate both proposed and existing installations. Because these two uses differ significantly, I discuss them separately, beginning with proposed installations. For a proposed installation, a department works out a complete plan (which, for Amoco, routinely includes having the plan reviewed by operations, maintenance, and installation, who are supposed to work as carefully as they would if they, not the HAZOP study, were the last step before construction of the installation would begin).

Once a department does all it can, including receiving approval (and funding) through the ordinary process, a HAZOP team is appointed, including a leader and a secretary. The team should consist of engineers experienced enough to "look at paper and know what that implies [about how a plant will run]." (One manager set the required experience level rather high, at "twenty-thirty years," but we interviewed one engineer with eight years of experience who had already served as a HAZOP leader.) No one involved in the original design is on the HAZOP team. Following a "formalized procedure," the team examines every aspect of the proposal, identifies possible flaws in the design, and makes recommendations as it sees fit. The secretary takes down all recommendations, ultimately sending one copy to those who developed the proposal and filing the other "downtown" (that is, at Amoco's corporate offices). This usually takes "one to four months."

Once the HAZOP team completes its work, a response team is appointed, including only one member of the original HAZOP team. Apparently, for some projects at least, the response team may consist entirely of managers. It is supposed to respond to each HAZOP recommendation. (There may be several hundred.) Its response will also be filed downtown. Ordinarily all, or almost all, the HAZOP

recommendations are incorporated into the original plan. Any rejections must be justified in the written response. Once the review is complete, the project proceeds. (We received no indication what would happen if a recommended change put a project over budget.)

That is the procedure for HAZOP review of a proposed installation. HAZOP can also be used to review an existing installation. The chief difference is that the result of such a HAZOP review will be recommendations piled on one or another engineer's desk beside ordinary work orders with which they will have to compete. This seems to be HAZOP's Achilles heel. Several managers told us that had Union Carbide used a HAZOP procedure to design its plant in Bhopal, "Bhopal" would not now be a household word. They could well be right. But, had HAZOP come into use only *after* the Bhopal plant was built, the HAZOP study might only have produced a series of recommendations which, though accepted by everyone, would, at the time of the disaster, still have been sitting on the desk of an engineer too busy "putting out fires."

Nonetheless, we recommend something like a HAZOP review even for existing operations. Although the review cannot guarantee that everything recommended will be done, it seems likely at least to call attention to important flaws in existing installations. It can set an agenda. For most companies, perhaps, identifying serious problems in some such constructive way as this is at least half of ensuring that the problems will be resolved relatively quickly.

A Breakdown in Normal Communications

Company B (as I shall call it) is a large customer-oriented manufacturer. As at the other companies at which we interviewed, engineers and managers at Company B generally worked by consensus. Company B had no open-door policy, ombudsman, or other formal appeals procedure. While going over the boss's head was generally considered a bad idea, the company did have frequent "review meetings" at which technical disagreements could be aired. These seemed to provide an important forum for "bringing others in." Bringing others in was also done more informally. Like other large companies at which we interviewed, Company B was working hard to improve communications between engineering functions, especially between development and manufacture. And, like our other customer-oriented companies, Company B had a code of ethics with little relevance to engineering. Over all, then, Company B would seem to differ in no fundamental way from other companies at which we interviewed.

Yet, Company B clearly did differ. It seemed to have a communications problem much like the one Feynman reported at NASA. The evidence for this claim may be divided into four categories. Company B differed from other companies we interviewed in (1) the way managers and engineers felt about each other, (2) the amount of information managers withheld, (3) the prominence of "top-down engineering," and (4) the way management chose to encourage an important development project.

Managers Versus Engineers

Unlike most of our interviewees, those at Company B had little doubt about whether they were engineers or managers. Thus, one manager told us, "I was an engineer until a few weeks ago. [Then] I was promoted to chief engineer." Though his former job as supervising engineer also involved a good deal of managing, he did not then consider himself a manager. Another interviewee spoke with equal assurance even though a demotion had not changed his job at all: "I was a manager before a recent reorganization flattened the organization a bit. Now, I'm not, though I was a group leader before and after reorganizationwith the same responsibilities as before."

Why were interviewees at Company B so much clearer than our other interviewees about whether they were engineers or managers? The answer is that Company B made the distinction sharp and important. As one engineer explained, "[Company B] gives better benefits to managers than engineers." Another engineer made the same point, while suggesting one disadvantage of making the distinction so sharp: "Around here many things, including fringe benefits and office space, treat engineers one way and managers another. The differences between engineers and managers are emphasized. They are in separate camps." This engineer also referred to engineers turned manager as "former peers." We heard nothing like this at any other company.

Withholding Information

Engineers and managers at Company B agreed that engineers did not withhold technical information at all or only did so just long enough to double-check it. Their answers were similar to those at other companies*except* that there was no mention of engineers trying to cover up mistakes. Managers at Company B were also like managers at other companies in being unanimous that they did not withhold technical information from their engineers. Where Company B really differed from other companies was in the answers engineers gave to that question.

The engineers were virtually unanimous in reporting that their managers *did* withhold technical information from them. For example, one engineer told us that he "frequently felt that they didn't tell me the whole story." When we asked, "When?" he responded: "Whenever I couldn't reach their conclusion on the same facts." Another engineer gave this list of technical information managers were withholding: "[Information] about cost. Proprietary information, too. That is, either information that's not directly relevant to what I must do or is too sensitive to risk leaking." Another engineer added this example: "We are reasonably sure that there is a potential big overseas buyer for the [new technology we are working on], but no one is leveling with us about it. We are in the dark on this and I don't like it." Yet another engineer described a different sort of withholding: "Sometimes they want us to be underinformed, maybe so as not to prejudice us or they don't think we need to know how bad a problem it ise.g., that we had the same complaint before and thought we fixed it. More often, it's not deliberate. They just don't see the relevance of the information, e.g., they have divided a problem into parts that are too small."

What explains this difference in the way engineers and managers answered the question about whether managers withheld information? It is worth recalling that at other companies we interviewed, the *managers* stressed how important it was for engineers to include business considerations in their engineering decisions. At Company B, managers *never* made this point. Instead, the engineers did. Indeed, the engineers at Company B seemed to accept the broad conception of engineering that managers at other companies were encouraging their engineers to adopt. But, at Company B, the managers did not seem to share that conception. They withheld information that managers at other companies did not withhold. They withheld it simply because they did not think it relevant to technical engineering decisions and seemingly without realizing that their engineers did not share their conception of what engineers need to know.

Top-Down Engineering

"Top-down engineering" does not mean typical management functions like setting a general development strategy, standard of quality, or even the timetable for a particular project. It refers to something much more specific: management's involvement in the details of engineering. At other companies at which we interviewed, both engineers and managers thought that managers should leave the engineering to the engineers. We heard that thought expressed at Company B, too, but with this difference: The target was not (as at other companies) primarily the low-level manager clinging to his "former love." The target was management generally, especially *upper* management.

Company B apparently has a history of "engineering from the top down." An engineer employed there for almost a decade recalled, "It used to be that engineers didn't count for much. The manager ruled or overruled. This happened too often in the past. We would be told, `The data must be wrong.' Some management guys don't have an open mind, but this happens a small percentage of the time now. Engineers are being more encouraged. We've become more involved. There has been more delegation and that's good."

While that engineer stressed how much worse things used to be, others stressed how bad they still were. One told us, "If my recommendations fit a pet theory, then they are acknowledged. If not, I have to make one hell of an argument. . . . There was this case with the seal. . . . My manager said, `If you think about it, this seal should really work.' But it didn't work. Then the idea was changed from let's see if it works to how much leakage is O.K. in using the seal. This adds to the costs and the risks, but we're going ahead with it anyway." Another engineer told a similar story: "[Recently,] we were looking at two nozzles for spraying fuel into a cylinder. We could get a 10% improvement with almost no cost one way; or a possible 20% improvement doing it another way, but at considerable cost in redesign and no guarantee it would work. [I recommended the 10% improvement.] Management, not my boss, but someone higher up, decided to go for the 20%."

The engineers at Company B were virtually unanimous, "Managers here still try to do too much of the engineering." We heard the same thing from two *newly promoted* managers. One described decision making in his company this way: "Managers provide proper manpower and tools and work with engineersexcept sometimes, when there is a management-driven decision. Then the manager gets into the engineering itself. That's bad." The other new manager described the appeal process this way: "There is no formal process. After all, technical disagreements are hardly ever dramatic. If I'm unhappy, I just keep trying to change my boss's mind. I try to wear him down. [But] sometimes the heat comes from on top. We are told, `Consider this design. Look at it. Tell us in detail what you think.' Then the process feeds back up. These top-down things give us the most trouble."

What he meant by trouble became clear when he answered our question about what he would do differently if he had full control of engineering: "[There] are too many projects initiated by top management, from the vice president on down. I would prefer this changed. It creates tension at lower levels because of the mode of introduction. People are told to do this, to do that, that this is what we need. This creates bad feelings and destroys creativity. These top-down actions can be very specific and detailed. They can take the form of designs and actual sketches. `This is what we want.' All this is out of control, in my opinion."

Though the *new* managers complained about top-down engineering as much as the engineers did, the more experienced managers did not. They did, however, answer question 3 (about how decisions are made) in a way confirming what the engineers told us (and suggesting the managers were on the engineers' side). "Decisions are made top down," one manager began, "[but] we would like to push decisions down the organization." Another made the same point: "[Engineers] play as big a role as we think they can handle. This is easier said than done. I try to push decisions as low as possible. But you can't delegate then not stay in touch. I like to have engineering decisions or firm recommendations made at the project manager, group leader, or bench engineer level."

Unintentionally Discouraging Bad News

Company B undertook a major technological initiative on which its future success may depend. The initiative was not simply a research and development project. The assembly line was being prepared simultaneously. Because the project involved a major leap in technology, many parts of the project were crucial to its success. Had any of these parts proved impossible to develop, or impossible to develop in time or economically, Company B would have had nothing marketable for its large investment.

Both the engineers and managers we interviewed were involved in work on one or another part of this new technology (as well as on other projects of more immediate concern). The engineers (and new managers) mentioned work on this new technology frequently, especially when asked whether Company B took large risks. The experienced managers *never* mentioned the new technology. One even denied that Company B ever took risks, even after we restated the question to include financial risks. We seem, then, to have uncovered a disagreement between managers and engineers at Company B similar to the one Feynman reported at NASA. The engineers recognized risks that the seasoned managers did not.

Of course, the similarity is not perfect. The risk at Company B concerned its financial safety, not anyone's life or health. Engineers differed from managers on what would seem to be a question of business rather than engineering. And, unlike the engineers at NASA, the engineers at Company B had not yet been proved right.

Such differences are irrelevant now, however. Even if the engineers were wrong, Company B would still have had a communications problem. As one engineer noted, "[There is] too much rumor around here. . . . I wish the managers here would just admit the problems we're having with [the new technological initiative] and tell us how they hope to respond." Clearly, management's message was not getting through.

There are at least two reasons to think the engineers were right. The first is obvious. Whether a new technology can work is itself a technical question about which engineers are likely to be better informed than anyone else. Or, as one group leader at Company B put it, "Guys at my level know all the problems. But there's a filtering process upward. Lots of things we don't tell unless asked." Insofar as the financial risk the company was taking is itself a function of that technical risk, the engineers would be likely to have good information even about the business risk involved. The second reason to think the engineers were right is that management itself took strong action to move the project along. Unfortunately, the action management took seemed likely to have the opposite effect. The action also suggests how large a gap divided engineers and senior management.

Company B called in a management consultant, "Doctor Feel-Good" ("DFG"). DFG tried to spur creativity through a motivation program for managers and senior engineers. The engineers who told us of DFG's program made it sound like a series of pep rallies. Whatever the program was in fact, the engineers tended to think it sillyor an admission of management's desperation. DFG clearly was *hurting* engineering morale (just the opposite of what management must have intended). But, perhaps more serious, DFG also seemed to be damaging communications between engineers and managers, the very communications upon which any technological breakthrough depended. "[The] effect of [DFG]," said one engineer, "has been to make engineers feel out of step when they report that something won't work."

The flow of bad news upward had at least been slowed. Senior management might well be the last to know how bad things were; they might not find out until it was too late to do anything about it. Perhaps our interviews already show the filtering process at work. Though the engineers talked openly about the technical bottlenecks, shortage of staff, and the business risks, experienced managers did not. They were positive about what they were doing. If they were no more open with their engineers and fellow managers than they were with us, it is easy to see how they might help create, however unintentionally, an environment in which even engineers would feel pressured to tone down bad news. As time went on, these managers, and those above them, would be more and more cut off from what the ordinary engineer knew.

Here is Feynman's "game"with this difference. The disaster was yet to come and might never happen. The company might yet "luck out." But, even if disaster struck, it would not produce a public scandal, only a lot of red ink or, at worst, the ruin of a good company. 33

Conclusions

Our first hypothesis was that the boundary between engineer and manager would be relatively clear in most companies because the staff-line mode of organization would force the distinction to be made clear. In fact, we found almost no trace of the staff-line distinction. What we found in its place was something much more like the distinction made in universities between faculty and administrators.

In most universities, senior administrators (president, vice presidents, and deans) hold faculty appointments. Many still do some teaching. Ordinary faculty, on the other hand, do considerable administrative work, whether as department chair or through various departmental, college, or university committees. Faculty differ from senior administrators only in degree (though "administrative staff" are more like what engineers call technicians). Some ordinary faculty may be paid more than any administrator, even the university president.

In most companies at which we interviewed, the distinction between engineers and managers was similarly one of degree. A bench engineer was an engineer who spent most of his time at his bench (like an "ordinary faculty member"). A pure manager was an engineer who no longer did any engineering himself. Especially in large companies, there might be several grades of engineer-manager. In general, the distinction between engineer and manager did not seem to determine pay, benefits, or weight in technical decisions.

The one company that seemed to make the distinction between engineer and manager as sharply as we originally expected did not seem to have any more of a staff-line organization than the other companies at which we interviewed. Yet, though only for accounting purposes, the sharpness of the distinction seemed to hurt relations between its engineers and managers, making engineers feel as if they and managers belonged to "separate camps." This bad feeling may have contributed to the poor communications we found there.

Our second hypothesis was that engineers would be primarily concerned with safety and quality while managers would be primarily concerned with costs and customer satisfaction. This hypothesis was generally confirmed but in a way suggesting that the concerns overlap more than commonly thought. Managers in most companies usually paid more attention to costs and customer satisfaction in their *initial* response to an engineer's recommendation than the engineers *initially* did. In all companies at which we interviewed, however, decision was generally by consensus, not by management fiat. Decision by consensus required managers to inform engineers about considerations of costs and customer satisfaction they may have overlooked. No doubt as a result of that, most engineers we interviewed had a much better appreciation of such business matters than we expected. Even allowing for the fact that most managers we interviewed were trained as engineers, decision by consensus seemed to have a corresponding effect on managers. They seemed to have a better appreciation of engineering considerations than we expected. *Decision by consensus itself appears to be an important means of maintaining good communications* between engineers and managers.

Our third hypothesis was that engineers would tend to defer to management judgment because management had ultimate responsibility for decisions. This hypothesis derived from our assumption that engineering would be treated as a staff function (with no responsibility for decision) while management would be a line function. Yet, the hypothesis was in fact independent of that assumption. It could have been confirmed even if, as it turned out, engineering was a line function. Engineers could still have routinely deferred to management.

Our findings here are therefore significant in their own right. Deference to management was *not* what was expected of engineers. Quite the contrary. Engineers were expected to "go to the mat" on any question of safety or quality they considered important. Even managers who expressly reserved the right to overrule an engineering recommendation emphasized the need for engineers to "hammer" at them anyway. Engineers themselves expressed no deference to management on questions of *safety.* There they expected their recommendation to be "final." Only on questions of quality, customer satisfaction, or cost were they willing to let management have the last wordand, even then, they were willing to give management an "earful" first. Here again the analogy with decision making in a university (where faculty "advise" but expect to have administrators take their advice) seems much closer than decision making in the military (wherewe are toldofficers "command" and "subordinates" are expected to "obey").

Our fourth hypothesis was that the more hierarchical organizations were more likely to suffer a communications breakdown than the less hierarchical. This hypothesis, like the previous one, was derived from the assumption that the companies at which we interviewed would have a traditional (quasi-military) hierarchy. Though their tables of organization made them look as hierarchical as we assumed they would be, none of the companies at which we interviewed was in fact organized in that way. The small companies were too personal for formal hierarchy to matter much. Even in the large companies, the use of consensus and bringing other people in meant that individual managers could not control information or access in the way they would have in a traditional hierarchical organization. (And, in addition, the managers generally did not want to.) Even the communications gap we found in Company B did not result from hierarchical organization but from a combination of other factors, including too narrow a definition of engineering considerations, too much interference from the top in the details of engineering, a failure to consult directly with those most likely to know, and the use of motivational techniques likely to discourage the reporting of bad news. The absence or presence of a code of ethics or formal appeal procedure seemed to have little part in technical communications between managers and engineers.

Our fifth hypothesis was that we could develop a procedure for identifying a communications gap between engineers and managers if one existed. We now have some support for this hypothesis. Our open-ended interview identified what seemed to be a serious communications gap at one company (Company B). The interviews also provided us much useful information about how engineers and managers generally work together.

Our sixth hypothesis was that we could add to the stock of procedures for preventing a communications gap or at least to procedures for helping to eliminate such a gap once it appears. We came across two, the informal bringing others in and the formal technical review.

Recommendations

I (and the research group) believe this research justifies the following recommendations:

1. *Companies should try to soften the distinction between engineer and manager as much as possible.* Too sharp a distinction (as in Company B) seems to create resentment that can interfere with communication. Providing for a promotional ladder for bench engineers parallel to management's may help reduce the feeling that managers are "above" engineers. Managers, especially, seem to welcome the possibility of bringing in a *senior* engineer (that is, a "technical person" with rank equivalent to "manager") when they disagree with an engineer's recommendation. Companies should also look for other ways to treat engineers and managers as professional employees, differing only in specific function and responsibilities (for example, by avoiding differences in benefits based on classification as "manager" or "engineer").

2. *Engineers should be encouraged to report bad news.* Communication is most likely to break down between engineers and managers when procedures or other aspects of the work environment discourage engineers from reporting bad news (for

example, design problems). Top-down engineering may be justified at times, but it should be accompanied by on-site visits with the bench engineers doing the work ("management by walking around"). Senior management needs to remember how much bad news is likely to get filtered out by several layers of management. Senior managers should also be wary of motivational techniques that discourage bad news or otherwise inhibit the give-and-take that is a precondition of decision by consensus working well.

While on-site visits, especially informal surprise visits with bench engineers, can undercut the authority of mid-level managers, that is not a necessary consequence. Undercutting can be avoided by *open* discussion of the rationale for the visit, emphasis on the helping (rather than the controlling) role of managers, and (when a problem *is* discovered) a focus on solving the problem rather than finding someone to blame.

3. *Companies should check now and then for signs of trouble in relations between managers and engineers.* Such trouble may not be obvious to managers inside the company even if it is obvious to the engineers there. How many subordinates tell a superior more bad news than he asks for? One way for senior management to discover trouble is to meet informally with small groups of bench engineers and ask. Another way is to have outsiders interview engineers and managers in the way we have.

4. *Companies should encourage both engineers and managers to settle technical disagreements by informally bringing other experts in.* Companies should also consider adopting an open-door policy, ombudsman, or other formal appeals procedure. Though such formal procedures are seldom used to settle technical disagreements between managers and engineers, they nonetheless seem to help establish an environment in which even technical information flows more freely.

5. *Companies should look for formal procedures that bring out bad news that might otherwise be missed.* The most effective procedure of this sort we came across was Amoco Chemical's HAZOP study. Though this procedure is probably too elaborate for most companies (that is, those with a less dangerous technology), it may provide a useful ideal against which any company can measure its own technical review procedures. Of particular value, is that: (1) the reviewing body consists entirely of engineers who, though having the appropriate experience, have had no part in developing the plans (or process) they evaluate (and so, no built-in conflict of interest); (2) the plans have to stand on their own (the drafters not being there to defend them); and (3) all recommendations are put in writing, rejecting a recommendation requires a written justification, and both recommendation and rejection are kept on file (thus assuring later accountability). Such an independent review gives everyone directly involved in a project considerably more incentive than they would otherwise have *not* to play down bad news in the early stages of a project. At a minimum, however, we think companies should encourage engineers to put their doubts in writing and circulate them among all those concerned.

6. *Companies should not expect a general code of ethics to have much impact on engineering decisions.* Any company that wishes to make safety or quality more central in its engineering decisions probably has to do so through specific technical specifications. It may also find training engineers in their profession's code helpful, because these codes are generally more specific about problems engineers face than is a general business code. Such training may also confirm engineers in the belief that their employer wants them to be advocates for engineering standards.

7. *Companies should try to improve the way they use bad news.* Companies cannot learn from their mistakes if they do not remember them. In particular, companies should consider including information about how parts failed in technical manuals (or data bases) engineers use or, at least, bring engineers together from time to time to discuss failures they have learned from.

8. *Technical engineering courses should include more about the place of cost, manufacturability, and other business considerations in engineering.* One manager in fact told us that, except for the graduates of co-op programs, engineers fresh out of college were poorly prepared to think about the range of considerations routinely part of good engineering. There seemed to be general agreement that engineering education is now too narrow.

9. *Engineers should be trained to make a case for their recommendations.* Ability to present data clearly, orally or in writing, and the ability to make arguments from the data seem to be essential to participating effectively in decision by consensus. Right now, engineers seem to have to learn these skills on the job. They are, however, skills any school of engineering can teach.

10
Professional Autonomy: A Framework for Empirical Research

Employed engineers sometimes claim that their status as employees denies them the autonomy necessary to be "true professionals." Such claims also appear in important scholarly work. For example, in *The Revolt of the Engineers,* Edwin Layton observed: "Employers have been unwilling to grant autonomy to their employees, even in principle. They have assumed that the engineer, like any other employee, should take orders. . . . [But] the very essence of professionalism lies in not taking orders from an employer." [1] What are we to make of the claim that professionalism is inconsistent with being an employee (or, at least, with taking orders from an employer)? Is it a conceptual truth (a deduction from definitions) or an empirical one? How might it be provedor disproved?

The purpose of this chapter is to answer these questions by developing a conception of *professional* autonomy. We have no such conception now (though some claim otherwise). What we have instead are conceptions of *personal* (or moral) autonomy applied to the workplace. These conceptions help us understand neither the specific contribution of professional constraints to personal autonomy nor the ways corporate organization and professional responsibility might be consistent.

The literature on autonomy may be divided into three categories: (1) a general philosophical literature on "personal" autonomy, (2) a philosophical literature explicitly concerned with "professional autonomy"; and (3) a sociological literature concerned with autonomy in the workplace. These three literatures, though related in principle, seem in practice to have grown up largely independent of one another. Let us consider them in order. Having seen what they have to offer, we should be in position to develop our own conception of professional autonomy and see what research, if any, it suggests.

Personal Autonomy

Over the last thirty years, philosophers have developed a substantial literature on "personal autonomy" in part at least because traditional conceptions of liberty or freedom seemed not to do justice to concerns about the effect that brainwashing, hypnotic suggestion, advertising, and other mind-altering techniques might have on the moral authority of agents. Brainwashing, for example, leaves us at liberty to do what we wantbut, by distorting what we want, seems to deprive the resulting decisions of something necessary for them to be accorded the respect to which they would otherwise be entitled.

The locus of most of this work was political philosophy (the autonomy of citizens given the state's control of education, information, and public discussion), medical ethics (the autonomy of patients), and business ethics (the autonomy of customers subject to advertising). This work went on under the title "personal autonomy" to distinguish it from two older subjects: "political autonomy," which is concerned with what makes a state or nation self-governing, and "moral autonomy," which is concerned with the conditions for moral responsibility (or moral goodness). The reason for distinguishing personal autonomy from political autonomy is self-evident: Individual persons are neither states nor nations. The reason for distinguishing personal autonomy from moral autonomy is not self-evident.

On many conceptions of moral responsibilityindeed, on mostthe conditions necessary for moral autonomy (for example, rationality) are also conditions necessary for personal autonomy. The term personal autonomy must, I think, be treated *not* as signaling a subject different from moral autonomy but as signaling a different emphasis within the same subject. Those concerned with personal autonomy are to be understood as concerned primarily with protecting agents (whether in political philosophy, medical ethics, or business ethics) from certain undesirable influences, or with reasons for respecting their decisions, not with evaluating their conduct morally. Those concerned with moral autonomy are, on the other hand, to be understood as concerned with such evaluation rather than with protecting moral agents against certain undesirable influences. For our purposes, this difference in emphasis does not matter. I therefore generally use personal autonomy for both.

Conceptions of personal autonomy resemble each other in treating the autonomy of an act as dependent on some feature of the agent. They differ only in what that feature is. For some, an act is autonomous only if the agent is autonomous (at the moment of the act). We may call these agent-centered conceptions. For other conceptions, an act is autonomous only if the desire leading to the act is autonomous. We may call these conceptions desire centered.

Agent-centered conceptions may say little (indeed, nothing) about "autonomous desires." For example, on Gerald Dworkin's recent account, a person is autonomous insofar as (and only insofar as) she has certain capacities ("the capacity . . . to reflect on [her] first-order preferences, desires, wishes, and so forth, and the capacity to accept or to attempt to change these in light of higher-order preferences and values"). [2] Desires as such are neither autonomous nor nonautonomous; autonomy is a function of the way the person decides. An act (or choice) is autonomous only insofar as it results from the exercise of these capacities of the agent.[3]

Desire-centered conceptions, in contrast, consider a person to be autonomous (or to have personal autonomy) only if (or only insofar as) his acts (or other choices) are autonomous, and consider his acts to be autonomous only if, or only insofar as, they derive in the appropriate way from desires, motives, or the like that are themselves autonomous. Autonomy is primarily a characteristic of desires and only derivatively of acts or persons. So, for example, a person might be autonomous under such a conception only insofar as his desires are.

All desire-centered conceptions of autonomy now available are, I think, either historical, hypothetical, or structural. In *historical* conceptions, a desire is autonomous if it results from a certain process or is *not* the result of certain processes. For example, on this conception my present desire to eat chocolate chip cookies would be autonomous if it actually originated in an appropriately reflective process but not if it originated in hypnotic suggestion or early socialization into a "chocoholic" family. 4

Hypothetical conceptions of autonomy differ from historical conceptions in focusing on a possible future rather than on the actual past. For example, on the hypothetical conception I have defended elsewhere, my desire for chocolate chip cookies is autonomous if it *would survive* repeated and vivid exposure to all the relevant factssuch as the weight I am likely to put on and the unpleasantness of eventually having to choose between a crash diet and a heart attack. If the desire *would not survive* exposure to such facts, it is not autonomous.5

For *structural* conceptions, a desire is autonomous if it stands in a certain relationship to other current desires of the person (whatever the desire's actual history or possible future). For example, according to Harry Frankfurt's account, a person's first-order desire is autonomous if it is one with which that person actually *identifies*that is, with which his other desires mesh in a certain way.[6] The history of the desire is relevant, if at all, only insofar as it affects a person's willingness to identify with the desire. According to another structural conception, a desire is autonomous if, and only if, it fits the person's actual life plan.[7]

Though these conceptions of autonomyboth agent centered and desire centereddiffer in many ways, they share one striking feature that is relevant here. According to none is the employer-employee relation necessarily inconsistent with autonomy. According to agent-centered conceptions, the crucial question is: *Does the employer leave the employee with the relevant capacities to reflect on his desires and to accept or change them based on higher-order desires?* While some hierarchical organizations may so regiment employees that independent thought is impossible, that does not seem to be true of all or even most organizations employing engineers. Certainly, it was not true of the organizations studied in chapter 9. According to desire-centered conceptions, the crucial question is: *Does the employer instill desires in an inappropriate way, or instill desires that could not survive exposure to the facts, or instill desires with which the employee cannot identify?* Again, while the answer may be yes for some employers, it seems to be no for othersperhaps most. Few organizations seem to turn their employees into automatons.

If the employees of a certain organization are not automatons, they should be able to act autonomously in their workplace just as they can outside. That they are obeying orders is not enough to show that they are not acting autonomously. If, for

example, they did as they were told because upon reflection they had concluded that the employer knew what she was doing (or that coordination among many employees was more important than getting any one decision right), they might well be both autonomous and scrupulously obedient under any of the conceptions of personal autonomy identified here.

That it might lead to this conclusion may explain why those concerned with professional autonomy generally ignore the literature on personal autonomy. That literature seems to settle where it should elucidate. That it seems to settle too much does not, however, explain why those concerned with professional autonomy use the term "autonomy," much less justify its use. Why talk of "autonomy" rather than "freedom," "control," or even just "responsibility"? To answer that question, we must examine the literature of professional autonomy.

Professional Autonomy

The literature on professional autonomy seems to distinguish two related senses of professional autonomy. In both, acts are more central than in conceptions of personal autonomy. In one sense of professional autonomy, "the organizational," autonomy is regulation by one's own profession, rather than regulation by the "laity". In the other sense, "the individual," autonomy is control of one's own work, rather than control by client, patient, employer, or the like. 8

Organizational autonomy is primarily a property of the profession as a whole. A profession is autonomous insofar as it has control over its own code of ethics, standards for admission to the profession (including licensure or certification), and disciplinary procedures: "In practice, autonomy [in this sense] exists when the leaders of a profession define or regulate the nature of the services offered in the following ways: they control recruitment and certification of members, and set the standards of adequate practice."[9] Organizational autonomy is a close relative of political autonomy.

In the United States, no profession is fully autonomous in this sense. Lawyers, for example, are licensed by a state agency (usually, the state supreme court) and at least the final stages of discipline are in that agency's hands. Although the American Bar Association does prepare a "model" code of ethics, the states do not have to adopt it, and those that do adopt it are free to make changesand sometimes do. Lawyers are, of course, much involved in the state's regulation of lawyers, but that involvement is at the state's pleasure, not the profession's.

Engineers in the United States differ from lawyers in this respect. The state does not make licensing a precondition for the practice of engineering within its jurisdiction. Generally, states require licensing only for those engineers who work as lawyers traditionally have, offering technical advice to an unsophisticated public or preparing documents for a public record. Those engineers who work as employees of a manufacturer or other organization capable of judging credentials need not be licensed, because they do not serve the public directly but only *through* an employer. This difference between lawyers and engineers seems unrelated to the sense of professional autonomy that interests us. Our questions would remain even if the United States licensed all engineers, as Canada and Mexico do;[10] a licensed engineer can be an employee and, as an employee, have much the same problems of autonomy as an unlicensed engineer.

That brings us to the second sense of professional autonomy, the *individual*. We may distinguish at least three analyses of this sort of autonomy in the literature.

One is clearly connected with *personal* autonomy. For example, K.R. Pavlovic defines the individual autonomy of engineers as "relative absence of restrictions on action . . . [and] of coercion [when] the actor is the initiator of action rather than simply the medium." [11] This definition has three undesirable features. First, it is largely negative ("an absence"), while professional autonomy seems to be something positive (a capacity for a certain sort of action). Second, because liberty is often thought of as the absence of restrictions on action, Pavlovic's definition seems to confuse autonomy with liberty. Third, insofar as "the initiator" requirement adds anything to liberty, the addition is unexplained. The definition thus seems to *assume* an analysis of professional autonomy rather than to offer one.

A second analysis *is* related to organizational autonomy. For Paul Camenisch, for example, individual professional autonomy means "[ultimate] assessment only by one's professional peers, not by laypersons, even when the latter is the professional's employer."[12] Though this analysis rings true, it also rings hollow. Everything depends on how we understand "ultimate assessment." We have already seen that, according to at least one understanding of "ultimate assessment," no profession has individual autonomy (or, at least, none has that the state licenses).

Camenisch did not explicitly discuss the ultimate assessment of engineers. He might have learned something from doing so. Whatever might be true of licensed professions, unlicensed professions like engineering seem to lack a noncontroversial way to understand "ultimate assessment." Of course, like a lawyer or physician, an engineer cannot practice his profession without a client or employer. There is, then, a clear sense in which the market provides the ultimate assessment of an engineer, as it does for lawyers and physicians. If an engineer cannot find a client or employer, he cannot practice his profession.

There is, however, also clearly a sense in which the ultimate assessment belongs not to the employer but to other engineers. An engineer can have an employer and still not practice her profession. Even if she has a degree in engineering and a job with "engineer" in the title, she might, for example, still only be the building's janitor. To practice engineering, she must actually be engaged in what is engineering in more than name. What that is (as I argued in chapter 3) something for engineers to decide, however informally, rather than for those who know little or nothing about engineering. Here, then, is an ultimate assessment that engineers must make, an assessment which, though present in law and medicine, tends to be concealed by state-operated licensing.

The law courts provide yet another possible venue for ultimate assessment. Whatever engineers say, the courts can find an engineer's work to fall below the standard of reasonable care, impose huge damages, and so force the engineer from the field. Courts can even force standards of care on the profession as a whole and so decide what shall, and what shall not, be engineering practice. The engineering profession, the employers of engineers, and the clients of engineers may be powerless to undo what a judge or jury has done. A court's finding of malpractice seems as ultimate

an assessment of an engineer's work as any. Law and medicine are, of course, also subject to this sort of ultimate assessment.

So, great care is required to work out an understanding of ultimate assessment that is both defensible and relevant to engineersand, indeed, relevant to most professions as they are in fact practiced in the United States. My own intuition is that nothing of value will come from the attempt. We cannot understand what makes a certain assessment "ultimate," if any is, until we understand individual (professional) autonomy. Once we understand individual autonomy, we need not worry about whether any assessment is ultimate.

A third conception mirrors the sociological literature discussed next. For Kenneth Kipnis, professional autonomy is "control over the conditions or content of work." 13 This is an extremely demanding conception of professional autonomy. Professional autonomy in this sense seems to be inconsistent both with the normal authority of employers and with the cooperation and division of labor necessary to make any large organization work. Yet, only one philosopher, Mike Martin, has noted how demanding this analysis is, and only three writersAdina Schwartz and Heinz Luegenbiehl, as well as Martinhave sought to provide a conception of managerial control (and organizational cooperation) consistent with leaving to professionals *enough* control over the conditions or content of work to preserve the professional's autonomy.14 Although Martin's piece is especially suggestive, even it does not deal directly with our subject, "professional" autonomy (though it uses the word). Martin argues, in effect, that ordinary morality, not anything distinctly professional, determines what the employer can demand without threatening autonomy. This is, in essence, the position of Schwartz and Luegenbiehl as well. They therefore provide an answer to the question, "How can an employer's authority be consistent with an engineer's *personal* autonomy?" They never reach our question, "How can an employer's authority be consistent with an engineer's *professional* autonomy?" They do not even see that this might be a different question.

Sociological Literature

In 1939, Vannevar Bush, MIT engineer and soon-to-be mobilizer of American scientific talent during World War II, suggested: "We may as well resign ourselves to a general absorption as controlled employees, and to the disappearance of our independence. We may as well conclude that we are merely one more group of the population . . . forced in this direction and that by conflict between the great forces of a civilized community, with no higher ideals than to serve as directed."[15] This pessimistic suggestion rests on three controversial assumptions.

First, there is the assumption that working in large organizations is new to engineers (Bush's "we"). In fact, as we have seen, most engineers always worked in large organizations, beginning with the military, going on to the railways, and then into manufacturing. Most engineers were always "controlled employees."[16] Like the military, the clergy, and the professoriate, engineering was never independent in the sense a profession of independent practitioners can be.[17] Bush's statement seems much more appropriate to physicians or lawyers today than to engineers at any time in their history: Physicians and lawyers, after almost two centuries during which they practiced primarily as "free professions," are now becoming primarily employees of large organizations, some headed by members of their own profession and some not. [18]

Second, there is Bush's assumption that this "loss of independence" is something engineers must "resign" themselves to, that it is plainly an evil. We have long known that few engineers, especially those with only a B.S., feel that being free of supervision is important.[19] Generally, engineers accept supervision as part of what it is to be an engineer (or, at least, an engineer engaged in important work). The problem seems to be to find the right kind of supervision.[20]

The question of *control* over what is done with the engineer's work is, of course, a distinct question. But here again engineers are often thought to be at a disadvantage when compared with such "true professionals" as lawyers or physicians. The engineer's employer decides whether to do what the engineer recommends while, some say, the lawyer or physician can simply do it. This supposition seems even more of a mistake than the supposition that lawyers and physicians have complete control over what they do. Like engineers, lawyers and physicians are primarily advisors. Under ordinary conditions, they can say what they like, insist on it as much as they like, but if the client or employer says no, they can do nothing. A will is only a draft until the client decides it is good enough to sign. A physician who forces a competent patient to submit to treatment is guilty of criminal battery. Whatever professional autonomy is, it cannot be control over one's client or employer.

Third, Bush assumes that being "controlled employees" means that "we" can have "no higher ideals than to serve as directed"in other words, that the status of employee is inconsistent with professionalism. This, of course, is the assumption this chapter is to help evaluate. The empirical literature does *not* address it. Instead, it addresses autonomy defined in some such way as this: "a condition in which the performer, rather than someone else, determines the sequencing of tasks which comprise the job and how long one performs a given task before switching to another."[21] Although this sort of control is, to some degree, a precondition of professional autonomy, it is clearly different. Every profession must at times adjust to the schedule of others. Even the physician may have to drop everything and come to the hospital when the baby is ready to be born. No one supposes such emergencies to threaten his professional autonomy even if he has such emergencies several times a day.[22] Hence, most empirical work on the autonomy of engineers is not directly relevant to their individual professional autonomy.

One near exception seems to be the work reported in chapter 9. My colleagues and I interviewed sixty engineers and managers in ten companies. We found few engineers or managers with absolute control over any significant decisions, but we did find considerable room for discussion and a strong tendency to seek consensus. We certainly got the impression that engineers were free to exercise their professional judgment (one obvious interpretation of professional autonomy); indeed, some managers seemed to go out of their way to stress the importance of engineers "sticking to their guns." Unfortunately, we were not then concerned with professional autonomy, so, our observations are no more than suggestive.[23] What more we should have done depends on what individual professional autonomy is. We must now work out a useful conception.

A Conception of Individual Professional Autonomy

The preceding examination of the literature on autonomy suggests three criteria of adequacy for any conception of individual professional autonomy. First, any adequate conception should explain the relation between professional autonomy and personal autonomy or, failing that, explain the importance of professional autonomy in some other way. Second, any adequate conception of professional autonomy should make the professional autonomy of an individual employee an empirical question or, failing that, explain why many people consider it to be empirical. Third, any adequate conception of professional autonomy should suggest ways to test the empirical content, if any, of claims concerning professional autonomy; it should yield a practical research program or, failing that, explain why none is possible. A conception meeting these three conditions would bring together, as much as possible, the philosophical, professional, and sociological literature concerned with workplace autonomy.

How do we proceed? First, I sketch what I hope will be a relatively uncontroversial conception of "acting as a member of a profession." Second, I identify a conception of personal autonomy suitable for our purposes. Third, I show that one can act autonomously, in this sense while acting as a member of a profession. Professional autonomy is a special kind of personal autonomy: acting as a member of a profession. Fourth, I show that one can act autonomously as an employed member of a professionthat employment and professional autonomy are not in principle inconsistent.

Having done all that, in the next section, I suggest some relatively easily conducted research to tell us how much professional autonomy employed engineers actually have.

Profession

There are no professions of one. To act as a member of a profession is to act as a member of a group. What kind of group? For our purposes, *a profession is a number of individuals sharing an occupation voluntarily organized to earn a living by serving some moral ideal in a morally permissible way beyond what law, market, and ordinary morality require.* 24 This definition is important enough to deserve amplification.

Professions are voluntary. We must claim membershipwhether by seeking a license to practice the profession, by applying for a job calling for a member of that profession (for example, "engineer"), or just by announcing membership in that profession (for example, "I am an engineer"). We can always leave a profession by giving up the license (if there is one), withdrawing from practice, and ceasing to claim membership.

Professions are organizations. We are not members just because we claim to be. We must also meet certain minimum standards of competence and conduct that the group treats as a condition of membership. Professions vary in degree of organization. Some have formal tests for admission, licensing bodies, disciplinary committees, and the like. Most have schools from which would-be practitioners should graduate, a written code of ethics, and various associations speaking for the profession in certain contexts. All recognize a distinction between those who, in virtue of competence and conduct, belong to the profession and those who, falling short in some way, do not belong though they claim to ("quacks," "charlatans," "impostors," and so on). A profession is more than an occupation; it is a discipline.

All professions have special, morally permissible standards for conducting the business of members. Typically, the primary purpose of these standards is to offer nonmembers (the client, employer, or public) some benefit or protection beyond what law, market, or (ordinary, preprofession) morality require. [25] These standards differ from profession to profession. So, for example, while engineers undertake to use their distinctive knowledge, skill, and judgment in ways that hold the public health, safety, and welfare paramount, lawyers do not. Professional standards are always morally permissible; a "profession of thieves" is no more a profession than play money is money. Not every discipline can be a profession (in this sense).[26]

Professions differ from charities, mutual assistance societies, and other altruistic organizations in being concerned with how members earn their living. There is no profession of amateurs. A profession is nonetheless not an ordinary business or occupational organization. A profession differs from an ordinary business in being for persons in a single occupation or, at least, in a family of occupations sharing a common body of knowledge, skill, and judgment. A profession differs from a trade association, union, or other occupational organization in having as its primary purpose something beyond benefiting its members. A profession differs from both businesses and occupational organizations in being designed primarily to serve a certain moral ideal in a certain way. Physicians organized to serve health; lawyers, justice within the law; and so on.

The "moral" in "moral ideal" is meant to exclude nonmoral ideals (the ideal of prudence, for example). A moral ideal is moral both in the minimal sense of being morally permissible (as, for example, stealing competently is not) and in the stronger sense of being morally good (that is, tending to support morally right conduct). But a moral ideal is also moral in a much stronger sense. A moral ideal is a state of affairs which, though not morally required, is one that everyone (that is, every rational person) wants others to approach when possible, wanting that so much as to be willing to reward, assist, or at least praise such conduct if that were the price for others to do the same. Moral ideals have a claim on us that nonmoral ideals do not. Professions are, by definition, praiseworthy (in the way voluntarily undertaking any laudable responsibility is) because each profession, by definition, undertakes to serve a moral ideal.27

To be a member of a profession is, then, to be subject to a special set of standards. To act as a member of a profession is openly to carry on one's business according to those standardsfor example, to declare in word and deed, "I work as an engineer [that is, as engineers are supposed to work]." Can one be subject to such standards and still be autonomous? Before we can answer that question, we must decide what we mean by "autonomous."

An act's voluntariness creates a presumption in favor of its autonomy (on any plausible conception of personal autonomy). If we can voluntarily make a promise without compromising our (personal) autonomy, we should be able to join a profession without compromising our autonomyeven if membership involves, as promising does, commitment to acts we would not otherwise do. So, because professions are voluntary organizations, the presumption must be that anyone acting as a member of a profession acts autonomously. 28

But that is only a presumption. Voluntariness does not guarantee autonomy. Even the content of a commitment can undercut the presumption of autonomy. So, for example, however voluntary, the promise to subject ourselves forever and in all respects to the arbitrary will of an immoral person does not seem autonomous. Although the promise renounces personal autonomy forever, its effect is only a symptom of the problem with its autonomy. The problem is that the promise does not seem to be either the act of an autonomous person or an act that an autonomous desire would motivate. We find it hard to imagine how an autonomous agent could voluntarily make such a commitment (and mean it). We doubt the autonomy of such a commitment until we hear an unusual, and convincing, explanation of why, appearances to the contrary notwithstanding, the promise is autonomous. So, we need to explain why voluntary membership in a profession is not like making such a promise. We need some way to distinguish those voluntary commitments that are autonomous from those that are not.[29] What help can the conceptions of personal autonomy we identified provide?

Agent-centered conceptions have nothing to say about what we can do autonomously. A promise to subject ourselves forever and in all respects to the arbitrary will of an immoral person would be autonomous, according to agent-centered conceptions, if we are autonomous; and all we need to be autonomous is the capacity to reflect on our desires, to change them in light of higher-order desires, and to act accordingly. This result points up two weaknesses in agent-centered conceptions. First, agent-centered conceptions do not require a tight connection between the act (in this case, a promise) and the agent's capacities to reflect (whatever they may be). A commitment is autonomous if the person making it is autonomous, however careless or ill-informed at the time. Second, agent-centered conceptions seem to rely on a weak procedural notion of rationality. Rationality consists in having some capacity for self-criticism and correction. There is no limitation on the content of the processshence, no way to guarantee that we cannot autonomously make even such an outrageous promise as we are now imagining. Agent-centered conceptions of autonomy seem unsuited to our purposes.[30]

What about desire-centered conceptions? All desire-centered conceptions of personal autonomy avoid this first weakness. Indeed, they seem designed to do just that. All require a tight connection between an autonomous desire and the act. For an act to be autonomous, the motivating desire must itself be autonomous.

Desire-centered conceptions differ from one another both in how they determine which desires are autonomous and in the relation they require between desire and

act. Historical conceptions require a certain history (for example, one avoiding hypnotic suggestion) for a desire to be autonomous; structural conceptions require a certain peaceful relation between the desire in question and others the person has; and hypothetical conceptions require that the desire be able to survive certain tests. Historical and structural conceptions are alike in requiring only that the desire motivating the act be autonomous for the act to be. Hypothetical conceptions may require more: for example, that the choice of the act (as well as the desire) be able to survive certain testssuch as vivid and repeated exposure to all relevant facts. Nonetheless, all desire-centered conceptions might share with agent-centered conceptions their second weakness, too weak a notion of rationality. Whether they do depends on how the crucial notion of autonomous desire is filled in.

All desire-centered conceptions are alike in having certain "internal constraints" on what counts as an autonomous desire: for example, "fitting the agent's life plan". These internal constraints, differing from conception to conception, may or may not amount to "procedural rationality." Most desire-centered conceptions of personal autonomy are also alike in lacking any provision for "substantive rationality." So, for example, most cannot declare nonautonomous the desire to have one's arm removed just to have it removed; some contingent fact about the person determines whether that desire is or is not autonomous. Only my hypothetical conception is different in this respect. Unlike all other conceptions (agent centered as well as desire centered), mine requires some correspondence between the desire and the external world. On my hypothetical conception, the desire in question must not be such as to weaken when exposed to the relevant facts. 31 It must, in this sense at least, be rational.

If we combine my conception with certain minimal assumptions about human psychology, we can identify certain substantive constraints on what can be autonomous. For example, suppose that, all else equal, people prefer liberty to subjection. Any desire to subject oneself to another just to do itas in the autonomy-renouncing promise we have imaginedshould, upon exposure to the reality of such subjection, disappear (or at least weaken enough to change the decision). Because the desire is not rational, any choice dependent on it would not be autonomous.

Other conceptions do not give this result even when supplemented in the way mine was. Common senselike preferring liberty to subjectionis no guarantee that people will not sometimes act foolishly, that they will not sometimes develop desires inconsistent with their own common sense, or that they will not otherwise fail to use all the information available. Contingency dogs our acts. My hypothetical conception escapes such contingencies by requiring the act's motivating desire to be capable of passing a test that depends on more than what the agent's psychology happens to be at a given moment. The desire must be able to survive repeated, vivid exposure to the world beyond the agent.

Because my hypothetical conception seems the most demanding conception of personal autonomy available, any argument relying on it to show that one can act autonomously as a member of a profession should withstand substituting one of the other, less demanding conceptions of autonomy. If we can explain how, according to this conception, personal autonomy is consistent with membership in a

profession, we should be able to do the same using any other plausible conception of personal autonomy. So, in what follows, I understand personal autonomy to mean autonomy according to my hypothetical conception.

Autonomy in Professions

If acting as a member of a profession is to be consistent with acting autonomously (as we are now conceiving autonomy), the profession has to be more than voluntary. It has to be a commitment consistent with all the relevant facts. What are facts? What makes them relevant?

By "facts" I mean, at least, (1) common sense, what "everyone" knows (that people generally prefer life to death, that depriving people of food can kill, that people know that, and so on), and (2) special knowledge actually available to people who inquire (what lawyers know about the law, what biologists know about genes, what you can look up in a public record, and so on). A fact is "relevant" to choice of an act if, and only if, exposure to it would, all else equal, strengthen or weaken the agent's resolve to do the act (whether by arousing new desires or by strengthening or weakening a desire already motivating the act). To have all the facts relevant to a decision vividly and repeatedly before one is to be fully informed.

A member of a profession can act autonomously in that capacity if, and only if, his actual choice accords with what he would have chosen if fully informed and motivated only by rational desiresthat is, desires that have themselves survived exposure to all the relevant facts. "Full information," a standard generally too costly for practice, is reasonable here because it applies only to a hypothetical choice. We do not ask anyone actually to make this choice under these conditions. We ask only that, given full information and other appropriate conditions, a psychological theory would tell us what the individual's actual choice would be or, at least, what options would be open. If we call such a choice rational, our question has become: *How could anyone rationally choose to act as a member of a profession?* 32 This is not a hard question.

To be a member of a profession is to be subject to standards of conduct. These are, as such, burdens (because, all else equal, liberty is better than subjection to a standard). If the standards in question were arbitrary, being subject to them would be little different from being subject to the arbitrary will of an individual. It would be an unredeemed burden. But all else is not equal for the standards of one's profession. Those standards are not arbitrary. They must, of course, be morally permissible. They must, in addition, be designed to serve the moral ideal to which the profession is committedor they would be, for that ideal, entirely arbitrary and so, strictly speaking, not the profession's standards at all. Someone who objects to acting according to a standard she believes inconsistent with, or just independent of, service to the moral ideal in question does not object to acting as a member of the profession. Instead, she objects, as a member of the profession, to the claim that acting as a member of the profession includes acting according to that standard.

Members of a profession may be members because they want to serve the ideal in question. They then have some commitment to whatever is in fact necessary to serve that ideal. But, even if someone is a member for less noble reasonsfor

example, just to earn a livinghe has a commitment to the standards in question. He has entered this particular profession because of what it is, hoping for the benefits that come from claiming honestly to belong to it rather than to another or none at all. He should (as a fully informed rational agent) understand that those benefits depend in part on maintaining certain standards. Who would claim to be an engineer, for example, if engineers were generally thought incompetent or dishonest? He should (as a rational agent) remain in the profession only as long as the benefits exceed the costs by enough to make membership the best option available for him.

Each profession is a cooperative practice. Each member bears certain burdens and expects other members to do the same. If most do as they should, the profession should have a good reputation and each member should be better off acting as a member of the profession than acting as an individual. If too many shirk, however, the practice produces no net benefit, and those who bear their share of the burdens suffer most. Because each profession is a voluntary cooperative practice, its standards have the same moral claim on members that the rules of a morally permissible game have on voluntary players. Violating a professional standard is a form of cheating. Members of a profession are therefore morally bound to act as their profession requires. They may sometimes have a justification or excuse for not doing as they should (just as they might for breaking a promise), but their profession will, like a valid promise, always burden their conduct with obligations they would not have but for their profession. The burden is not onerous, however, because there is always the morally permissible alternative of leaving the profession.

For any individual, membership in a profession may or may not be rational. But, given what professions are, the voluntariness of membership creates a strong presumption that membership is rational for those who actually are members. In turn, the rationality of membership vouches for the autonomy of acting as a member. We autonomously submit to the standards of a profession, when we can, because submitting to them belongs to the very practice generating the benefits that make membership rationally attractive and because taking these benefits without submitting to those standards is morally wrong. When we can no longer submit, we shouldand canquit. The autonomy one has as a member of a profession is not merely presumptive.

Employees and Professional Autonomy

An employer either hires a member of a profession as a member of that profession or hires him as something else. If she hires him as something else, he will not have to act "in a professional capacity." He will not be practicing his profession. He will be like the lawyer hired to teach tennis at a country club or the engineer who ends up as a company's comptroller. Insofar as what he does is not done in his professional capacity, he may ignore his profession's standards. Any problem of autonomy he has is not a problem of *professional* autonomy.

If, however, a member of a profession is hired as a member of that profession (for example, as an engineer), he may have a problem of professional autonomy. He *may* because, as a professional, he is supposed to do as his profession says while, as an employee, he is supposed to do as his employer says. The two commitments create a potential for conflictbut only a potential. Problems of professional autonomy can actually arise only if the employer orders the professional to do something his profession forbids. There is good reason to expect this not to happen *often:* Why hire someone as an engineer for example, if you do not what him to work as engineers typically do? If you simply want someone to obey your orders, why not hire someone without a profession (who would ordinarily be less expensive, too)?

While there is good reason to expect the employed professional not to have problems of professional autonomy often, there is also good reason to expect such problems *sometimes:* Just as people sometimes prefer theft to honest labor, so employers sometimes want professionals in name but not in deed. For example, an employer, who wants to ship an order in time may tell the engineer in quality control to "work the data" until the tests come out "right." In effect, the employer wants to substitute her judgment for the professional's while claiming the professional's authority for it. Obeying such an order would turn the professional into a marionette. Such an order is inconsistent with professional autonomy.

But not all orders are like that. For example, the typical specifications for an engineering project"under 2,000 pounds, under $2,000, and under twenty months"simply state a technical problem. Nothing in them is inconsistent with an engineer's professional autonomy. The engineer can both act as an engineer should and do as ordered. Similarly, even when an employer says, "Drop everything and figure out what's wrong with this windshield wiper," the employer's order need not threaten professional autonomy. As long as dropping everything is consistent with standards of professional practice, the employer's control over what is done and when it is done is consistent with professional autonomy. Of course, whether dropping everything is consistent with professional standards depends on what those standards are.

If we now return to the quotation with which we began this chapter, we can easily see that it contains a serious mistake. "Employers," Layton says, "have been unwilling to grant autonomy to their employees, even in principle." 33 What I just argued, in effect, is that employers must, both in principle and in practice, grant employed professionals professional autonomy. Employers must because otherwise they cannot have the benefit of employing professionals. "[Employers] have assumed that the engineer . . . should take orders," Layton continues, "[but] the very essence of professionalism lies in not taking orders from an employer."34 What I just argued is that the essence of professionalism consists in part of taking orders, those consistent with acting as a professional, and in part of not taking orders, those inconsistent with acting as a professional. To be a "true professional" is to act as the employer orders insofar as the orders are consistent with the profession's standards.35

Possible Research on Professional Autonomy So Conceived

If we look again at the sociological literature supposedly concerned with workplace autonomy, we can see how small modifications could convert much of it into research on professional autonomy. The problem with the existing research is a relatively unrefined conception of professional autonomy. Professional autonomy (or even autonomy in general) is not simply a matter of quantity (how many decisions) or mere quality (decisions about order, timing, content, or whatever). Some decisions matter more than others; and professional standards determine which those are. Research on professional autonomy should, then, begin by using the standards of the profession in question to identify which decisions matter professionally and which do not. The relevant decisions may well vary substantially from profession to profession even in the same workplace. Any research on the professional autonomy of engineers, for example, must begin by distinguishing those decisions engineers claim for themselves from those they leave to management. An order to ignore safety might violate an engineer's professional autonomy, when an order to ignore cost would not.

Therefore, a questionnaire should begin by trying to determine the standards the professional takes herself to be subject to. The questionnaire might ask, for example, "Which factors are your professional responsibility?" There would then follow a list to choose from (safety, health, quality, cost, beauty, and so on). The list should be developed taking the profession's formal standards into account, but in fact the answers may not mirror what is professionally required. Professionals are not always as well informed as they should be. How great the difference is between ideal and reality is, for any particular profession, an empirical question, one about which it would be good to have more information. Though what the profession requires is crucial for determining whether a professional actually has professional autonomy, what the professional supposes her profession to require is crucial for determining whether the professional feels that she has such autonomy.

Later questions should ask how often the professional employee is ordered to do something inconsistent with her professional responsibilities (as well, of course, as how often she is overruled or ignored, though overruling or ignoring is consistent with professional autonomy but not with professional control or job satisfaction). The questionnaire should also ask what the professional can do when she is overruled or ignored on a question she believes her professional judgment should decide. Can she, for example, appeal an order to higher authority? What happens if she does? The answers to such questions should reveal how much tension exists in fact between acting as a member of the profession and acting as an employee.

We have, it seems, now turned the question of how much professional autonomy employed engineers have into an empirical question for which ordinary methods of social research should be adequate. Indeed, researchers can "ask" similar questions of "free professions." Clients sometimes order even free professionals to do things contrary to professional standards (or, at least, ask such things in a way that makes saying no difficult). Data comparing both the frequency of such incidents among "free" and "captive" professionals and the outcomes might, or might not, show free professions to have more professional autonomy than employed professions.

EPILOGUE:
FOUR QUESTIONS FOR THE SOCIAL SCIENCES

This chapter tries to draw some lessons from the preceding ten chapters. In doing that, it identifies four questions concerning engineering for which I would like to have answers. The questions all seem to be of the kind that the social sciences in general, if not science and technology studies (STS) in particular, could, and should, be helping with. The four share at least two other features as well. First, any of them might arise while teaching engineering ethics, advising engineers on ethical questions, or otherwise engaging in "engineering ethics." Second, answering them would serve both practical philosophy and professional practice.

The four questions suggest a paradox. Though the social sciences should already be hard at work on them, in fact they hardly touch the subject. Indeed, when I ask about engineering, social scientists generally refer me to books that turn out to be about science (especially physics, biology, and medicine) or technology (objects and their consumers, processes, and victims). Consider, for example, Donald Mackenzie's very interesting *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance,* a book often presented to me as decisive proof that the social sciences are giving engineering its due. This is certainly a book about engineering. Its subject is an engineering problem, the development of specifications for what constitutes a direct hit with a long-range missile; its cast of characters is also largely engineers). Yet, it is proof of my thesis, not evidence against it. The words "engineer" and "engineering" are (except for the title of its chapter 3) virtually absent. For all the reader is told, the book has nothing to do with engineering. But the index has a substantial number of listings for "applied science." No attempt is made to distinguish the contribution of engineers to the debate from the contribution of scientists (if any), politicians, or the like. [1] Here is a classic illustration of the way the profession of engineering, central to modern technology, seems to be almost invisible to social scientists, even those who study technology.

Of course, a few social scientists have done some useful work on engineering, especially, if we include historians among social scientists. (I will give some examples later.) The trouble is that social scientists have done far too little (especially when compared to what they could do or what they have done for the physical sciences), what they have done has yet to form a distinct field of study, and what little they have done has not been designed to help with engineering ethics. 2 So, this final chapter is in part a plea for an overdue adjustment in focus.

I proceed in this way. First, I briefly explain what I take engineering ethics to be, summarizing the book's main argument. Next, I state and discuss my four questions, making clear what each asks, why the answer might be important for engineering ethics as I have interpreted that subject, what would constitute an adequate answer, and how social scientists might help. Last, I consider what barriers stand in the way of answering the questions. Everything I say is both sketchy and preliminary, an invitation to begin a discussionprologue as much as epilogue.

Engineering Ethics

Engineering ethics is a kind of applied, or practical, philosophy. It is concerned with understandingand helping to resolvecertain moral problems arising in the practice of engineering. These problems can be approached in at least five ways: philosophical, casuistic, technical, social, and professional.3

The first three approachesthe philosophical, casuistic, and technicalare alike in assuming that engineers are held only to the same moral standards as nonengineers. Professional organization, if it matters at all, matters as a mere "expression" of fundamental moral concerns, as an aid or barrier to doing what should be done anyway, profession or no.

The philosophical and casuistic differ from the technical in relying solely on the facts of a particular situation to transform general standards into specific directives. They differ from each other in the way they determine those general standards. The philosophical appeals to some moral theory (utilitarianism, Kantianism, virtue theory, or the like) to determine (along with the facts) what should be done.4 The casuistic appeals instead to ordinary moral standards (either explicitly, for example, by citation of a commonly accepted moral rule like "Don't kill" or "Don't take unnecessary risks," or implicitly, by comparison of cases, ormost oftenby some combination of these).5

The technical approach differs from the philosophical and casuistic insofar as it relies (instead or in addition) on *special* "principles of [good] engineering" derived from the "nature" of engineeringprinciples of competence or skill. Those special principles (together with ordinary morality and the specific facts of a situation) determine what should be done in that particular situation. The nature of engineering may be timeless (a Platonic idea) or a product of history (like the English language), but, at any time, it is a given, not something subject to change in the way a statute or contract is.[6] These first three approaches commit one or another of the fallacies identified in chapter 3.

The social approach to engineering ethics resembles the technical in beginning with something special about engineers or engineering. It differs from the technical in understanding this specialness as, at least in part, a product of social decision (the role society constructs for engineers). For the social approach, the standards of engineering ethics derive not from the nature of engineering as such but from a morally binding "contract" with society or from society's morally binding dictate. For the social approach, standards of engineering ethics are more or less arbitrary, that is, dependent on what society and engineers together happen to agree on or what society happens to decide.[7]

The professional approach, the last on my list, resembles the social insofar as both recognize a certain arbitrariness in what may turn out to be "ethical." The professional approach differs from the social in placing that arbitrariness in the profession of engineering rather than in the decisions of society as such or in an agreement engineers make with society. For the professional approach, society (like morality or the nature of engineering) is generally a mere "side constraint," not the primary, or equal, party in determining the content of engineering ethics.[8] I call this approach professional to emphasize the distinctive place it assigns the profession. For this approach, and for this approach alone, a morally binding code of ethics, typically the work of a professional society, is a central fact.[9] This last is, of course, the approach I take.

This book noted early that "ethics" is ambiguous. We can use it (1) as a mere synonym for ordinary morality, (2) as the name of a specifically philosophical study (the attempt to understand morality as a rational undertaking), or (3) as special standards of conduct morally binding on members of a group because they belong to that group ("special" both because the standards do not apply to everyone and because they go beyond what law, market, and ordinary morality require). All five approaches to engineering ethics can use ethics in the first two senses (though the technical tends to ignore the second). But only the social and professional approaches can use it in the third sense; only they recognize engineering ethics as including special, morally binding standards of conduct.

I distinguish these five approaches because distinguishing them allows us to see important common ground and reveals some important differences as well. All five recognize how important understanding what engineers do is to understanding what they *should* do. None of the approaches supposes that we can do much of interest in engineering ethics without knowing a good deal about engineering, especially about what moral problems actually arise in practice and what resources are available for resolving them. "Practical philosophy," however approached, requires an understanding of the relevant practice.

The five approaches nonetheless differ somewhat concerning what understanding is necessary. For example, the philosophical approach makes an understanding of the history of professional codes seem beside the point. For the philosophical approach, the central relation is between some moral theory and the situation of the individual professional.10 For the professional approach, however, the history of the profession is much more important because that history should give insight into how to interpret the profession's code and that code is central to determining what the professional should do. This difference concerning what understanding is necessary may well affect the questions those committed to a particular approach ask about engineering.

Commitment to the professional approach, though evident throughout this book, should not matter much for what I shall do now. Although I do not expect everyone to agree that I am asking just the right questions, I do hope that everyone agrees that I am asking the right sort of question. Social scientists who find another approach more to their liking than the professional can ask somewhat different questions and organize their research accordingly. They will still serve engineering ethicsin part at least by showing how empirically fruitful the other approaches can be.

What is Engineering?

The first question I would like the social sciences to help answer is one with which this book began: "What is engineering?" My attempt to answer it took me into fields of history and sociology all but deserted. Why is this question on my list? By now, the answer should seem familiar. Because I take the professional approach, engineering ethics is, for me, the ethics of engineers, a special group. I therefore need to know who is in the group (and so subject to its special standards) and who is out (and so not subject to them). Determining who is an engineer and who is not is not easy, as chapter 3 made clear. We can, of course, settle many cases intuitively. For example, someone with a B.S. in mechanical engineering from an ABET-accredited school (say, from IIT in 1975), licensed to practice nuclear engineering, and with twenty years of experience designing nuclear power plants, certainly is an engineer (for purposes of engineering ethics). And just as certainly, the operator of a diesel locomotive or the janitor of an apartment building, though called engineer, certainly is not. But what about those called software engineers or genetic engineers? They generally do not have an ABET-accredited degree but, unlike diesel operators or janitors, generally have an education similar to that of engineers and do work similar to engineering. And what about the chemist or physicist who does work engineers also do and who, unlike software engineers or genetic engineers, may well work beside engineers strictly so called?

Anecdotal evidence makes me think that engineers (strictly so called) are pretty clear about who is an engineer and who is not. Generally, software engineers and genetic engineers are not; the chemists or physicists may be "adopted" after demonstrating certain skills on the jobbut, until then, they are outsiders, whatever title they hold and whatever work they do. Couldn't sociologists tell us as much about this line drawing as they have about the line drawing between science, non-science, and pseudo-science? 11

The question "*Who* is an engineer?" soon leads to a question actually on my list of four, one of interest to all approaches to engineering ethics: "*What* is engineering?" Even those who do not recognize engineers as having a profession different from science or technology, still need to distinguish, for example, those moral problems properly belonging in a course in engineering ethics from those properly excluded. Not all moral problems engineers face, even in the workplace, are problems of engineering ethics. Some are problems of business ethics or just ordinary moral problems.

Though "What is engineering?" is a philosophical question, historians can help answer it in at least two ways. Walter Vincenti's *What Engineers Know and How They Know It* provides a good example of the first way. [12] By using the techniques of historical studyespecially, the gathering and analysis of documents to reconstruct a sequence of eventsVincenti was able to help us see engineers at work, to distinguish their work from that of scientists, and so to help us understand some differences between engineering and science. We need more work on the difference between engineering and science.[13] We also need similar work to help us understand the difference between engineering and architecture, between engineering and industrial design, between computer engineering and software engineering, and even between chemical engineering and industrial chemistry (especially when, as sometimes happens, engineers and chemists seem to be doing the same job).

Vincenti's work is a series of what we might call historical case studies. Sociologists can do something similar using participant observation. *The Soul of a New Machine* is almost an example of what sociologists could do.[14] I say "almost" because Tracy Kidder, while describing the work of engineers in informative detail, never tries to figure out what distinguishes what they do from what the people in software do (or why the department he studied wanted engineers while software did not).[15]

Historians can also contribute to our understanding of engineering in a way sociologists cannot. Historians can tell us about the historical process of defining engineering.[16] Layton's *Revolt of the Engineers*[17] is an important example of what can be donebut, in my view, one that leaves most of the work undone. Layton's focus is on the United States before World War Iwhen the United States was still a cultural backwater. The crucial events in professional development may well have occurred in France, England, or Germany. After all, engineering came to the United States from France, with American engineering schools copying the French at least up to the Civil War; engineering codes of ethics were adopted in England almost a half century before they were adopted in the United States. We need a trans-Atlantic history of engineering's definition.[18]

In chapters 1 through 3 I argued that what such a history would teach is that we *cannot usefully define* engineering by genus and species, as Artistotleans would, or even by what engineers do or how they do it (their function or method). The useful definitions treat engineers as members of a certain historical community, the profession of engineering, and then define that community in terms of certain historically developing criteria including education, experience, and commitment to certain ways of doing certain things. Engineering is what engineersat the time in questiontypically do that members of other occupational groups don't. Engineering has ethics built into it insofar as, and only insofar as, the engineering community has in fact adopted special morally permissible standards beyond what law, market, and ordinary morality require. This, I believe, is what such a history would show. But, without the right sort of historical research, research careful to distinguish the profession of engineering from various competitors, including proto-engineers,

the best we can do is what I did, a philosopher's reconstruction of what historians have so far discovered.

What do Engineers do?

If we define engineering in some such way as I suggest, we can distinguish engineers from those doing similar work. Engineers are those whom the engineering profession recognizes as members (for example, for purposes of membership in engineering societies"at the professional level"). That way of identifying engineers would allow us to ask what, if anything, engineersat a certain momentcontribute that others do notthat is, what significance their special standards of conduct have for others. The answer may well interest many in the history, sociology, and philosophy of technology because it provides a way to study what effect, if any, differences in profession have on the technology members of professions make or use.

Although a number of writers stress the importance of engineering (or, rather, technology) *to* science, I don't think anyone has much to say about the importance of engineers *in* science (engineers strictly so called). Yet, at most "science" laboratories I have visited, including Argonne, engineers seem to outnumber scientists (though accurate figures were hard to get). The only exception was a Red Cross lab where there were no engineers. There physicians (or, at least, M.D.s) outnumbered the scientists (Ph.D.s). What do engineers do in science labs? How much science is the work of engineers? Why?

The relevance of such questions for engineering ethics was brought home to me by a Department of Energy report of a whistleblowing incident at Argonne. [19] The whistleblower was described as a "metallurgist" butby training, experience, and (it seemed) commitmentshe was a metallurgical engineer.[20] The report described an internal investigation which, while siding with the whistleblower on matters of fact, clearly had trouble understanding why he was taking the science issues so seriously. I had less trouble understanding. It seemed to me he was doing what a good engineer should, though he might have done it more politicly. He was giving safety more weight than law, market, and morality requires, more weight than scientists commonly do; he was giving it the weight engineering requires.

Here then is one place where empirical work, historical or sociological, might help settle a dispute between philosophers. Both the philosophical and casuistic approaches to engineering ethics assume that engineers are not subject to any special standards, that their local situation or function is decisive in determining what they should do (and so, what they are likely to do). Studies of cases like that at Argonne, if they generally turned out as I believe they would, might provide substantial empirical evidence favoring those approachesthe technical, social, and especially professionalthat identify engineers as subject to special standards (whether of competence or conduct).

How do Engineering Decisions get Made?

Most engineering goes on in large organizations, governmental or commercial. Large organizations exist to do large jobs, doing them by dividing them into manageable parts. If these parts are too small, engineers assigned one of them could not determine what effect their work would have on the public health, safety, or welfare or even on their employer. Their work would be "bureaucratized," in one of the uglier senses of that ugly word. If most engineering work is bureaucratized in this sense, engineering ethics must either be irrelevant to most engineers or consist of matters tangential to engineering as suchfor example, treatment of other engineers. Engineering ethicsas now constitutedpresupposes a world in which engineers generally know what they do.

Here, then, is a sense of the question, "What do engineers know?" quite different from Vincenti's but as worthy of investigation. My own research, reported in chapter 9, and much anecdotal evidence as well, convinces me that engineers generally have a pretty good idea of who will use their work and how; they know what they do. Their work is not, and generally cannot be, bureaucratizedor, at least, not without prohibitive waste. Yet, although there is a large literature on business organization, relatively little of it is on technical organizationand very little on engineers in particular. [21] Worse, virtually no work has been done on decision rules in technical decision making. Although most of the organizational literature makes it sound like managers decide and employees, including engineers, either submit, perhaps dragging their feet, exit, or blow the whistle, the research reported in chapter 9 suggests something quite different, a process in which consensus is the rule, engineers generally have the power of veto over management decisions, and engineers are well informed in part at least because information is necessary to win their consent.

What can Engineers do?

Most engineers are employees, subject to termination of employment at the employer's will. Some writers have concluded from this that engineering is a "captive profession," that engineers have little room for professional autonomy, and that therefore there is little room for engineering ethics.22 I have already suggested one reason to think this view mistakenat least in some organizations, those that decide engineering questions by consensus. But what about an organization in which engineers are well informed but decision is not by consensus? What room for professional autonomy there?

Here we need philosophical work on the concept of "professional autonomy" sensitive to the problems of empirical research. Chapter 10 is an example of what can be done, but one taking the professional approach to engineering ethics. Those who do not share my approach may want to develop a philosophically defensible alternative. Alternatives would allow the social sciences to tell us whether different, philosophically defensible definitions of professional autonomy lead to different answers to empirical questions about how much professional autonomy engineers actually havefor example, which organizations, if any, actually eliminate or drastically confine the professional autonomy of engineers. We would then have a better idea when talking about the professional responsibility of engineers makes sense (and what philosophical commitments, if any, underwrite such talk).

Conclusion

In 1994 the philosopher Carl Mitcham published an expansive, thoughtful, and informative book, *Thinking through Technology.* In one small corner, he argued that engineering ethics is part of science and technology studies. 23 While I agree that engineering ethics is *properly* a part of science and technology studiesor, at least, could beI think that, as a matter of fact, it is not. I have two reasons for so thinking.

First, engineering ethics has so far developed as a field of professional ethics. The professions include many nontechnical professions, everything from journalism to accounting, from lawyering to nursingfields that science and engineering studies would have trouble absorbing. So, at best, engineering ethics would have to divide its citizenship between two distinct fields. So far, it has not even done that. Even in a field such as medical ethics, where empirical research is much more extensive than in engineering ethics and where technology is also a major source of ethical issues, the people doing professional ethics are different from those doing science and technology studies. Whatever can be said about science and technology studies and engineering ethics as abstract fields, as living research communities, they were, and remain, largely separate. So, for example, typical journals in science and technology studies (*Technology and Culture; Science Studies; Science, Technology, and Human Values;* and so on) would not appear on most lists of professional ethics journals; nor would typical professional ethics journals (*Business and Professional Ethics Journal, International Journal of Applied Philosophy,* *Science and Engineering Ethics,* and so on) appear on most lists of journals in science and technology studies.[24]

My second reason for thinking that engineering ethics is not now part of science and technology studies is that those working in science and technology studies are generally indifferent to professional ethics. *Thinking through Technology* bears the subtitle "The Path between Engineering and Philosophy" because Mitcham saw himself as mediating between two ways of doing philosophy of technology, the engineering way and the "humanities" way. Neither way pays much attention to engineering as a profession. The chief concern of both is technology rather than engineering. Rarely does someone on Mitcham's long list of contributors to one way or the other of doing philosophy of technology get closer to engineering ethics than technology assessment or public policy. That is not very close.

Will science and technology studies contribute substantially more to engineering ethics than they have so far? I don't know. But I hope they will. To understand moral problems we must see them in context. To understand problems of engineering ethics, we must understand the engineering context. Who among social scientists are better placed than those working in science and technology studies to describe, interpret, and otherwise improve our understanding of the context of engineering?

I said "hope," not "expect," because a large barrier seems to stand in the way of science and technology studies doing the work I am calling for. Science and technology studies grew up concerned with knowledge (for science) and things (for technology). Only in the last two decades have science studies come to focus on research communities rather than on science. Technology studies still seems focused on things, processes, and knowledge, on technology rather than on specific technological professions. I hope this book, whatever else it does, serves as an invitation to social scientists, especially those in science and technology studies, to consider studying the technological professions *as professions*, especially, engineering, the most important technological profession of them all.

APPENDIXES

Appendix 1
Questionnaire for Engineers

Explain project. Assure anonymity. Then ask: Are you an engineer or a manager?

1. What is your professional background?

    a. How did you come to work here?

    b. What does your company do? Example?

2. What do you do here?

3. How does your company make engineering decisions? Can you give an example?

    a. What part do engineers play in important design and operation decisions here?

    b. What part do managers play in important design and operation decisions here?

4. What are the most important factors determining company decisions on matters of engineering?

    a. Does your company take large risks in its technical decisions? Why?

    b. Does your company have a code of ethics?

5. Is the management of the company trained or versed in the company's technology? How current do you feel they are?

6. Are your engineering recommendations being acknowledged in such a way that you receive assurance that they have been received and will be acted upon in accordance with your statements? Explain.

a. What review process is in place for an engineer's concern?

b. Do you have, and participate in, a process of technical design review with your peers? With management on critical design specifications?

7. Do you think there are any communications problems between your supervisor and his supervisors? Examples?

a. Do you ever find it necessary to withhold information from your superiors? If so, explain?

b. Have you ever felt that your superiors were not telling you the whole truth? If so, explain.

9. Have you ever felt that safety or quality were being sacrificed for reasons with which you did not agree? If so, explain.

a. What would you do if you thought safety or quality were being sacrificed?

10. On what issues do you think professional engineers should be content to see their judgment superseded? On what issues should the engineer's judgment be the last word?

11. If you don't like what your immediate superior is doing, what can you do about it?

a. Does your firm have a formal open door policy? Is it used to appeal technical decisions? How does it work?

12. Are engineers good management material? Why or why not?

    a. What transition training or coaching is provided for an engineer promoted into management?

    b. In what important ways must a promoted engineer change?

13. If you had full control over the engineering work in your company, what would you do differently? Why?

    a. Are your engineering recommendations being affected by considerations or pressures that deny you the opportunity to provide the optimum solution to some problem?

13* What questions should a manager ask you to get the information he needs to make the right decision? Which, if any, of these questions is a manager *least* likely to ask?

14. Are there any questions we didn't ask that we should have? Anything you want to add to what you have already said?

The star following a number indicates the question was added after interviewing began.

Appendix 2
Questionnaire for Managers

Explain project. Assure anonymity. Then ask: Are you an engineer or a manager?

1. What is your professional background?

    a. How did you come to work here?

    b. What does your company do?

2. What do you do here?

3. How does your company make engineering decisions?

    a. What part do engineers play in important design and operation decisions here?

    b. What part do managers play in important design and operation decisions here?

4. What are the most important factors determining company decisions on matters of engineering?

    a. Does your company take large risks in its technical decisions? Why?

    b. Does your company have a code of ethics? What part does it play in your decisions?

5. Is the company's management trained or versed in the company's technology?

  a. How current do you feel they are?

  b. Should managers have a technical background?

6. Do you and your engineers always see eye to eye on technical questions? If not, when not? What happens?

7. How much weight does an engineer's recommendation have?

  a. Does an engineer's technical expertise weigh as heavily as management considerations in making decisions?

  b. What review process is in place for an engineer's concerns?

8. On what issues should professional engineers (on staff) be content to see their professional judgment superseded? On what issues, if any, should the engineer's judgment be the last word?

9. Do you ever find it necessary to withhold technical information from your engineers? If so, explain.

10. Have you ever felt that your engineers were not telling you the whole truth? If so, explain.

11. Are engineers good management material? Why or why not?

  a. What transition training or coaching is provided for an engineer promoted into management?

  b. In what important ways must a promoted engineer change?

12. If you had full control over the engineering work in your company, what, if anything, would you do differently? Why?

a. Are your recommendations now being affected or colored by considerations or pressures that deny you the opportunity to provide the optimum solution to some problem?

12* What questions should an engineer ask you to get the information he needs to make the right decision? Which, if any, of these questions is an engineer *least* likely to ask?

13. Are there any questions we didn't ask that we should have? Anything you want to add to what you have already said?

The star following a number indicates the question was added after the interview began.

Appendix 3
Interviewee Characteristics

Table 1: Total interviewed

	Engineers	Managers	Total
Customer-Oriented Companies (6)			
	3	1	4
	3	2	5
	2	6	8
	3	3	6
	5	4	9
	3	4	7
Engineer-Oriented Companies (4)			
	0	1	1
	3	4	7
	3	4	7
	4	2	6
	29	31	60

This table does not include three background interviews with managers not directly involved with engineers. Thecompany listed with no engineers had a dozen or so engineers; but we only interviewed their manager in the first trialof the questionnaire.

Table 2: Employment history

	Engineers (*n* = 29)	Managers (*n* = 31)
No. of employers		
Only 1	18	21
2 or more	11	10
No. of yrs w/present employer		

03	5	3
39	11	8
1019	8	4
20+	0	10
unknown	5	6

The range for engineers was from one to eighteen years; for managers, six months to thirty-nine years.

Table 3: Fields of engineering (determined by degree or, in its absence, by work experience)

Civil	Chemical	Electrical	Mechanical	Metalurgical	Unspecified
2	4	12	20	6	7

In addition: One engineer (not counted above) claimed degrees in *both* mechanical *and* electrical; and two others (alsonot counted above) claimed a B.S. in construction engineering, a close relative of civil. Of the remaining six interviewees,two had degrees in chemistry (and were working as chemical engineers) and one had an associate degree in qualityassurance. The three nonengineer managers would bring the total to 60.

NOTES

Preface

1. Charles Harris, Michael Pritchard, and Michael Rabins, *Engineering Ethics: Concepts and Cases* (Wadsworth: Belmont, Mass., 1995).

2. Walter G. Vincenti, *What Engineers Know and How They Know It* (Johns Hopkins University Press: Baltimore, 1990).

3. Samuel Florman, *The Existential Pleasures of Engineering* (St. Martin's Press: New York, 1976); and The Civilized Engineer (St. Martin's Press: New York, 1987).

Chapter 1

This chapter began as a GTE Lecture at the University of Wisconsin Center/Fond du Lac, October 13, 1992. I should like to thank those present, as well as my colleagues, Wilbur Applebaum (history) and Sid Guralnick (civil engineering) and my friend, Mike Rabins (Texas A & M) for help in sorting through the issues discussed here. The chapter appeared in a somewhat longer version and under the title "An Historical Preface to Engineering Ethics," in *Science and Engineering Ethics* 1 (January 1995): 33-48. Reprinted by permission.

1. See, especially, Paolo Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era,* translated by S. Attanasio (Harper and Row: New York, 1970). The *Oxford English Dictionary* gives 1615 as the first known use of the word "technology" in English.

2. David Noble claims that Jacob Bigelow, a Boston physician who helped found the Massachusetts Institute of Technology (1865) was instrumental in introducing "technology" (in its modern sense) into general usage. To establish his claim, Noble offers this quotation from Bigelow's *Elements of Technology* (1829):

> There has probably never been an age in which the practical applications of science have employed so large a portion of talent and enterprise of the community, as in the

> present. To embody . . . the various topics which belong to such an undertaking, I have adopted the general name of Technology, a word sufficiently expressive, which is found in some of the older dictionaries, and is beginning to be revived in the literature of practical men at the present day. Under this title is attempted to include an account . . . of the principles, processes, and nomenclatures of the more conspicuous arts, particularly those which involve the application of science, and which may be considered useful, by promoting the benefit of society, together with the emoluments of those who pursue them. (David Noble, *America by Design* [Alfred A. Knopf: New York, 1977] pp. 3-4)

My reading of this passage does not agree with Noble's. Bigelow refers to a revival of the term already beginning; hence, by his own admission, Bigelow probably is not "instrumental" in its revival. Further, Bigelow's own use of the term is barely distinguishable from that found in the old dictionaries to which he refers. The chief difference is the observation that *some* of the more "conspicuous arts" he describes "involve the application of science." He still seems far from the modern idea of technology as either inventions or the "science of invention."

3. See, for example, Plato's *Theaetetus* (III: 172-173): "[A] philosopher is a gentleman, but a lawyer is a servant. The one can have his talk out, and wander at will from one subject to another, as the fancy takes him . . . [but] the lawyer is always in a hurry."

4. Hannah Arendt, *The Human Condition* (Doubleday: Garden City, N.Y., 1959) p. 323n.

5. "If we assume that the Middle Ages ended with the fifteenth century, then a simple count of inventions made or adopted by Europeans during the period confirms that it was, as regards

technics, more creative than any previous epoch in recorded history." (*Dictionary of the History of Ideas: Studies of Selected Pivotal Ideas*, edited by Philip P. Weiner [Charles Scribner's Sons: New York, 1973] vol. 4, p. 359 [D.S.L. Cardwell, technology]) I am, of course, still comparing Greece's Golden Age with a similar stretch of time during the Dark Ages. Were I to compare the Dark Ages with the Hellenistic Period, I would hedge my claim a bit (and begin to worry about how to count inventions).

6. See, for example, Spencer Klaw, "The Faustian Bargain" in *The Social Responsibility of the Scientist*, edited by Martin Brown (Free Press: New York, 1971) pp. 3-18.

7. Who is this "we"? Certainly, you and I, but probably, as well, most inhabitants of the planet.

8. The modern prejudice against manual labor seems to vary from place to place and time to time. It is certainly less in the United States today than, say, in France a century ago. So, for example, it is today hard to imagine the events a French mechanical engineer (or mechanic) of the nineteenth century recalled. After church, he struck up a conversation with a young woman (with her mother standing by). When she found out that he built steam engines for a living, she shuddered:

> "What! You work, you are therefore exposed to all the filth that trade includes?" A bit vexed I responded, "But yes, miss, and I dare to believe that none is apparent at this moment." The mother turned her back and the eyes of my beautiful neighbor fell on my well-ground hands, which did not betray me, and she moved away. For her, I was a plague-stricken person. (Eda Kranakis, "Social Determinants of Engineering Practice: A Comparative View of France and America in the Nineteenth Century," *Social Studies of Science* 19 (February 1989): 5-70, at 13)

The whole paper is well worth reading both for the contrast it draws between French and American practice and for the cultural explanation it offers.

9. Though this description of science is no doubt biased in favor of the natural or physical sciences, it also applies (with a bit of stretching) to the social sciences. The social sciences can

be practiced as an attempt to understand human society from the outside, that is, as a part of nature. Of course, many social scientists now consider such value-free science to be impossible and its attempt likely to mislead.

10. *World Almanac* (World Almanac: New York, 1989) p. 158. This number must be taken only as a rough approximation. The Labor Department (three years later) set the number of engineers at 1,519,000 (*Occupational Outlook Handbook* [U.S. Department of Labor, Bureau of Statistics, Washington, D.C., May 1992], p. 64); whereas the National Science Foundation put the number at 2,849,800 (*U.S. Scientists and Engineers: 1988 Estimates,* Surveys of Science Resources Series, National Science Foundation, NSF 88-322, p. 6). Apparently, it is not easy to count engineers. Why?

11. "Principles of Medical Ethics" in *Codes of Professional Responsibility,* edited by Rena A. Gorlin (Bureau of National Affairs: Washington, D.C., 1986) p. 99.

12. The first of these modern professions was the apothecaries, a profession now deceased, which reorganized in 1815. The other liberal professions followed only slowly, beginning with the solicitors in the 1830s. See W.J. Reader, *Professional Men: The Rise of the Professional Classes in Nineteenth-Century England* (Basic Books: New York, 1966) esp. pp. 51-55.

13. Thomas Percival, *Medical Ethics; or A Code of Institutes and Precepts Adapted to the Professional Conduct of Physicians and Surgeons* (1803). The word "institutes" suggests that Percival's model here is in part at least jurisprudence. (Since the emperor Justinian's famous textbook, "institutes" signals that a book so

titled is a textbook or summary of the law, the rest of the title telling the particular jurisdiction, for example, Coke's *Institutes of the Laws of England*.) Percival in fact makes this connection in his introduction, indicating that he originally intended to call his text "medical jurisprudence." About half the text is a summary of English law a physician should know. Much of the rest consists of "precepts" (i.e., advice) rather than of standards of conduct (ethics strictly so-called). Medical ethics in the modern sense is actually a small part of that seminal work.

14. See, for example, M. David Burghardt, *Introduction to the Engineering Profession* (HarperCollins: New York, 1991) p. 26: "We shall assume that wherever there was an invention or innovation, engineering was required." Burghardt does not say the same about engineers. Can there be engineering without engineers? Or Billy Vaughn Koen, *Definition of the Engineering Method* (American Society of Engineering Education: Washington, D.C., 1985) p. 26: "After 20 or 30 centuries, the engineer learned how to correct this problem by allowing the front axle to pivot on a king bolt as stage three in the evolution of cart design." Engineers three or four thousand years ago?

15. See, for example, Ralph J. Smith, *Engineering as a Career, 3rd* (McGraw-Hill: New York, 1969) p. 22: "It has been said that the history of civilization is the history of engineering. Certainly it is true that the highly developed civilizations have all been noted for their accomplishments in engineering." Substitute "building" for engineering and there would be nothing to object to. The same is true of scholarly works such as Donald Hill, *A History of Engineering in Classical and Medieval Times* (Croom Helm: London, 1984). A careful researcher and writer, Hill argues for his application of "engineer" to ancient builders (rather than, as most writers do, just assuming the application to be obviously justified).

Yet he soon admits that "classical and medieval engineers did not have a quantified, scientific basis for their designs" (p. 5), that they lacked the formal training characteristic of modern engineers, and that they even lacked a full-time occupation (p. 7). They did engineering (read "building") as a sideline. So, whatever they were, they were not a professionor even an occupation.

16. Though we now translate *corps du génie* as "corps of engineers," there is in fact no exact English equivalent. While *génie* corresponds to the English "gin" (as in "cotton gin") and perhaps "jenny" (as in "spinning jenny") the French has less suggestion of "engines." Perhaps the best translation would be "corps of the contriver"though this lacks the sug-

gestion of magic (as in the English "genie"). Unlike the *corps du sappeur* ("the corps of spaders") for example, the *corps du génie* seems not to have taken its name from the implements it used but to have given those implements its name. This suggests an inherent novelty in what it did.

17. See Frederick B. Artz, *The Development of Technical Education in France, 1500-1850* (MIT Press: Cambridge, Mass., 1966) p. 48; or W.H.G. Armytage's history of engineering in Britain, (misnamed) *A Social History of Engineering* (Faber and Faber: London, 1961) pp. 96, 99.

18. Of course, many changes were made in the engineering curriculum (as well as many experiments with less demanding curriculum). Whole new subjects, such as thermodynamics or electricity, were added, and geometry and trigonometry gave way to a second year of calculus. For engineers, these may appear more than improvements in detailand, for many purposes, they certainly are. Yet, for our purposes, such differences between the French curriculum of 1799 and today's typical engineering curriculum hardly affect the gap between what engineers learn and what lawyers, physicians, or even architects learn. Those who wish to understand what distinguishes engineering from other professions must pay attention to what engineers have in common, especially over long stretches of time, rather than what divides them.

19. Artz, *Technical Education*, 47-48. I should perhaps warn that the members of this corps do not seem to have been known as "civil engineers" (*ingénieurs civils*) but as "road and bridge engineers." The French seem to have reserved "civil engineer" for engineers employed by private persons. All members of a corps,

whether of the *corps du génie (militaire)* or of the *corps des ponts et chaussées,* were state employees. The English term "civil engineer" may have derived from a misunderstanding of the French term (since the English, with a relatively weak state, had no exact counterpart to the *corps des ponts et chaussées*). Here is work for historians. Compare Kranakis, "Social Derterminants," esp. pp. 29-30.

20. Engineers also had some secret methods (for example, Monge's descriptive geometry). Artz, *Technical Education*, 106.

21. Ibid., 81-86.

22. But note Peter Michael Molloy's remark in *Technical Education and the Young Republic: West Point as America's École Polytechnique* (unpublished dissertation, Brown University, 1975) p. 105: "From a description of the curriculum, there should be no mystery for the change in the School's name in 1795 from *École des Travaux Publics* to *École Polytechnique.*" It remains a mystery to me.

23. Artz, *Technical Education*, 154-155.

24. Ibid., 160. I should, perhaps, say "this École Polytechnique." By 1830, the École Polytechnique had become so devoted to mathematics that (by American standards of the day) its graduates generally did not seem to practice engineering. This later École Polytechnique may, then, provide an early example of the ability of science education to crowd out engineering. See Molloy, *Technical Education*, esp. pp. 119-130. On the other hand, this interpretation may simply be unfair (within the French context). See Kranakis, "Social Determinants," esp. pp. 22-29, for reasons to think that the École Polytechnique remained an engineering school throughout the nineteenth century.

25. Artz, *Technical Education,* 160-161. I should perhaps add that only practical difficulties seem to have prevented all this from happening as early as 1802. Malloy is very good on this.

26. Eugene Ferguson, "The Imperatives of Engineering" in John G. Burke et al., *Connections: Technology and Change* (Boyd and Fraser: San Francisco, 1979) pp. 30-31. Ferguson's "imperatives" are, of course, Koen's "heuristics."

27. For a detailed study of one of these proxy measures that, in the end, had to be dis-

carded, see Walter G. Vincenti's discussion of "stability" in *What Engineers Know and How They Know It* (Johns Hopkins University Press: Baltimore, 1990) pp. 51-108.

28. In the absence of government action, engineering societies developed codes both to enhance efficiency (by promoting standardization) and to maintain safety. These codes set standards for engineers to follow "voluntarily" and provide "model codes" legislatures can adopt. For more on this point, see chapter 7 (in this volume). Since this activity has been criticized as a usurpation of a governmental function, Ferguson's complaint that engineers should have done more of it seems unfairat least until he offers a theory of which activities belong to government and which to private organizations or individuals.

29. Not all engineering designs dumb down a job. Many engineering designs "automate," that is, eliminate the routine work of many while creating technically sophisticated jobs for a few. These designs may be regarded as the limiting case of dumbing down or as an entirely different way of doing without large numbers of highly skilled workers. I don't think much turns on how it is categorized.

30. For more on the military connections of engineering, together with the connections between the military and technology, see Barton Hacker's, "Engineering a New Order: Military Institutions, Technical Education, and the Rise of the Industrial State," *Technology and Culture* 34 (April 1993): 1-27.

31. Artz, *Technical Education,* 162.

32. Is this a description or a prescription, a statement of what civil

engineering is or a statement of what it should be? That is not a hard question but it is one that should give philosophers a reason to pay more attention to professions than they generally do. Thedgold's definition is probably both descriptive of civil engineers generally and, for *that* reason, prescriptive for anyone who wants to carry on his occupation under the title "civil engineer." How can that be? That is a question addressed here in chapters 4 and 10.

33. Accreditation Board of Engineering and Technology, *Code of Engineering Ethics*, first principle (1985). (emphasis added). Whereas tense suggests description, context suggests prescription. Here again we see the congruence of description and prescription characteristic of professions.

34. Compare Koen, *Definition*, esp. 63-65. Koen rightly points out that engineers sometimes go beyond science (what we now know) and sometimes ignore science (because truth is too expensive) and so at least part of the time cannot be said to be applying science. This is, I believe, an important point but one quite distinct from the one I am making. Perhaps engineering differs from applied science in enough ways that the interesting question is not how engineering differs from applied science but why they were ever thought to be the same.

35. All "exceptions" are in the electrical engineering department. Whether they are truly exceptions is a matter about which I remain uncertain. On the one hand, these professors of engineering were educated as engineers; on the other, they considered their location in an engineering department to be an accident. They admittedindeed, declaredthat they could just as well, or even better, have been lodged in a physics department. They seem, therefore, to have lost their identity as engineers along with their interest in

helping to make something useful. In that respect at least, they constitute evidence for, rather than against, my claim.

36. Compare Vincenti, *What Engineers Know,* 161: "Engineers are after a theory they can use for practical calculations. . . . To obtain such a theory they are willing, when necessary, to forgo generality and precision . . . and to tolerate a considerable phenomenological component. Scientists are more likely to be out to test a theoretical hypothesis . . . or infer a theoretical model."

37. For some historical background on this use of "ethics," as well as my rationale for preferring it, see Michael Davis, "The Ethics Boom: What and Why," *Centennial Review* 34

(Spring 1990): 163-186. For those who ask why codes of professional ethics must be morally permissible. The short answer is: If not morally permissible, they cannot be morally binding; if not morally binding, they would seem to be more accurately described as an ethic, mores, ethos, custom, or practice than as ethics (strictly speaking). Insofar as this book proves how useful my way of understanding professional ethics is, it provides close to a full answer to that question.

38. I am, of course, assuming that American engineers did not have an "unwritten code" before then. That may seem a daring assumption. It is not. Most "unwritten law" is in fact written. For example, the "unwritten constitution" of England is recorded in royal charters, parliamentary debates, case law, and even newspaper reports. It is unwritten only in the sense that there is no authoritative document such as the U.S. Constitution. Humans have great trouble coordinating what they do without putting expectations into words and, in large organizations, without putting those words on paper. So, the apparent absence of any written codes of engineering ethics in the United States before 1900even in the unofficial form that Percival produced for English physicians a century earlier or that Sharswell produced for American lawyers in the 1830sis, I think, decisive evidence against the existence of any unwritten code.

39. Compare chapter 8 (in this volume).

40. Though I make this claim about what morality demands without argument, and in the belief that it is both true and obvious, I should admit that certain utilitarians, those moral theorists who think morality consists in maximizing overall happiness or social

utility, do not. Their theory makes morality much more demanding, which has proved a problem for their theory, not a problem for ordinary moral agents.

Chapter 2

This chapter began as the first Annual Engineering Ethics Lecture, funded by GTE, at Wayne State University, Detroit, Michigan, November 19, 1992. I would like to thank those present for a useful discussion. I should also thank Mike Rabins (mechanical engineering, Texas A & M) and my colleagues Tom Misa (history) and Sid Guralnick (civil engineering) for many helpful comments on an earlier draft, and Bill Pardue for helping to track down many of the references given here.

1. See, for example, Lawrence P. Grayson, "The American Revolution and the `Want of Engineers,'" *Engineering Education* 75 (February 1985): 268-276.

2. See chapter 1 for a defense of this claim.

3.

> Sylvanus P. Thayer was appointed director in 1817, by which time enrolment and teaching staff had increased to 250 cadets and 15 professors covering mathematics, "engineering," and natural philosophy, recently joined by Claude Crozet (1790-1864) a graduate of the École Polytechnique, who introduced the teaching of descriptive geometry to the college, and in 1821 published the first textbook on the subject. . . . Thayer graduated from Dartmouth in 1807, and from the Military Academy in 1808. He had studied military engineering developments in France and this influence was evident in his reorganization of the curriculum and mode of instruction at West Point. He used texts employed at the École Polytechnique, divided classes into small sections, required weekly class reports, and developed a grading system. (George S. Emmerson,

Engineering Education: A Social History [Crane, Russak & Company: New York, 1973], pp. 140-141).

While Thayer seemed to dislike the overly theoretical approach the French took to engineering education, his primary reason for not taking over more of the curriculum of the École Polytechnique seems to have been the relatively poor preparation of American students (and the desire, or necessity, not to make admission too difficult).

4. Though Partridge did now and then teach a course in civil engineering at West Point, he was not a civil engineer (and, apparently, was barely qualified to teach the course). Because he rejected most of the innovations introduced by his successor as superintendent, Sylvanius Thayer, the West Point Partridge tried to reproduce was the pre-1817 version (which may have much to do with the failure of Norwich to equal Thayer's West Point in either quality or quantity of engineers graduated). For more on this subject, see Thomas J. Fleming, *West Point: The Men and Times of the United States Military Academy* (William Morrow: New York, 1969) esp. pp. 3-14, 34.

5. Daniel Hovey Calhoun, *The American Civil Engineer: Origins and Conflict* (Technology Press [MIT]: Cambridge, Mass., 1960) p. 45. Compare James Gregory McGivern, *First Hundred Years of Engineering Education in the United States (1807-1907)* (Gonzaga University Press: Spokane, Washington, 1960) pp. 38, 42-45; and Emmerson, *Engineering Education,* 141-142. I have not found the corresponding figures for the number of military engineers (though, given that the Army does not seem to have been able to

absorb all West Pointers, few Norwich graduates could have found work as military engineers during this period).

6. All the histories of engineering education cited here ignore both the Virginia Military Institute and the Citadel. Most also ignore both Annapolis and the impact of naval engineers on the development of mechanical engineering in the land-grant schools after the Civil War. For one who does not, see Monte A. Calvert, *The Mechanical Engineer in America, 1830-1910* (Johns Hopkins Press: Baltimore, 1967) esp. pp. 48-51. A surprising number of engineering schools werelike Texas A&Mvirtually military academies until the 1960s. Such facts lead me to suspect that the relation between engineering and military education was, until quite recently, a lot closer than the histories of engineering education indicate. That relationship might explain much about the characteristic attitudes of American engineers in times pastand why some of these may be fading (for example, engineers' political conservativism).

7. McGivern, *First Hundred Years,* 50-51. See also Ray Palmer Baker, *A Chapter in American Education: Rensselear Polytechnic Institute, 1824-1924* (Charles Scribner's Sons: New York, 1924) pp. 48-56.

8. Baker, *American Education,* 35, 44-46. But about twenty-five of Rensselear's graduates from the period before 1840 eventually became engineers. Calhoun, *American Civil Engineer,* 45.

9.

> Though Eaton [the school's first director] had insisted that most colleges attempted to teach so many subjects that they could teach none of them well, and that Rensselaer should limit its activities primarily to the sciences, progress in them had been so rapid that

> Greene [the new director in 1847] concluded that it was again time [for the school] to narrow its field. (Baker, p.p. 39-40).

Note that engineering is here considered part of "the sciences."

10. Frederick B. Artz, *The Development of Technical Education in France, 1500-1850* (MIT Press: Cambridge, Mass., 1966) p. 267.

11. Emmerson states (without evidence) that Rensselear's new curriculum was modeled not on that of the École Polytechnique but on the École Centrale [d'Arts et Metiers] of Paris. Emmerson, 148, 153-156. McGivern says the same. See McGivern, 59. But neither tries to explain Rensselaer's "Polytechnic" (or what difference Greene would have seen between these institutions).

12. The British did, it is true, establish a school of military engineering at Woolwich in 1741. The school retained a number of notable applied mathematicians who wrote some elementary textbooks engineers found useful. Emmerson, *Engineering Education*, 33. Yet, unlike West Point, Woolwich seems to have had little influence on engineering generally, or on engineering education in particular, even in England, until the second half of the nineteenth century (if at all), that is, not until after talent replaced patronage as the primary means of gaining entry (and something like the French curriculum was adopted). Reader, *Professional Men*, 96-97. Compare Artz, *Technical Education*, 261.

13. W.H.G. Armytage, *Social History of Engineering* (Faber and Faber: London, 1961) pp. 160-161. Jonathan Williams, the first superintendent of West Point, observed in 1802: "To be merely an *Engineer* . . . is one thing, but to be an *Officieur du Génie* is another. I do not know how it happened but I cannot find any full English Idea to what the French give to the profession." Quoted in Peter Michael Molloy, *Technical Education and the Young Republic: West Point as America's École Polytechnique, 1802-1833* (unpublished dissertation, Brown University, June 1971) 241-242. The irony, of course, is that (as I explained in chapter 1) when the term "engineer" was brought into English, it was brought in to

name people who had special skills similar to those that distinguished the French *officieur du génie* from the architects, millwrights, and the like that the English already had. Because the English (and Americans) were not yet able to copy the French method of educating engineers, "engineer" in English could not carry the same import as *officieur du génie.* Perhaps today, the term Williams so felt the need for would be "professional engineer" (or "degreed engineer"). Molloy is very good on American backwardness in understanding engineering. See, esp., pp. 425-463.

14. For a more or less complete listing of the dozen or so "engineers or quasi-engineers" available for public works in the United States before 1816, see Calhoun, *American Civil Engineer,* 7-23. Calhoun is also good on what in American ways of doing things made it hard for even these few to find employment.

15. McGivern, *First Hundred Years*, 15-23.

16. Charles F. O'Connell, Jr., "The Corps of Engineers and the Rise of Modern Management, 1827-1856," in *Military Enterprise and Technological Change,* edited by Merritt Roe Smith (MIT Press: Cambridge, Mass., 1985) pp. 95-96.

17. Merritt Roe Smith, "Army Ordnance and the `American System' of Manufacturing, 1815-1861," in *Military Enterprise,* pp. 40-86.

18. James Kip Finch, *The Story of Engineering* (Doubleday: Garden City, N.Y., 1960) pp. 262-265. This Erie Canal school is, then, a throwback to the first days of the *corps du genie.* See chapter 1 (in this volume).

19. Finch, *Story,* 267-269.

20. Ibid, 268-269.

21. O'Connell, in *Military Enterprise*, 100-106. Note the initial resistence of the civilians to army-style standardization.

22. Smith, in *Military Enterprise*, 77-78. See also David A. Hounshell, *From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States* (Johns Hopkins University Press: Baltimore, 1984).

23. Edwin T. Layton, Jr., *The Revolt of the Engineers* (Case Western Reserve University Press: Cleveland, 1971) p. 3. The Census used the term "civil engineer." Layton believes that

term would, at that time, probably have included mechanical engineers (and, indeed, all other nonmilitary engineers). My guess is that "civil engineer" probably excluded most engineers (or proto-engineers) in mining and manufacture, who did not call themselves engineers (and certainly would not have called themselves "civil engineers"). Note, for example, the fields listed for the Lawrence Scientific School at about this time. This disagreement with Layton is, nonetheless, probably a quibble. Before the Civil War, the number of these other engineers was probably small compared to the number of civils. Here, though, it would be good to have more information.

24. The phrase in quotes is Steve Goldman's. See "The Social Captivity of Engineering" in *Critical Perspectives on Nonacademic Science and Engineering*, edited by Paul Durbin (Lehigh University Press: Bethlehem, Pa., 1991) pp. 121-146. But the sentiment seems to be widespread. See, for example, David Noble, *America by Design* (Alfred A. Knopf: New York, 1977). Noble's nostalgia for the lost shop culture seems to confuse inventing in general, which, indeed, can exist in small, and even isolated, organizations, and engineering (which is a special kind of inventing: centralizing, standardizing, and so on), which probably cannot. The shop culture, however admirable, seems to lose out to engineering in certain environmentscapitalist or not. (For example, engineers had much the same role in the Soviet Union as in the United States.) Noble contributes to our understanding of what might give engineering an advantage over shop culture (while giving that advantage a cast more sinister than necessary on the facts even as he presents them).

25. An ASCE was actually founded in 1852, its membership almost entirely in New York City. But, like other attempts at organizing engineers before the Civil War, that ASCE seems to have died out within a few years. The connection with the ASCE of 1867 is tenuous, another example of professions trying to add to their lineage. For a bit more on this, see Layton, *Revolt*, 28-29.

26. For some of this history, see also Bruce Sinclair, *A centennial History of the American Society of Mechanical Engineers, 1880-1980* (University of Toronto Press: Toronto, 1980); Terry S. Reynolds, *75 Years of Progress: A History of the American Institute of Chemical Engineers* (American Institute of Chemical Engineers: New York, 1983).

27. A. Michal McMahan, *The Making of a Profession: A Century of Electrical Engineering in America* (Institute of Electrical and Electronic Engineers: New York, 1984) chap. 11.

28. Perhaps the first branching came even earlier, with the split between artillery and military engineering. The roots of the two words"engine" (from Latin *ingenium* for a natural ability or genius) and "artillery" (from Latin *ars* for skill or art)suggests how close their relationship originally was.

29. James Kip Finch, *A History of the School of Engineering, Columbia University* (Columbia University Press: New York, 1954) pp. 65-66. This was also the time when the faculty of the school was renamed "the Faculty of Applied Science." French engineering seems to have grown from a single seed, but the American looks much more like three trees that grew into one (the French civil and military engineers, the German mining and metallurgical "engineers," and the American and perhaps English mechanical "engineers") branching even as they combined.

30. Layton, *Revolt*, 3.

31. Compare Billy Vaughn Koen, "Toward a Definition of the Engineering Method," *Engineering Education* 75 (December 1984): 150-155.

32. Vincenti is very good on this subject.

33. Consider, for example, the expression "rocket scientist." In fact, there are virtually no rocket scientists. Almost everyone associated with the design, development, testing, deployment, and operation of rockets is an engineer. Whatever success rocketry has

had is largely due to engineers. "Rocket scientists" should not be getting credit for any of it.

34. Engineers also have a tendency to claim successes for engineering whether or not the person responsible was in fact an engineer by training. It is this tendency that leads engineers to claim, for example, that the builder of an Egyptian pyramid or the inventor of the cotton gin was an engineer. There is, it seems to me, considerable unfairness in claiming the successes for engineering while (as generally happens) blaming the failures on others, for example, "managers," "tinkerers," "technicians," or "scientists." I have therefore tried to develop a more even-handed concept of engineering.

35. The only exception I know of is recent: in some "software engineering," where engineers (or other programmers) directlyon a computerconstruct programs for computers. They do not write instructions for human beings (even in the indirect way engineers in research and development do) except insofar as they prepare the necessary documentation. Through their computer, software engineers actually give directions directly to "mechanical workers." Of course, as chapter 3 demonstrates, there are other reasons to wonder whether software engineering is engineering at all. For our purposes now, however, it is enough to point out that even these engineers, if that is what they are, must, while instructing machines, take into account the human environment in which the machines operate. Their technical knowledge, like that of most engineers, still includes much about how people and things work together.

36. Compare Calhoun, *American Civil Engineer*, 77: "The engineer

role was specialized out of the executive role." Even an engineer working in research and development is engaged in developing instructions for production of some safe and useful physical systemif she is working as an engineerhowever many steps may stand between the original research and the final product. Koen's otherwise intelligent discussion of design seems to miss entirely the role of design as instruction to others.

37. Several professors of engineering have told me that this is now changing, that engineers are increasingly working in groups bringing together engineers from different fields. This may be, but my own interviews with working engineers did not reveal much integration, even in research. Here we have an empirical question about which it would be good to have more information. But, whatever turns up, I am sure that engineers will not for many years achieve the integration of fields commonplace in law offices or hospitals.

38. For example, the most scientific of the major engineering societies, the Institute of Electrical and Electronic Engineering (IEEE), is the only one to forget that it had a code of ethics (rediscovering it in the 1970s only after it had written a new one). For a bit more on this, see Michael Davis, "The Ethics Boom: What and Why," *Centennial Review* 34 (Spring 1990): 163-186, esp. pp. 173-174. The IEEE's recent efforts in ethics seem to signal an important change. But do they? It would be interesting to have a detailed analysis of what is really going on.

39. For example:

> Much time is wasted in our colleges and technical schools over higher mathematics. Every engineer will have to agree with me that the cases where the use of the higher calculus is indispensable are so few in our practice, that its study is not worth the time expended upon it, and we

have the highest authority for saying unless its use is constantly kept up we become too rusty to use it at all. Unless the student possesses extraordinary genius for mathematics, I would limit its study to the ordinary analysis. (Thomas C. Clarke, "The Education of Civil Engineers," *Transactions of the American Society of Civil Engineers* 3 (1875): 557 [quoted in McGivern, *First Hundred Years*, 113]).

Because, even now, I hear practicing engineers make this point, I must wonder whether teaching calculus (two years of it at present) may not have more to do with shaping the mind (or "weeding out" a certain sort of mind) than with imparting the calculus itself. It is easy to imagine programs in which much of calculus is a technical elective and the remainder integrated (in practical form) into engineering science courses themselves. For a longer and more critical discussion of the calculus requirement (one rather hard on it) see Sally Hacker, *Doing it the Hard Way* (Unwin: Boston, 1990) pp. 139-154.

40. For an interesting discussion of this debate, though largely limited to mechanical engineering, see Calvert, *Mechanical Engineer,* 63-85.

41. Calhoun, *American Civil Engineer,* 45.

42. Ibid., 50-53.

43. The practical success of West Point is easy to underestimate. Consider, then, what was said by Francis Wayland, president of Brown University, 1827-1855. Near the end of his term, which included bringing engineering to Brown, he observed enviously that "the single academy at West Point, graduating annually a smaller number than many of our colleges, has done more toward the construction of railroads than all our one hundred and twenty colleges united." Quoted in McGivern, *First Hundred Years*, 91.

44. Ibid., 152-154.

45. Calvert, *Mechanical Engineer,* 203.

46. McMahan, *Making of a Profession,* 33-43.

47. Compare: "The Society would have been a small one and of limited influence had its membership been restricted to the type of consulting or creative engineer alone. The factory engineer is more and more a manager of men. . . . The engineer must be what he is often called, a businessman." Frederick R. Hutton (1907) Secretary of the American Society of Mechanical Engineers. Quoted in Layton, *Revolt*, 37.

48. Of course, some engineering societies, especially in their early years, admitted into membership persons who, though not school-trained, were "in responsible charge" of engineering work for a number of years. The criterion was, it should be noted, not simply "being in charge" but being in "responsible charge" for a certain length of timelong enough, presumably, for the person to show that he could do the job. And, even this criterion looks more like a political compromise than a natural definition.

49. Compare Layton, *Revolt*, esp. 58-60.

50. See, esp., ibid., 25-52. This vagueness may explain why (like the original ASCE) at least one twentieth-century engineering society, the short-lived American Association of Engineers, allowed architects to join. See Peter Meiksins, "Professionalism and Conflict: The Case of the American Association of Engineers," *Journal of Social History* 19 (Spring 1983): 403-421, esp. 406. The exclusion of rank-and-file workers may indicate a class bias, but I think it indicates more than that. Many people who called themselves engineers, for example, train drivers or scientific tinkerers, would have seemed ignorant of much engineers had in common, even engineers who came up through the ranks. What Layton in fact reports is, I think, part of the process by which "engineer" came to mean in English what it did in French (and what Williams understood by *officieur du génie*).

51. For a hilarious example of how too much emphasis on "science" can interfere with the practice of engineering, see Bruce Seely, "The Scientific Mystique in Engineering: Highway Research at the Bureau of Public Roads, 1918-1940," *Technology and Culture* 24 (October 1984): 798-831. Note also Edna Kranakis's description of the decline of French engineering during the nineteenth century, "Social Determinants of Engineering Practice: A Comparative View of France and America in the Nineteenth Century," *Social Studies of Science* 19 (February 1989): 5-70.

52. McGivern, *First Hundred Years*, 65. Note that engineering here means what we now call civil engineering. Though grouped with civil engineering, both what we call mining (and metallurgical) engineering and mechanical engineering are not conceived as engineering (properly so-called). Here is further evidence that we should be more cautious about thinking of engineering as "fragmenting" during the nineteenth century. As I would tell the story, higher education played a crucial part in giving engineering a unity it did not originally have in the United States (and might never have achieved otherwise). In this regard, it is worth noting that early civil engineers seem generally to have failed at both mechanical engineering and mining. Calhoun, *American Civil Engineer*, 82-87.

53. McGivern, *First Hundred Years*, 64-69.

54. Ibid., 79-82. Compare the history of the École Polytechnique after 1804.

55. See Bruce Seely, "Research, Engineering, and Science in American Engineering Colleges: 1900-1960," *Technology and Culture* 34 (April 1993): 344-386); and Lawrence P. Grayson, "A Brief History of Engineering Education in the United States," *Engineering Education* 68 (December 1977): 246-264, esp. 257-261.

56. Engineers were, of course, aware quite early that engineering had a creative aspect. But other aspects of engineering, especially the drudgery of drafting and calculating, may have meant that few engineers actually got to be "creative." If so, then computers may have shifted dramatically the balance between drudgery and

creativity; that shift may, in turn, partially explain the current emphasis on design. But what explains the decline of "shop training"? (Even would-be employers do not seem to want engineering schools to prepare students for the shop floor.) Has engineering changed in some fundamental way in this century (or has industry)?

57. For more, see chapter 10 (in this volume).

58. This is quite clear in, for example, Walter G. Vincenti, *What Engineers Know and How They Know It* (Johns Hopkins University Press: Baltimore, 1990).

59. For others who have noted the sad state of our understanding of engineering, see James K. Feibleman, "Pure Science, Applied Science, Technology, Engineering: An Attempt at Definitions," *Technology and Culture* 2 (Fall 1961): 305-317: M. Asimov, "A Philosophy of Engineering Design," in Friedrich Rapp, ed., *Contributions to a Philosophy of Technology* (Reidel: Dordrecht, Holland, 1974) pp. 150-157; George Sinclair, "A Call for a Philosophy of Engineering," *Technology and Culture* 18 (October 1977): 685-689; Taft H. Broome, Jr. "Engineering the Philosophy of Science," *Metaphilosophy* 16 (January 1985): 47-56; Paul T. Durbin, "Toward a Philosophy of Engineering and Science in R & D Settings," in Paul Durbin, ed., *Technology and Responsibility* (Reidel: Dordrecht-Holland, 1987) pp. 309-327.

60. This is, of course, not intended as a definition of "profession" but merely as a sketch of one, one adequate for our purposes now. For more of what I mean by "profession," see chapters 4 and 10, and some of my other works on the subject: "The Moral Authority of a Professional Code," *NOMOS* 29 (1987): 302-337; "The Use of Professions," *Business Economics* 22 (October 1987): 5-10; "Vocational Teachers, Confidentiality, and Professional Ethics,"

International Journal of Applied Philosophy 4 (Spring 1988): 11-20; "Professionalism Means Putting Your Profession First," *Georgetown Journal of Legal Ethics* (Summer 1988): 352-366; "Do Cops Really Need a Code of Ethics," *Criminal Justice Ethics* 10 (Summer/Fall 1991): 14-28; "Science: After Such Knowledge, What Responsibility?," *Professional Ethics* 4 (Spring 1995): 49-74.

61. Quoted in McGivern, *First Hundred Years*, 106. At the same place, he offers similar examples from the American Institute of Mining (1873) and the American Society of Mechanical Engineers (1880).

62. Grayson, "Brief History," 254.

63. Ibid., 258. Today that organization is the Accreditation Board of Engineering and Technology (ABET).

64. This claim will seem controversial only to those, mostly sociologists and those who defer to them, who wish to equate "profession" with "skilled occupation" (or with "licensed skilled occupation"). There are at least two reasons to reject this equation. First, members of a profession are usually at pains to claim that they belong to a profession, not just a skilled occupation. The equation makes their claim false by definition, leaving the question why anyone would say such a thing. Second, as we shall see, ethical standards do seem to give considerable insight into talk about "profession."

65. For more on this, see Michael Davis, "The Ethics Boom."

66. For a good (if somewhat jaundiced) account of this period, with its effects both on industry and engineering, see Noble, *American by Design.*

67. The electrical engineers seem to have had the greatest difficulty here (an eight-year process). See McMahan, *Making of a Profession,* 112-117.

68. For an enlightening discussion of the ways people change, see Mortimer R. Kadish, *The Ophelia Paradox: An Inquiry into the Conduct of Our Lives* (Transaction: New Brunswick, N.J., 1994).

Chapter 3

I should like to thank Helen Nissenbaum, Ilene Burnstein, and Vivian Weil for helpful comments on my first draft of this chapter. A short version appeared as "Defining Engineering: How to Do It

and Why It Matters," *Journal of Engineering Education* 85 (April 1996): 97-101; a full version (under the present title and, despite the date, a year later) appeared in *Philosophy and the History of Science: A Taiwanese Journal* 4 (October 1995): 1-24. Reprinted by permission.

1. Gary A. Ford and James E. Tomayko, "Education and Curricula in Software Engineering," *Encyclopedia of Software Engineering,* vol. 1 (John Wiley & Sons: New York, 1994) p. 439.

2. "In the 1991 Computer Society [of the Institute for Electrical and Electronic Engineers] membership survey, over half (54 percent) of the current full members polled indicated that they consider themselves software engineers, as did 40 percent of the affiliate members." Fletcher J. Buckley, "Defining software engineering," *Computer* 2 (August 1993): 77.

3. There are no hard numbers for software engineers (though I have heard estimates as high as three million worldwide). The claims made here merely constitute my compilation of the opinions of those who seemed to have the best chance of being right.

4. See, for example, Mary Shaw, "Prospects for an Engineering Discipline of Software," *IEEE Software* (November 1990): 15-24. Though she begins this intelligent article with a definition of engineering and devotes much of its body to the history of engineering, her topic is really the growth of disciplines generally. She could have written much the same article, using law, medicine, or even auditing, rather than engineering, as the paradigm of a disciplinewith more clarity about what she was doing.

5. This definition, the work of the National Research Council's Committee on the Education and Utilization of the Engineer,

appears in Samuel Florman, *The Civilized Engineer* (St. Martin Press: New York, 1987) pp. 64-65.

6. Compare the more elegant Canadian definition:

> The "practice of professional engineering" means any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising, or managing any of

> the foregoing that requires the application of *engineering* principles, and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment. (Emphasis added)

Canadian Engineering Qualifications Board, *1993 Annual Report* (Canadian Council of Professional Engineers: Ottawa, 1993) p. 17. The report contains no definition of engineering principles.

7. Similar problems arise for "genetic engineer" and might arise for other "engineers," for example, "social engineers." (This problem of definition is, of course, not limited to engineers: lawyers are no more successful defining the practice of law or doctors the practice of medicine.)

8. The IEEE defines software engineering as "application of a systematic, disciplined, quantifiable approach to the development, operation and maintenance of software: that is, the application of engineering to software." Buckley, "Defining Software Engineering," 77. This definition (or, rather, that "that is") begs the question whether the systematic, disciplined, and quantifiable approach in question is an application of engineering to software or the application of a different discipline. Not all systematic, disciplined, and quantifiable approaches to development, operation, and maintenance are necessarily engineering. Indeed, that software is primarily not a physical but a mathematical (or linguistic) system at least suggests that engineering principles have only limited application.

9. Florman, *The Civilized Engineer,* 65-66.

10. I charitably ignored the "or" in "mathematics and/or the natural sciences." There never was a time that the training of engineers did

not include a good deal of both mathematics and the physical sciences (at least chemistry and physics). If software engineers do not generally have similar training in the physical sciences, no amount of training in mathematics will fill the gap between them and the great body of engineers strictly so called.

11. It is perhaps worth noting that engineers do in fact produce beautiful objects, for example, the Brooklyn Bridge or the typical computer's circuit board. Nonetheless, engineers are not artists in the way architects are. For engineering, beauty is not a major factor in evaluating work; utility is.

12. Compare Fletcher J. Buckley, "Background to the Motion [to have the IEEE CS Board of Governors appoint an ad hoc committee to initiate the actions to establish software engineering as a profession] (April 15, 1993)":

> In 483 B.C., Xerxes, King of Persia and Media, as part of his campaign to conquer Greece, ordered two floating bridges to be constructed across the Hellespont to provide passage for his army from Asia to Europe. After the bridges were completed, a storm arose and the bridges were destroyed. Xerxes had the engineers killed and another set of bridges constructed, thus demonstrating at that time, the existence of standards of personal accountability for professionals working in their field of competence.

This passagelike its twin in Buckley, "Defining software engineering," 76is remarkable for its misunderstanding of both engineering and professions. Buckley has, of course, no reason to call the builders of Xerxes bridge engineers rather than bridge builders, no reason even to describe them as professionals rather than skilled men. He certainly overlooks whether the bridge's failure was due to incompetence or to forces beyond any builder's competence to manage at the time. Like a similar story about having the sea flogged, this one seems to be more about the arbitrariness of Persian rulers than about the standard of accountability to which anyone would want to be held. Its place in a motion concerned with organizing software engineering as a "profession" is therefore (at best) inauspicious.

13. Compare, for example, the Roeblings, father and son, both engineers (by today's

standard definition) with the millwrights, industrialists, and other contemporary bridge builders most of whom would today not be allowed to design or build bridges. Were these other "technologists," self-taught and relatively slapdash, as much engineers as the Roeblings because much of what they built worked?

14. Consider, for example, L.A. Belady, in "Foreword," *Encyclopedia of Software Engineering*, p. xi: "[The] term software engineering expresses the continued effort to put programming into the ranks of other engineering disciplines."

15. Engineers, especially civil engineers, like to count the Roman builders among their profession. When asked why, they usually point out how enduring the Roman roads, aqueducts, theaters, and other constructions proved to be. This answer seems to me to offer evidence *against* their thesis as if it were evidence for it. Engineers are fond of the saying, "An engineer is someone who can do for one dollar what any fool can do for ten"or, as ABET put it more prosaically, "Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, *economically*, the materials and forces of nature for the benefit of mankind." That the Roman builders built so much that outlasted their empire by more than a thousand years at least suggests that they spent where an engineer would have saved. When we recall that none of Rome's great builders made a career of building but instead, oversaw public works one year and a province's government the next, we must conclude that though great builders, they could never qualify for admission to an engineering society at

the "professional level." They may have "functioned as engineers" (however anachronistically), but they were not members of the profession (or even employed in the underlying occupation).

16. For a spirited defense of this mistake, see John T. Sanders, "Honor Among Thieves: Some Reflections on Professional Codes of Ethics," *Professional Ethics* 2 (Fall/Winter 1993): 83-103. If the article's title does not show what is wrong with equating competence with profession, the article's suggestion that we consider the *mafia* to be a profession should.

17. Note that Florman, generally so astute about engineering, endorses this equation of conscientiousness with ethicalness. Florman, *The Civilized Engineer,* 104.

18. Are either of these provisions, or any other, unique to engineering, an expression of its essential nature? I know of none. A particular professional code seems to me to involve a distinctive reworking of general moral ideals to fit certain conditions and aspirations, distinctive but not necessarily unique.

19. In the United States, the codes date from the second decade of this century. In Great Britain, they came almost a half century earlier. The counterpart for these codes didn't appear on the continent of Europe, or in other civil law jurisdictions, until well after World War II. Why?

20. For more details, see Lawrence P. Grayson, "A Brief History of Engineering Education in the United States," *Engineering Education* 68 (December 1977): 246-264.

21. See chapter 4 (in this volume) for a defense of this response. Meanwhile, note that the IEEE's code of ethics applies only to "IEEE members." It is a code of ethics for members of a technical society, notlike the codes of ABET or the National Society of

Professional Engineers (NSPE) codethe code of a profession. Indeed, I would attribute its shortening over the years to the attempt to cover a membership in which the proportion of engineers is declining and both the number and kinds of nonengineers are increasing. Generally, codes of ethics grow with experience; shrinkage is therefore a sign of trouble.

22. Shaw, "Prospects," 22.

23. Michael S. Mahoney, "The Roots of Software Engineering," *CWI Quarterly* 3 (December 1990): 325-334, at 326.

24. Ibid., 327.

25. For example, some practicing engineers, until recently, encouraged schools of engineering to reduce the academic requirements for a degree in favor of more "shop experience." Yet, attempts to take the shop-experience approach very far seem to produce foremen rather than engineers. Apparently, the very abstractness for which the practitioners criticized engineering education contributed to success as engineers even when (as the practitioners correctly noted) the specific skills taught (for example, advanced calculus) generally went unused. Why?

26. Some electrical engineering departments offer degrees of this description, for example, in "computer engineering, software option."

27. There is, of course, more than one code of ethics for U.S. engineers. This may suggest that engineering in the United States is not one profession but several. That suggestion should not be embraced. Of the three major codes usually mentioned on such occasions, the IEEE code is not a professional code at all; it applies not to engineers (as a professional code should) but to IEEE members (whether engineers or not). Because it also contains nothing more demanding than the other codes and nothing inconsistent with them, we may ignore it here. The other two major codes do apply to engineers as such, differing only in detail (with the NSPE code generally being somewhat less demanding). Because the NSPE seems to have developed its code with state enforcement in mind, I think it reasonable to treat the ABET code as the basic professional code (especially because most engineering societies endorse it). So, when I speak of the engineer's code here, it is the ABET code that I intend.

28. See, for example, John D. Musa, "Software Engineering: The Future of a Profession," *IEEE Software* (January 1985): 55-62. Musa presents software engineering as a profession independent of engineering (though his use of the term engineering suggests the opposite).

29. Compare Shaw, "Prospects," 21:

> Unfortunately, [the term "software engineering"] is now most often used to refer to life-cycle models, routine methodologies, cost-estimation techniques, documentation frameworks . . . and other techniques for standardizing production. These technologies are characteristic of the commercial stage of evolution`software management' would be a much more appropriate term.

Chapter 4

This chapter began as the first third of *Engineering Codes of Ethics: Analysis and Applications,* a "module" prepared with Heinz Luegenbiehl in 1986 for a series published by IIT's Center for the Study of Ethics in the Professions under a grant from the Exxon Education Foundation (the same series in which chapter 7 appeared). Though this module was never published, a shorter and substantially different version appeared as "Thinking Like an Engineer: The Place of a Code of Ethics in the Practice of a Profession," *Philosophy and Public Affairs* 20 (Spring 1991): 150-167. Reprinted by permission. I should like to thank the series' Advisory Panel, Heinz Luegenbiehl, the editors of *Philosophy and Public Affairs*, and those who listened patiently to one version or another for much useful advice.

1. David E. Sanger, "How Seeing-No-Evil Doomed the Challenger," *New York Times,* June 29, 1986, sec. 3, p. 8.

2. *The Presidential Commission on the Space Shuttle Challenger*

Disaster (U.S. Government Printing Office: Washington, D.C, 1986). v. I, p. 94. The preceding narrative is based on testimony contained in that volume (esp. pp. 82-103).

3. William H. Wisely, "The Influence of Engineering Societies on Professionals and Ethics" in *Ethics, Professionals, and Maintaining Competence: ASCE Professional Activities Com-*

mittee Specialty Conference, Ohio State University, Columbus, Ohio, 1977 (American Society of Civil Engineers: New York), 1977, pp. 55-56.

4. See, for example, A.G. Christie, "A Proposed Code of Ethics for All Engineers," *Annals of American Society of Political and Social Science* 101 (May 1922): 99-100.

5. What is the origin of the term "bench engineer"? I have encountered two guesses. One attributes the term to a bitter analogy with galley slaves, who rowed their life away chained to a bench. The other guess involves a more pleasing analogy with scientists, especially physicists and chemists, who worked at "benches" with their lab equipment around them. For scientists, a "bench scientist" is a real scientist; those scientists who devote themselves to supervision, to meetings, and so on are no longer doing science but administration. Neither of these analogies is appropriate for engineering. On the one hand, except for draftsmen (who did work side by side in large rooms, seldom leaving the drafting board) few engineers seem to spend even a majority of their day in one place. They have technicians to supervise, "fires to put out," and meetings to go to. Both movement and administration are more central to engineering than to science.

6. William H. Wisely, "The Influence of Engineering Societies on Profesionalism and Ethics" in *Engineering Professionalism and Ethics* (Robert E. Kreiger: Malabar, Fl. 1983) p. 33.

7. Andrew G. Oldenquist and Edward E. Slowter, "Proposed: A Single Code of Ethics for All Engineers," *Professional Engineer* 49 (May 1979): 8-11.

8. Note, for example, the quotation from A.G. Christie at the beginning of this chapter; or Morris Llewellyn Cooke, "Ethics and the Engineering Profession," *Annals of the Association for Political and Social Science* 101 (May 1922): 68-72, esp. 70.

9. See, for example, W.J. Reader, *Professional Men: The Rise of the Professional Classes in Nineteenth-Century England* (Basic Books: New York, 1966) esp. pp. 51-55.

10. Recall Thredgeld's famous definition (cited in chapter 1): "[The] profession of civil engineer [is] the art of directing the great sources of power in nature for the use and convenience of man."

11. For further defense of this theory of profession, see Michael Davis, "The Moral Authority of a Professional Code," *NOMOS* 29 (1987): 302-337; "The Use of Professions," *Business Economics* 22 (October 1987): 5-10; "Vocational Teachers, Confidentiality, and Professional Ethics," *International Journal of Applied Philosophy* 4 (Spring 1988): 11-20; "Professionalism Means Putting Your Profession First," *Georgetown Journal of Legal Ethics* 2 (Summer 1988): 352-366; "Do Cops Really Need a Code of Ethics," *Criminal Justice Ethics* 10 (Summer/Fall 1991): 14-28; "Science: After Such Knowledge, What Responsibility?," *Professional Ethics* 4 (Spring 1995): 49-74; and "The State's Dr. Death: What's Unethical about Physicians Helping at Executions?" *Social Theory and Practice* 21 (Spring 1995): 31-60.

12. Compare Michael Davis, "The Special Role of Professionals in Business Ethics," *Business and Professional Ethics Journal* 7 (1988): 83-94.

13. Devotees of decision theory will instantly recognize the convention in question as the solution to the coordination problem commonly known as the prisoner's dilemma. I avoid the term here

because it seems wholly out of place when there are no prisoners and when the choice posed is far better than a dilemma. Like many other technical terms of decision theory, "prisoner's dilemma" seems more likely to mislead those not familiar with it than to grant insight.

14. I hope this appeal to fairness raises no red flags, even though the principle of fairness has been under a cloud ever since the seemingly devastating criticism it received in Robert Nozick, *Anarchy, State, and Utopia* (Basic Books: New York, 1974). I limit my use to obligations generated by *voluntarily* claiming benefits of a cooperative practice that are otherwise not available. Most attacks on the principle of fairness are on the "involuntary benefits" version. See, for example, A. John Simmons, *Moral Principles and Political Obligations* (Prince-

ton University Press: Princeton, N.J., 1979) pp. 118-136. And even those attacks are hardly devastating. One can either refine the principle, as Richard Arenson did in "The Principle of Fairness and Free-Rider Problems," *Ethics* 92 (July 1982): 616-633; or, as in Michael Davis, "Nozick's Argument *for* the Legitimacy of the Welfare State," *Ethics* 97 (April 1987): 576-594, show that Nozick's original criticism, and most subsequent criticism, depends on examples that, on careful examination, fail to support the criticism.

15. I do not claim that the engineers treated safety as paramount because they knew what the ABET code said. When you ask a lawyer about a professional code, she is likely to tell you she studied the ABA code in law school and, claiming to have a copy around, will produce it after only a few minutes of searching her desk or bookshelves. When you ask an engineer the same question, he is likely to tell you that his profession has a code while admitting that he never studied it and that he has none around to refer to. He may even admit to never having seen a copy. Yet, anyone who has spent much time working with engineers knows that they do not treat safety in the same way managers do (hence Mason's plea to "take off your engineering hat"). The engineers' code of ethics seems to be "hard-wired" into them. Interestingly, engineers are not the only professionals for whom the written code seems to play so small a part. For another example, see Michael Davis, "Vocational Teachers, Confidentiality, and Professional Ethics," *International Journal of Applied Philosophy* 4 (1988): 74-90.

16. I do not claim that Lund would explain his decision in this way.

Indeed, as I suggest in chapter 5 (in this volume), I think his explanation would be quite different, though no less troubling.

17. For criticism of this analysis, though one that misunderstands it, see Nigel G.E. Harris, "Professional codes and Kantian duties" in *Ethics and the Professions*, edited by Ruth F. Chadwick (Avebury: Aldershot, England, 1994) pp. 104-115.

18. For a good summary of these other contributing causes, see Diane Vaughn, *The Challenger Launch Decision* (University of Chicago Press: Chicago, 1996).

19. Philosophers will note that this is not one of the four standard senses of responsibility (capacity-responsibility, liability-responsibility, causal-responsibility, or role-responsibility); nevertheless, it seems to me to be a legitimate sense. I should like to thank Jeff McMahan for pointing it out to me (in another context).

Chapter 5

An early version of this chapter was read at the Center for the Study of Ethics in Society, Western Michigan University, Kalamazoo, October 27, 1988, under the title "Keeping Good Apples from Going Bad." A later version, under the present title, was read at the Philosophy Colloquium, Illinois Institute of Technology, March 30, 1989 and, somewhat revised, published as "Explaining Wrongdoing" in the *Journal of Social Philosophy* 20 (Spring/Fall 1989): 74-90. Reprinted by permission. I would like to thank those present at these two events for their encouragement and criticism. I would also like to thank Paul Gomberg for his careful reading of the penultimate draft and Fay Sawyier for helping me to see microscopic vision for the first time.

1. My wrongdoers, for example, are not like the "hard men" in Jack Katz, *Seductions of Crime: Moral and Sensual Attractions of Doing Evil* (Basic Books: New York, 1988). Katz's criminals do indeed seem to will evil.

2. *"Price Fixing and Bid Rigging in the Electrical Manufacturing Industry," Administered Prices: Hearings before the Senate Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary*, pt. 27, 1961, 16652.

3. "After the Fall: Fates Are Disparate for Those Charged with Inside Trading," *Wall Street Journal,* November 18, 1987, p. 22.

4. For example, 46% of all aggravated assaults and 52% of all burglaries go unreported. *Crime in the United States* (Federal Bureau of Investigation, U.S. Department of Justice: Washington, D.C.:, 1980) pp. 20, 23.

5. See chapter 3 (in this volume).

6. Compare Lawrence Kohlberg, *Essays on Moral Development* (Harper and Row: San Francisco, 1981).

7. Compare Chester A. Barnes, *The Functions of the Executive* (Harvard University Press: Cambridge, Mass., 1938) p. 276:

> It is apparent that executives frequently fail. This failure may be ascribed in most cases, I believe, to inadequate abilities as a first cause, usually resulting in the destruction of responsibility. But in many cases it may be inferred that the conditions impose a moral complexity and a moral conflict not soluble. Some actions which may within reason appear to be dictated by the good of the organization as a whole will obviously be counter to nearly all other codes, personal or official.

8. See, for example, Jan Elster, *Ulysses and the Sirens,* rev.ed. (Cambridge University Press: New York, 1984), for a good treatment of weakness of will.

9. Mike W. Martin, *Self-Deception and Morality* (University Press of Kansas: Lawrence, Kansas, 1986). Martin defines self-deception in a way consistent with modern psychology, producing a conception of self-deception likely to be useful in practice. Most work on this subject is, instead, concerned with logical puzzles

created by assuming a unitary self that must both know and not know at the same time.

10. For a convenient survey of the literature on self-deception that brings out the range of mental states that might be included within that capacious term, see Alfred Mele, "Recent Work on Self-Deception," *American Philosophical Quarterly* 24 (January 1987): 1-17. For discussion of the related phenomenon of shifting responsibility, see Stanley Milgram, *Obedience to Authority: An Experimental View* (Harper and Row: New York, 1974). I did not discuss the hypothesis Milgram's work might suggest because, as far as I can see, no one ever offered to take responsibility for Lund's actions. Lund's claim that he had "no choice" is not an appeal to the authority of othersthough it is something equally troubling. After all, what can be more obvious than that Lund had a choice? He could simply have said "no" and taken the consequences.

11. I would like to thank Vivian Weil and Michael Pritchard for helpful criticism of one or another early version of the explanation of microscopic vision. They are, however, not responsible for any errors that remain.

12. I derive this information from a video of Boisjoly's appearance before Caroline Whitbeck's engineering design course, "Company Loyalty and Whistleblowing: Ethical Decisions and the Space Shuttle Disaster" (January 7, 1987), especially his answers to student questions.

13. For a bit more on the differences between the way managers and engineers approach risk, see chapter 9 (in this volume).

14. Of course, we are here assuming that a well-run organization would divide its decisions into two categories, engineering

decisions and management decisions, with engineers having the last word in one category and managers having the last word in the other. Another possible arrangement is to recognize that the two categories overlap far too much to allow such a division in responsibility and to require managers and engineers to reach a consensus. For more on this possibility, see chapter 9 (in this volume).

15. This is the standard view of relations between managers and engineers that chapter 9 challenges. I state it here without endorsement.

16. Literature on the Challenger disaster generally assumes that management's way of dealing with risk was clearly wrong. For a rare and thoughtful attempt to make management's case, see William Starbuck and Frances Milliken, "Challenger: Fine-Tuning the Odds Until Something Breaks," *Journal of Management Studies* 25 (July 1988): 319-340.

17. In fact, our price fixer had no memory of ever seeing the policy. *Price Fixing*, 16152. For a somewhat different version of this story (including the claim that he must have seen the policy) see James A. Waters, "Catch 20.5: Corporate Morality as an Organizational Phenomenon," *Organizational Dynamics* 6 (Spring 1978): 3-19. Waters emphasizes "organizational blocks" to proper conduct rather than the normal processes that concern me. But I believe nothing I say here is inconsistent with what he says. Wrongdoing in a complex organization is likely to have many contributing causes. Waters and I differ only in being interested in different contributing causes. It is, of course, an empirical question whether either of us is even partly right (though one very hard to test decisively with the information we have or are likely to get). I would say the same about Saul W. Gellerman, "Why `Good' Managers Make Bad Ethical Choices," *Harvard Business Review* 64 (July-August 1986): 85-90.

18. The same is true of business ethics. Business professors who limit themselves to technical matters do not simply fail to do good. However unintentionally, they *actively* contribute to the wrong

their students do, if they eventually do wrong. They help to blind their students to something the students might otherwise see.

19. See, for example, Robert M. Liebert, "What Develops in Moral Development?," and Mordicai Nisan, "Content and Structure in Moral Development: An Integrative View" in *Morality, Moral Behavior, and Moral Development,* ed. by William M. Kurtines and Jacob L. Gewirtz (John Wiley & Sons: New York, 1984) pp. 177-192, 208-224.

20. Caroline Whitbeck, "Teaching Ethics to Scientists and Engineers," *Science and Engineering Ethics* 1 (July 1995): 299-308.

Chapter 6

Early versions of this chapter were presented at the Neil Staebler Conference, Institute of Public Policy Studies, University of Michigan, Ann Arbor, February 17, 1988; at Aquinas College, Grand Rapids, Michigan, September 21, 1989; and at the Mechanical Engineering Bi-Weekly Seminar Series, Western Michigan University, Kalamazoo, Michigan, October 3, 1989. I would like to thank those present, as well as my colleague Vivian Weil, for helping me see the many sides of whistleblowing. I would also like to thank the editor of *Business and Professional Ethics Journal* for his helpful comments and some useful references. Originally published in *Business and Professional Ethics Journal* 8 (Winter 1989): 3-19.

1. For a summary of what is or could be offered, see Martin H. Malin, "Protecting the Whistleblower from Retaliatory Discharge," *Journal of Law Reform* 16 (Winter 1983): 277-318. For some suggestion of how ineffective that protection is, see Thomas M. Devine and Donald G. Aplin, "Whistleblower ProtectionThe Gap

Between the Law and Reality," *Howard Law Journal* 31 (1988): 223-239; and Rosemary Chalk, "Making the World Safe for Whistleblowers," *Technology Review* 91 (January 1988): 48-57.

2. The literature describing the suffering of whistleblowers is, of course, large. For a scholarly summary, see Myron Peretz Glazer and Penina Migdal Glazer, *The Whistleblowers: Exposing Corruption in Government and Industry* (Basic Books: New York, 1989). There is, in contrast, little about how the organization either suffers or benefits. Why?

3. The holder of a "professional position" is more likely to become a whistleblower than an ordinary employee. See, for example, Marcia P. Miceli and Janet P. Near, "Individual and Situational Correlates of Whistle-Blowing," *Personnel Psychology* 41 (Summer 1988): 267-281.

4. Compare Chester A. Barnes, *The Function of the Executive* (Harvard University Press: Cambridge, Mass., 1938).

5. For a good discussion of the problems of defining "whistleblowing," see Frederick Elliston et al., *Whistleblowing Research: Methodological and Moral Issues* (Praeger: New York, 1985) esp. pp. 3-22, 145-161.

6. Even this definition should be used with caution. In most organizations, there are "ordinary" channels the use of which does not offend and "extraordinary" channels the use of which offends. Sometimes we can only determine that a channel is extraordinary by using it. Those using an extraordinary channel are treated as whistleblowers (and, indeed, are often so labeled even when they are not whistleblowers according to thisor any other standarddefinition). Similarly, the dispute between a whistleblower and her organization may in part be over whether her objection is a moral rather than a technical one (everyone agreeing that *if* the objection is moral, she would be justified). But, because they think the objection is not a moral one, they consider her a "disgruntled employee," not a whistleblower. I do not intend what I say here to turn on how we resolve such difficult cases. For a good summary of the recent literature of definition, see Marian V. Heacock and Gail W. McGee, "Whistleblowing: An Ethical Issue in Organizational and Human Behavior," *Business and Professional*

Ethics Journal 6 (Winter 1987): 35-46. See also Michael Davis, "Some Paradoxes of Whistleblowing," *Business and Professional Ethics Journal* 15 (Spring 1996): 3-19.

7. I have in mind especially the response to whistleblowers within academic institutions. See, for example, Bruce W. Hollis, "I Turned in My Mentor," *The Scientist* 1 (December 14, 1987): 1-13.

8. William Shakespeare, *Anthony and Cleopatra* (Act II: sc. 5).

9. Robert Jackall, *Moral Mazes* (Oxford University Press: New York, 1988), esp. 105-112, 119-133.

10. Why this asymmetry? One reason may be that inaccurate whistleblowing is less likely to make news. Newspapers, police departments, and senior managers are constantly receiving "tips" that don't pan out. These are not news. Another reason inaccurate whistleblowing receives little attention may be that reliably determining that a particular whistleblower is inaccurate can be difficult. The whistleblower's evidence may establish only a presumptive case against an organization. The organization may not be able to reply in full without revealing proprietary information or violating the privacy of other employees, leaving outsiders no way to know that the whistleblower is mistaken. Or, the organization in question may not be able to make a determination without great expenseand therefore may never bother. Much whistleblowing seems enveloped in the organizational equivalent of what Clausewitz called "the fog of battle." If we knew more about cases of inaccurate, mistaken, or otherwise flawed whistleblowing, perhaps our assessment of the overall good effect of whistleblowing would change. Perhaps whistleblowing, like tyrannicide, is so likely to hit the wrong target that it cannot in practice be justified. This is a subject about which we need to know more.

11. See, for example, Dick Polman, "Telling the truth, paying the price," *Philadelphia Inquirer Magazine*, June 18, 1989, pp. 16ff.

12. For an interesting analysis of this traditional view of organizational authority (and related issues) see Christopher McMahan, "Managerial Authority," *Ethics* 100 (October 1989): 33-53.

13. I owe this observation to Thomas Devine. I found no research that confirms or disconfirms it.

14. For a procedure I doubt will do much good, see Theodore T. Herbert and Ralph W. Estes, "Improving Executive Decisions by Formalizing Dissent: The Corporate Devil's Advocate," *Academy of Management Review* 2 (October 1977): 662-667. Dissent is likely to be more effective if the dissenter is not viewed as "just going through the motions" and likely to be more common if not the job of just one personor so it seems to me. But here is another question about which we need to know more.

15. Compare James Waters, "Catch 20.5: Corporate Morality as an Organizational Phenomenon," *Organizational Dynamics* 6 (Spring 1978): 3-19.

16. *Moral Mazes*, for example, 105-112.

17. These are, of course, matters of what is now often called "culture." For a good discussion, see Charles O'Reilly, "Corporations, Culture, and Commitment: Motivation and Social Control in Organizations," *California Management Review* 31 (Summer 1989): 9-25.

18. This claim is defended in chapter 5 (in this volume). See also M. Cash Matthews, "Ethical Dilemmas and the Disputing Process: Organizations and Societies," *Business and Professional Ethics Journal* 8 (Spring 1989): 1-11.

19. Michael Davis, *One Social Responsibility of Engineering Societies: Teaching Managers About Engineering Ethics,* Monograph #88-WA/DE-14 (American Society of Mechanical Engineers: New York, 1988).

20. Perhaps the best example of such a person is Roger Boisjoly (if

we can count his testimony before Congress as whistleblowing). The warnings Boisjoly gave on the night before the Challenger exploded were (though technically accurate) in the bloodless language in which engineers generally communicate. He never said, for example, "This decision could kill seven human beings." How might things have gone had Boisjoly (or anyone else present) said something of that sort when NASA pressured Thiokol to approve a launch? It is a hard question, to be sure, but one that at least suggests the potential power of language at the moment of decision. For details, see *The Presidential Commission on the Space Shuttle Challenger Disaster* (U.S. Government Printing Office: Washington, D.C.: June 6, 1986).

Chapter 7

This chapter began as pages 1-26 of Paula Wells, Hardy Jones, and Michael Davis, *Conflicts of Interest in Engineering* (Kendall/Hunt Publishing Company: Dubuque, Iowa, 1986) a module in the Series in Applied Ethics funded by the Exxon Education Foundation. Reprinted by permission. I would like to thank the staff of IIT's Center for the Study of Ethics in the Professions and the Advisory Panel of the Series for help both in formulating the original project and in carrying it to completion, and Michael Pritchard for several perceptive comments on the published version.

1. *American Society of Mechanical Engineers v Hydrolevel Corporation*, 456 U.S. 556 (1982).

2. Ibid., 559.

3. *Voluntary Industrial Standards: Hearing before the Senate Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary*, 94th Cong., 1st sess. 1975, 153-214 at 173.

4. Ibid., 174.

5. Ibid., 176, 184-185.

6. *ASME v. Hydrolevel*, 561-562.

7. Ibid., 563.

8. The critical sentence reads: "If a means for retarding control action is incorporated in a low-water fuel cutoff, the termination of the retard function must operate to cutoff the fuel supply before the boiler level falls below the visible part of the water guage glass." That sentence replaced: "It should be carefully noted that regardless of the design of any automatic

low water cutoff, the intent of the first sentence in paragraph HG-605(a) is that such low water fuel cutoff devices function so that the fuel supply shall be actually stopped when the surface of the water falls to the lowest visible part of the water gauge glass." Senate, 188, and *ASME v. Hydrolevel,* 130. If (as it seems) there is no important difference (but clarity) between these two sentences, why should anyone be concerned about James's part in substituting one for the other?

9. Priscilla S. Meyer, "Knocking the Competition: How Rival's Use of `Industrial Code' Report Created Problems for a Tiny Company," *Wall Street Journal* July 9, 1974, p. 44.

10. *Voluntary Industrial Standards,* 213.

11. *ASME v. Hydrolevel,* 564.

12. It is perhaps worth pointing out that this *is* a controversial assumption. The appellate court described Hardin's conduct as "fraud, a willful and knowing misrepresentation of the code" (without offering any additional evidence). *Hydrolevel v. ASME,* 125. And the legal counsel for the American National Standards Institute lumped James with Hardin as "two renegades" (again, without any additional evidence). William H. Rockwell, *"Hydrolevel* Decision as Applied to Antitrust Violations of Standards Making Organizations," *Perspectives on the Professions* 3(3) 1983: 3-5. On the other hand, in 1975 ASME claimed there was nothing to what Hardin and James did beyond the mere "appearance of wrongdoing." Nancy Rueth, "A Case Study," *Mechanical Engineering* 97 (June 1975): 34-36, at p. 36. That was still ASME's position a decade later. See, for example, Charles W.

Beardsley, "The Hydrolevel CaseA Retrospective," *Mechanical Engineering* 106 (June, 1984): 66-73; or Rockwell, *"Hydrolevel* Decision," 5.

13. There are, of course, some respects in which natural duties are not absolute. I will point out two later.

14. *Voluntary Industrial Standards*, p. 179.

15. *Hydrolevel v. ASME*, 123.

16. *ASME v. Hydrolevel*, 559; and Beardsley, 72.

17. Tekla S. Perry, "Antitrust Rule Chills Standards Setting," *IEEE Spectrum* 11 (August 1982): 52-54.

18. Compare *Voluntary Industrial Standards*, p. 214, where ASME's attorney (Mr. Stanton) makes a similar point.

19. Ibid., 205.

20. Ibid., 175.

21. Ibid., 211.

22. Ibid., 206.

23. Ibid., 210.

24. Ibid., Compare James's comment, ibid., 190.

25. Ibid., 211.

26. In what follows, I use the current Code of Ethics (1995). The relevant provisions are similar to those of the code in force during 1971-1972 in most relevant respects (though the format is much different).

27. Senate, 192, 211-212; and *Hydrolevel v. ASME*, 126.

28. See *ASME v. Hydrolevel*, 571 n. 8, for evidence that James' employer thought James so influenced (or, at least, was willing to defend James' unpaid activities within ASME on that basis).

29. These are published in batches several times a year in *P.E. Professional Engineer*, the official publication of the NSPE. These opinions have also been collected (up till 1990) in six volumes under the title *Opinions of the Board of Ethical Review* (National Society of Professional Engineers: Washington, D.C.).

30. *Voluntary Industrial Standards*, p. 211.

31. Compare Bernard Gert, *Morality: A New Justification of the Moral Rules* (Oxford University Press: New York, 1988).

32. There is a family of consequentialist views"rule utilitarianism"which holds that one should generally follow rules ("rules of thumb," "prima facie rules," or the like) rather than always decide how to act by considering the consequences case by case. The idea is that the rules should be designed so that generally following them maximizes good consequences in the long run. We may ignore this refinement because all forms of rule utilitarianism either fit the definition of moral rules given here or suffer from the same lack of information about consequences as any other attempt to determine what Hardin and James did wrong solely by considering the consequences of their acts. See David Lyons, *Forms and Limits of Utilitarianism* (Oxford University Press: Oxford, England 1965).

33. For more on my understanding of all this (including my reasons for denying that I am operating with a form of rule utilitarianism) see Michael Davis, "The Moral Legislature: Morality without an Archimedean Point," *Ethics* 102 (July 1992): 303-318.

34. This is an old point about the self and its interest, but one that may deserve more stress than I give in the text. Consider someone so honest that he could not live with himself if he behaved dishonestly. For him, a dishonest action would be irrational (as well as, and because it is, immoral). It would, in other words, be contrary to his self-interest, given the kind of self he is. For the virtuous, virtue really is a reward.

35. Logicians might want to claim that every rule with its

exceptions can be rewritten as a rule without exceptions. For example, "Don't kill, except in self-defense or defense of the innocent" might just as well be written "Don't non-defensively kill." Whatever the clumsiness of such rewriting, the logicians are formally right. They are, however, morally wrong. The "Don't____, except____" form of moral rules captures an underlying logic the exceptionless form does not. All else equal, killing people requires justification, justification that has to fit the killing under one of the exception clauses. That is not true of not killing. Those who obey the main clause of a moral rule need no justification; those who violate the main clause do, even if what they do comes under one of the exceptions.

36. We are, of course, assuming, that engineers can, as moral agents, only be bound by a code insofar as the code is itself interpreted in a way consistent with morality. Although that assumption should be uncontroversial, it has not always been. See, for example, Benjamin Freedman, "A Meta-Ethics of Professional Morality" in *Moral Responsibility and the Professions*, edited by Bernard Baumrin and Benjamin Freedman (Haven Publications: New York, 1983) pp, 61-79; or Alan H. Goldman *The Moral Foundations of Professional Ethics* (Rowman and Littlefield: Totawa, N.J. 1980), who argues that some professionals (for example, judges) are exempt from certain moral constraints while acting in their professional capacity. (Note, however, that Goldman does not argue that engineers are exempted in this way.) For what seems to me a decisive refutaton of this "separationism," see Alan Gewirth, "Professional Ethics: The Separatist Thesis," *Ethics* 96 (January 1986): 282-300.

37. The original version of this definition, like some engineering codes, included a phrase ("or to perform some other service for him or her") suggesting that engineers do something beyond offer

professional judgment and that conflict of interest might arise when they are providing that other service. I cannot deny that engineers occasionally do work not involving judgment, but I have yet to think of a case in which such work involves a conflict of interest. Understanding conflict of interest requires recognizing the fundamental importance of judgment in the very concept.

38. Michael Pritchard, "Conflict of Interest: Conceptual and Normative Issues," *Academic Medicine* 71 (December 1996): 1305-1313, suggested that the "interest" in conflicts of interest should be interpreted as limited to something we might "pursue, act in behalf of, or act for the sake of." Ibid., 1309. Mere wants, desires, or other circumstances tending to interfere with

competent judgment should not be counted as capable of creating a conflict of interest. Pritchard's suggestion would, I think, have to be taken if "conflict of interest" were a term in which the parts preserved their meaning (as they do in "conflicting interests"). But, in fact, it is idiom, carrying a meaning more or less independent of its parts. Utility, not etymology, may therefore shape what interpretation we give it. There are, I think, at least two reasons not to allow "interest" to be confined to interests (strictly so called). First, practice is not so neat. Note, for example, that section II.4(a) of the NSPE code recognizes "any business association, interest, or other circumstance which would influence or appear to influence their judgment" as requiring disclosure as "known or potential conflicts of interest." Second, it is not clear what the practical advantage of limiting "interests" to interests strictly so called would have. Presumably, the "other circumstances" should be disclosed anyway. Must we have separate (but otherwise parallel) rules for them?

39. For a more extensive defense of this analysis, see Michael Davis, "Conflict of Interest," *Business and Professional Ethics Journal* 1 (Summer 1982): 17-27; and Michael Davis, "Conflict of Interest Revisited," *Business and Professional Ethics Journal* 12 (Winter 1993): 21-41.

Chapter 8

The first version of this chapter was presented to a session of the First World Congress of Biomechanics, La Jolla, California, August 31, 1990; a much enlarged version was published as "Codes of Ethics, Professions, and Conflict of Interest: A Case

Study of an Emerging Profession, Clinical Engineering," *Professional Ethics Journal* 1 (Spring/Summer 1992): 179-195. I would like to thank those few present at La Jolla, especially one of my co-panelists, Caroline Whitbeck, for asking the right questions. I should also like to thank the three reviewers at *PEJ* for extensive comments on the second version. They are, of course, not responsible for a number of minor revisions I have made since.

1. For more about clinical engineering, see Michael J. Shaffer and Michael D. Shaffer, "The Professionalization of Clinical Engineering," *Biomedical Instrumentation and Technology* (September/October 1989): 370-374; and Pamela Saha and Subrata Saha, "Ethical Responsibilities of the Clinical Engineer," *Journal of Clinical Engineering* 11 (January/February 1986): 17-25.

2. Compare John Kultgen, *Ethics and Professions* (University of Pennsylvania Press: Philadelphia, 1988) p. 216. Although I agree with Kultgen's experimentalism ("Every code must be treated as a hypothesis to be tested and adapted while following it") I emphatically reject his Cartesianism ("A rational code would contain the results individuals would have reached themselves if they had reasoned objectively long enough on an adequate base of experience"). As I shall try to show later, a code of professional ethics necessarily involves certain public conventions (much as do standards of safety or reliability). What matters most is that members of the profession in question apply the same standard (not which of several morally permissible standards is applied). This is not to say that the convention chosen does not matter, only that no amount of "objective reasoning" can substitute for a coordinated decision. A professional standard need not represent a preexisting consensus; it may in fact create that consensus (much as a promise can create an agreement where none existed before). A profession's

code of ethics is the solution of a coordination problem, the sort of practical problem no individual can solve alone.

3. For more on conflict of interest, see chapter 7 (in this volume).

4. This "assurance" is, of course, merely a psychological fact. Whether it corresponds to reality, whether one can govern one's judgment as much as one believes one can, is not easily determined. Determination cannot be left to the engineer's own judgment, because that is in

question. (The ancients Greeks had a saying relevant here: "Whom the gods would destroy, they first make mad.") Outsiders, other engineers or other employees of Big Bill, might well doubt the engineer's ability to govern his judgment. Indeed, the engineer's problem arises in large part because that is a reasonable judgment on the evidence availableand he has no way to add evidence that would change that judgment.

5. Does this provision make sense? Can anyone be "sure" of not being influenced? Certainly, provided the decisions in question do not involve judgment (for example, because there is only one drug, device, or appliance that could be prescribed). Financial interest cannot create a conflict of interest where it cannot affect judgment.

6. Here I am following the new IEEE code (adopted August 1990).

7. In what sense is this standard higher and not just different? It is higher in at least two senses. First, it is higher in the sense of "more demanding." One satisfies the lower standard in satisfying the higher and then does something more. Second, it is higher in the sense of "morally better." People who satisfy this higher standard deserve praise they would not deserve for satisfying the lower standard. These two senses are, though related, not the same. We can at least imagine higher standards in the first sense ("new heights in torturing") that are not higher in the second.

8. The NSPE's Code of Ethics is, of course, not the NSPE's last word on this (or any other) ethical question. As explained in chapter 7 (in this volume), NSPE's BER regularly issues opinions on questions like that posed here. Indeed, it deals with questions very close to this one. See, for example, BER 69-13 and BER 71-6,

which seem to explain why the NSPE's code now sets a standard lower than other engineering societies do. *Opinions of the Board of Ethics Review* (National Society of Professional Engineers: Washington, D.C.) collected in six volumes to date.

9. For a fuller statement of this argument (but in the context of lawyering) see Michael Davis, "Professionalism Means Putting Your Profession First," *Georgetown Journal of Legal Ethics* 2 (Summer 1988): 341-357.

10. If this claim seems to need more defense, recall the argument of chapter 3 (in this volume).

11. For more on this use of codes, see Heinz C. Luegenbiehl, "Code of Ethics and the Moral Education of Engineers," *Business and Professional Ethics Journal* 2 (Summer 1983): 41-61. But note that I do not agree with Luegenbiehl in thinking of a code of professional ethics as mere "guidelines." See also Michael Davis, "Who Can Teach Workplace Ethics?" *Teaching Philosophy* 13 (March 1990): 21-36.

12. John Ladd, "Collective and Individual Moral Responsibility in Engineering: Some Questions" in *Beyond Whistleblowing: Defining Engineers' Responsibilities*, edited by Vivian Weil (Center for the Study of Ethics in the Professions, Illinois Institute of Technology: Chicago, 1983) pp. 102-103.

13. Like ordinary morality, professional ethics does have an external aspect as well. Most professionals are ethical in part because they do not want to suffer the (justified) criticism, circumspection, or boycott that unprofessional conduct invites. What distinguishes both ethics and ordinary morality from (mere) law is that this external "sanction" is only one reason; there is an

internal "sanction" as welland this internal sanction is generally good enough most of the time to sustain obedience.

14. Caroline Whitbeck, "Teaching Ethics to Scientists and Engineers," *Science and Engineering Ethics* 1 (July 1995): 299-308.

15. Engineering, even more than medicine, seems to work by consensus. (See chapter 9 [in this volume].) Yet, unlike medicine, those writing on engineering seldom note this tendency (in print at least) and never consider what significance it might have for understanding engineering. For some idea of the problems decision by consensus raises for medicine (and

may raise for engineering as well) see the entire August 1991 issue of *Journal of Medicine and Philosophy.*

16. Codes of ethics are sometimes criticized for (as one of the *Professional Ethics Journal's* reviewers put it) "papering over" differences with "vague language." I have four objections to this criticism: *First*, the criticism seems to assume that language can be (absolutely) precise. That is certainly a mistake. Linguistic expressions differ from one another only in degrees of vagueness (or, what comes to the same thing, degrees of precision). *Second*, the criticism seems to overlook the alternative to the "vague language" in question. Given the differences allegedly "papered over," the alternative to the vague language in question would seem to be no language at all, that is, less precision than is in fact possible. The alternative to papering over differences would thus seem to be "magnifying" them. That hardly seems preferable. *Third*, the criticism seems to assume that there is something wrong with using language of a certain degree of precision when no agreement on anything more precise is possible. That too seems a mistake. Pushing precision beyond what is now possible can be expensive. The achievement may not be worth the expense. Given the practical purpose of any code of ethics, the prudent approach must, it seems to me, be to state what can be stated at the time. Such a statement does not paper over disagreements. The disagreements are not concealed but simply left as they were. Each member of the profession is free to interpret the language agreed to as seems right to her, to act accordingly, to answer for what she has done, and so to contribute to a fund of common experience out of which a more precise statement may in time grow. *Fourth*, the criticism seems to understate the essential role of language in all

this. Everyone does, or at least should, understand that any documentwhether code of ethics, table of tolerances, or even private lettercannot be taken to express any single state of mind in its author (or authors). The document says what it says, whatever its author actually intended. If the author was foolish, careless, or simply unlucky, the document may well say more, less, or even something radically different from what she intended. Like other acts, linguistic acts can misfire. Interpretation is not a matter of reading off the clear (or unclear) intention of an author. It is, rather, working with a text according to certain more or less definite procedures. A document is not a mere vessel transmitting well or poorly the intentions of its author. Interpretation begins where the author stopped.

Chapter 9

This chapter began as a project funded by a grant from the Hitachi Foundation of America and carried out under the direction of a seven-member panel of academics and practitioners in the Chicago area (the chapter's "we"). The panel included Thomas Calero (Business, IIT) Michael Davis (Center for the Study of Ethics in the Professions, IIT) Robert Growney (Corporate Vice President, Motorola) David Krueger (Director, Center for Ethics and Corporate Policy) Elliot Lehman (Chairman, Fel-Pro) and Lawrence Lavengood (Business, Northwestern University). Vivian Weil (Center for the Study of Ethics in the Professions, IIT) chaired the panel. Calero, Davis, and Krueger conducted interviews at the following companies: Fel-Pro Incorporated, Omni Circuits, Bosch Corporation, W.E. O'Neil Construction Company, Motorola, Inland Steel Company, Navistar, Amoco Chemical Company (two sites) Hitachi Automotive Products (USA) and Cummins Engine. We would like to thank these companies for their help both in setting

up the interviews and in making sure they went smoothly. We should also like to thank the following people for providing comments on the first draft of this report: Diana Stork (Business, University of Hartford) Deborah Johnson (Department of Science and Technology Studies, Rensselaer Polytechnic Institute) Peter Whalley (History, Loyola University of Chicago) and Steven Shortell (Business, Northwestern University). One or another summary of this chapter was presented at the National Society of Professional Engineers Annual Meeting

(Industry Practices Division) Charleston, South Carolina, January 21, 1992; at the National Conference on Ethics and the Professions, University of Florida, Gainesville, February 1, 1992; and at a seminar sponsored by the Department of Mechanical Engineering, Texas A & M University, March 12, 1992. The discussions that followed provided welcome confirmation of our results. A short version of this chapter was published as "Technical Decisions: Time to Rethink the Engineer's Responsibilities?," *Business and Professional Ethics Journal* 11 (Spring/Summer 1992): 41-55; a longer version as "Ordinary Technical Decision-Making: An Empirical Investigation," in *Responsible Communications: Ethical Issues in Business, Industry, and the Professions*, edited by James A. Jaska and Michael S. Pritchard (Hampton Press: Cresskill, N.J., 1996) pp. 75-106; and a complete version as Michael Davis, "Better Communication Between Engineers and Managers: Some Ways to Prevent Many Ethically Hard Choices," *Science and Engineering Ethics* 3 (April 1997): 171-212. Reprinted by permission.

1. Henry Petroski, "The Iron Ring," *American Scientist* 83 (May-June 1995): 229-232.

2. Note the crucial "seem" in this sentence. The issue of probabilities here is more complex than Feynman (or those he interviewed) indicates. For more on that complexity, see William H. Starbuck and Frances J. Milliken, "Challenger: Fine-Tuning the Odds until Something Breaks," *Journal of Management Studies* 25 (July 1988): 319-340.

3. Richard Feynman, "An Outsider's Inside View of the Challenger Inquiry," *Physics Today* (February 1988): 26-37, esp. 34.

4. Ibid.

5. Ibid.

6. For a good technical description of the "game" to which Feynman refers, see Trudy E. Bell, "The fatal flaw in Flight 51-L," *IEEE Spectrum* (February 1987): 36-51. Compare David A. Bella, "Organizations and Systematic Distortion of Information," *Journal of Professional Issues in Engineering* 113 (October 1987): 360-370.

7. Feynman, "Outsider's Inside View," 34.

8. Robert Jackall, *Moral Mazes: The World of Corporate Managers* (Oxford University Press: New York, 1988) pp. 112-119.

9. Albert Shapero, *Managing Professional People* (Free Press: New York, 1985).

10. Joseph A. Raelin, *The Clash of Cultures: Managers and Professionals* (Harvard Business School Press: Cambridge, Mass., 1986); and "The Professional as the Executive's Ethical Aidede-Camp," *Academy of Management Executive* 1 (August 1987): 171-182.

11. Raelin, "Executive Aide-de-Camp," 1987.

12. Chapter 5 (in this volume).

13. James A. Waters, "Catch 20.5: Corporate Morality as an Organizational Phenomenon," *Organizational Dynamics* (Spring 1978): 3-19.

14. Ibid. 11.

15. Harold Henderson, *"McGregor v. the NRC:* Why Did the Nuclear Regulatory Commission Fire One of Its Toughest Plant

Inspectors?," *Reader* (Chicago) Friday, July 22, 1988, pp. 1ff.

16. Brian Urquhart, "The Last Disaster of the War," *New York Review of Books,* September 24, 1987, pp. 27-30; and Thomas Petzinger, "Hangar Anger: Mechanic's Woes Show How Safety Became a Big Issue for Eastern," *Wall Street Journal*, June 9, 1988, pp. 1ff.

17. Waters, 1978; and Waters, "Integrity Management: Learning and Implementing Ethical Principles in the Workplace," in *Executive Integrity,* edited by Suresh Srivastva et al. (Jossey-Bass: San Fransciso, 1988).

18. Raelin, *The Clash of Cultures*, 246-263.

19. See, for example, Chris Argyris and Donald Schön, "Reciprocal Integrity: Creating Conditions That Encourage Personal and Organizational Integrity" in *Executive Integrity,*

edited by Suresh Srivastva et al. (Jossey-Bass: San Francisco, 1988) pp. 197-222; and Gerald E. Ottoson, "Essentials of an Ethical Corporate Climate" in *Doing Ethics in Business,* edited by Donald G. Jones (Oelgeschlager, Gunn and Hain: Cambridge, Mass., 1982) pp. 155-163.

20. The only exception we found is Bruce F. Gordon and Ian C. Ross, "Professionals and the Corporation," *Research Management* 5 (November 1962): 493-505.

21. Perhaps the most noteworthy exceptions are the very tentative studies by Bart Victor and John B. Cullen, "The Organizational Bases of Ethics Work Climates," *Administrative Science Quarterly* 33 (March 1988): 101-125; and Alan L. Wilkins and William G. Ouchi, "Efficient Cultures: Exploring the Relationship Between Culture and Organizational Performance," *Administrative Science Quarterly* 28 (September 1983): 468-481.

22. Tom Burns and G.M. Stalker, *The Management of Innovation* (Tavistock Publications: London, 1966). I would like to thank Peter Whalley for pointing out this book.

23. Barry A. Turner, *Man-Made Disasters* (London: Wykeham Publications, Ltd., 1978) esp. pp. 17-30, 57-67, 120-125, and 189-199.

24. Merrit R. Smith, ed., *Military Enterprise and Technological Change* (MIT Press: Cambridge, Mass., 1985) esp. pp. 11-14 87-116.

25. This, of course, is not the only way in which to use the terms "staff" and "line" in business. Most frequently, perhaps, these terms

are today used to distinguish between the historically oldest functional units of a business (production and sales) and the more recent (personnel, legal, accounting). On this version of the distinction, engineering might be either a staff or a line function (depending on the history of the company). Often too, the staffline distinction is used to contrast those functions that contribute (more or less) directly to the bottom line ("profit centers") with those that contribute only indirectly ("service functions"). On this version, some engineering functions (for example, operations and perhaps research) would be line functions while other engineering functions (for example, quality control or safety) would be staff functions. This diversity in the way the staff-line distinction is made today may itself signal that the original use no longer fits most American businesses.

26. Rosalind Williams, "Engineering's Image Problem," *Issues in Science and Technology* 6 (Spring 1990): 84-86.

27. The companies selected had business connections with one of the corporate members of our panel, with one of our two ethics centers, or with our sponsor (or even with some combination of these).

28. We had one interviewer on only three occasions, one for a whole day when there was no other way to schedule the interview, and twice for part of an afternoon when one interviewer had to leave early.

29. Williams, "Engineering's Image Problem," 84.

30. For more information about the characteristics of those interviewed, see Appendix 3 in this volume.

31. It is perhaps worth noting that no one mentioned a commonplace of academic criticism, the need for engineers turned

managers to learn to live with ambiguity. What explains the silence of our interviewees on this point? One possibility is that, as practitioners, they have already had to get used to ambiguity. Another possibility is that the crucial transition is not between engineering and technical management but between technical and nontechnical management. Here is a question that invites further research.

32. No member of our working group is altogether satisfied with the names we gave these three kinds of company. Our only defense is that, after far too much discussion, we could not do better.

33. For an apparently analogous case ending in a half-billion-dollar write-off at General

Electric, see Thomas F. O'Boyle, "Chilling Tale: GE Refrigerator Woes Illustrate the Hazards in Changing a ProductFirm Pushed Development of Compressor Too Fast, Failed to Test Adequately," *Wall Street Journal*, Monday, May 7, 1990, pp. 1 ff.

Chapter 10

An earlier version of this chapter was published as "Professional Autonomy: A Framework for Empirical Research," in *Business Ethics Quarterly* 6 (October 1996): 441-460. Reprinted by permission. I would like to thank the National Science Foundation for grant SBR-9320166 under which that article was written.

1. Edwin Layton, *The Revolt of the Engineers* (Case Western Reserve University Press: Cleveland, 1971) p. 5.

2. Gerald Dworkin, *The Theory and Practice of Autonomy* (Cambridge University Press: New York, 1988) p. 22.

3. Thomas Scanlon, "A Theory of Freedom of Expression," *Philosophy and Public Affairs* 1 (Winter 1972): 204-226; Adina Schwartz, "Autonomy in the Workplace" in *Just Business: New Introductory Essays in Business Ethics,* edited by Tom Regan (Random House: New York, 1984) pp. 129-166; Joseph Raz, "Autonomy, Toleration, and the Harm Principle," in *Issues in Contemporary Legal Philosophy: The Influence of H.L.A. Hart,* edited by Ruth Gavison (Oxford University Press: New York, 1987) 313-333; Stanley I. Benn, *A Theory of Freedom* (Cambridge University Press: Cambridge, 1988) esp. chapters 8 and 9; and Diana T. Meyers, *Self, Society, and Personal Choice* (Columbia University Press: New York, 1989).

4. John Christman, ed., "Introduction," *The Inner Citadel* (Oxford University Press: New York, 1989) p. 9.

5. Michael Davis, "Brandt on Autonomy" in *Rationality and Rule-Utilitarianism,* edited by Brad Hooker (Westview Press: Boulder, Colo., 1993) pp. 51-65; and Irving Thalberg, "Hierarchical Analyses of Unfree Action," *Canadian Journal of Philosophy* 8 (June 1978): 211-226. But the most famous hypothetical conception of autonomy is probably Kant's. For Kant, autonomy is acting in accordance with those maxims one can (without contradiction) will to be universal laws. Immanuel Kant, *Foundations of the Metaphysics of Morals,* 2d, edited by Lewis White Beck (Macmillan/Library of the Liberal Arts: New York, 1990) pp. 63-73. One need not actually will the maxim to be a universal law. It is enough that one *can.*

6. Gerald Dworkin, "Concept of Autonomy" in *Science and Ethics,* edited by Rudolph Haller, (Amsterdam: Rodopi Press, 1981) pp. 203-213. Harry G. Frankfurt, "Freedom of the Will and the Concept of a Person," *Journal of Philosophy* 68 (January 1971): 5-20.

7. Robert Young, "Autonomy and the Inner Self," *American Philosophical Quarterly* 17 (January 1980): 35-43.

8. Kenneth Kipnis, "Professional Responsibility and the Responsibility of Professions" in *Profits and Professions: Essays in Business and Professional Ethics,* edited by Wade L. Robinson, Michael Pritchard, and Joseph Ellin (Humana Press: Clifton, N.J., 1983) p. 16.

9. Arlene Kaplan Daniels, "How Free Should Professions Be?," in *The Professions and Their Prospects,* edited by Eliot Freidson (Sage: Beverly Hills, Cal., 1971), p. 39.

10. Actually, it would probably be better to say "as Canada and Mexico *try* to do." I was told by officers of engineering societies in both Canada and Mexico that many engineers in both countries who work in large companies are unlicensed. They will get into trouble if they are publicly identified as engineers (for example, in a newspaper article, during a television interview, or even on company letterhead) but not otherwise. So, the contrast with American practice is not nearly as sharp as it has seemed (and will probably become less sharp as the three countries move toward economic union).

11. K.R. Pavlovic, "Autonomy and Obligation: Is There an Engineering Ethics?" in *Ethical Problems in Engineering, 2nd ed.*, vol. 1, edited by Albert Flores (Center for the Study of the Human Dimensions of Science and Technology: Troy, N.Y., 1980) p. 90.

12. Paul F. Camenisch, *Grounding Professional Ethics in a Pluralistic Society* (Haven: New York, 1983) p. 30.

13. Kipnis, "Professional Responsibility," p. 16.

14. Mike W. Martin, "Professional Autonomy and Employers' Authority," in *Profits and Professions: Essays in Business and Professional Ethics,* edited by Wade L. Robinson, Michael Pritchard, and Joseph Ellin (Humana Press: Clifton, N.J., 1983) pp. 265-273; Adina Schwartz, "Autonomy in the Workplace," and Heinz C. Luegenbiehl, "Computer Professionals: Moral Autonomy and a Code of Ethics," *Journal of Systems Software* 17 (1992): 61-68.

15. Layton, *Revolt*, 7.

16. See chapters 1 and 2 (in this volume).

17. Daniel Hovey Calhoun, *The American Civil Engineer* (Technology Press-MIT: Cambridge, Mass., 1960) esp. pp. 182-199.

18. Cf. Stephen J. O'Connor and Joyce A. Lanning, "The End of Autonomy? Reflections on the Postprofessional Physician," *Health Care Management Review* 17 (Winter 1992): 63-72; George J. Agich, "Rationing Professional Autonomy," *Law, Medicine and Health Care* 18 (Spring-Summer): 77-84; and John Child and Janet

Fulk, "Maintenance of Occupational Control: The Case of Professions," *Work and Occupations* 9 (May 1982): 155-192.

19. Robert Perrucci and Joel E. Gerstl, *Professions without Community: Engineers in American Society* (Random House: New York, 1969) p. 119.

20. J. Daniel Sherman, "Technical Supervision and Turnover Among Engineers and Technicians: Influencing Factors in the Work Environment," *Group and Organization Studies* 14 (December 1989): 411-421; Steven P. Feldman, "The Broken Wheel: The Inseparability of Autonomy and Control in Innovation within Organizations," *Journal of Management Studies* 26 (March 1989): 83-102; and Bernard Rosenbaum, "Leading Today's Professionals," *Research-Technology Management* (March-April 1991): 30-35.

21. Gene F. Brady, Ben B. Judd, and Setrak Javian, "The Dimensionality of Work Autonomy Revisited," *Human Relations* 43 (1990): 1219-1228, esp. p. 1220; Paul E. Spector, "Perceived Control by Employees: A Meta-Analysis of Studies Concerning Autonomy and Participation at Work," *Human Relations* 39 (November 1986): 1005-1015, esp. p. 1006; Jiing-Lih Farh and W.E. Scott, Jr., "The Experimental Effects of `Autonomy' on Performance and Self-Reports of Satisfaction," *Organizational Behavior and Human Performance* 31 (1983): 203-222, esp. p. 205; Patrick B. Forsyth and Thomas J. Danisiewicz, "Toward a Theory of Professionalization," *Work and Occupation* 12 (February 1985): 59-76, esp. p. 60; Peter Meiksins, "Science in the Labor Process: Engineers as Workers" in *Professionals as Workers: Mental Labor in Advanced Capitalism*, edited by Charles Derber (G.K. Hall: Boston, 1982) pp. 121-140, esp. p. 131: and even Layton, *Revolt*, 5.

22. Martin, "Professional Autonomy," is good on this point.

23. See also Robert Zussman, *Mechanics of the Middle Class: Work and Politics Among American Engineers* (University of California Press: Berkeley, 1995), p. 222.

24. That "beyond" no doubt includes "competence." But I do not think competence the heart of the matter. For someone who does, see John T. Sanders, "Honor Among Thieves: Some Reflections on Professional Codes of Ethics," *Professional Ethics* 2 (Fall/Winter 1993): 83-103.

25. I say "typically" because a few professionsor quasi-professionshave an impersonal ideal. For example, science, at least on some conceptions, serves no client, employer, or public but the truth. What distinguishes professions from other occupations is not service to others as such but a moral ideal, defensible in part by the way serving it benefits others. The truth

of science, though an impersonal object of service, remains a morally good object of service (just as justice, health, and safety are) because the truths of science are important to us all, whether practically important (as much of physics, chemistry, and biology are) or just intellectually important (as much of astronomy, etymology, and anthropology are).

26. Must "profession" be used in this way? That depends on what is meant by "must." Both the dictionary and ordinary usage allow for other ways of using the word. So, if the question asks about what usage requires, the answer is certainly no. If, however, the question asks how I intend to use the word, or what usage I consider more helpful in this context, the answer is yes. I believe this way of using the word "profession" captures the project of the professions better than any other. (This is, of course, an empirical claim, one to be tested by asking members of professions, especially those who have thought most about what their profession means to them, to choose among this definition and the alternatives.)

27. Voluntarily undertaking to serve a moral ideal is, of course, not without its moral risks. Like promising, it opens one to crititicism to which one would not otherwise be open, the criticism that comes when one fails to do what one has undertaken. But it also provides a basis for further praise, the praise due one who has lived up to his commitment.

28. We are, of course, assuming that this "anyone" includes only sane adults of at least ordinary intelligence, in other words, the sort of people professions typically admit to practice.

29. This problem has its counterpart in political philosophy: Can one owe allegiance to law and still be morally autonomous? For a sample of the arguments against any consistency between legal obligation and moral autonomy, see Robert Paul Wolff, *In Defense of Anarchism* (Harper and Row: New York, 1970) esp. pp. 3-19. Although our question is easier to deal with than the politicalbecause membership in a profession is voluntary in a way subjection to law is notit is worth noting that one major approach to making legal obligation and moral autonomy consistent is social contract theory, which tries to understand subjection to law as if it were as voluntary as membership in a profession. The real voluntariness of professions does, however, change significantly what is necessary to preserve autonomy. Compare the solution I offer here with my response to Wolff, Michael Davis, "Avoiding the Voter's Paradox Democratically," *Theory and Decision* 5 (October 1974): 295-311.

30. Indeed, agent-centered conceptions probably have a different purpose in view, to distinguish those who have a *right* to autonomy we are bound to respect from those who have no such right. A right to autonomy is, typically, a right to have primarily self-regarding decisions respected whatever their apparent merit. It is not surprising then that agent-centered conceptions do not suit our purposes; the decisions of professionals are, typically, not primarily self-regarding (and are not supposed to be). Compare Dworkin, *The Theory and Practice of Autonomy*, p. 19: "I am not trying to analyze the notion of autonomous *acts."*

31. Kant scholars may object that I am being unfair to Kant. They might be right. Kant has a notion of "contradiction with a system of nature," that may provide a substantive test. Kant, *Foundations,* 39. I decline to use Kant here because so many have found this notion

too obscure to be helpful and because it seems less demanding than the test I propose.

32. For a defense of the equation of rationality with autonomy, see Davis, "Brandt on Autonomy" (and the work of Richard Brandt cited there).

33. Layton, *Revolt*,. 5.

34. Ibid.

35. We can now offer an analogous analysis of moral autonomy: Moral autonomy consists of being able to do as morality requires (when that ability includes both having the appropriate desires and having the capacity to act on them). So, one can both submit to law and be morally autonomous, as long as the law does not require anything morality forbids. This analysis of moral autonomy makes the relationship between moral and personal autonomy hard to sort out. For example, do I have personal autonomy whenever I can act as morality

requires or must I have other capacities as well (such as, say, the ability to look after my own interests)?

Epilogue

I read the first draft of this chapter, under the title "Questions for STS from Engineering Ethics," at a session of the Society for the Social Study of Science Annual Meeting, Charlottesville, Virginia, October 22, 1995. I would like to thank those present, both audience and other panelists, but especially Vivian Weil, for many helpful comments.

1. Donald Mackenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (MIT Press: Cambridge, Mass., 1990). Another recent book often offered to me as evidence that the social sciences are already studying engineering is Robert J. Thomas, *What Machines Can't Do: Politics and Technology in the Industrial Enterprise* (University of California Press: Berkeley, 1994). Engineers (so described) do now and then have walk-on parts, but there is no attempt to study their contribution systematically, much less to consider who among the managers is in fact an engineer (operating as such). Indeed, the focus of this book seems to be the machinists on the shop floor.

2. What Steve Woolgar hailed as "The Turn to Technology in Social Science Studies," *Science, Technology, and Human Values* 16 (Winter 1991): 20-50, has so far not reached engineeringexcept for those who equate technology with engineering. That equation is quite common. Consider, for example, an early piece, James K. Feibleman, "Pure Science, Applied Science, Technology, Engineering: An Attempt at Definition," *Technology and Culture* 2

(1961): 305-317. Engineering actually receives no definition or, indeed, hardly a mention after the titleand the only extended discussion of engineering concerns "Roman engineers." The Romans called those guys "builders" ("architects"). "Engineer" is (as we learned in chapter 1) a relatively recent coinage; reference to ancient engineers should at least come with a justification (and quotation marks to signal the anachronism). Feibleman's errors have been repeated for more than thirty years.

3. In the context of medical ethics, I callfor obvious reasonsthe technical "the therapeutic." Michael Davis, "The State's Dr. Death: What's Unethical about Physicians Helping at Executions?" *Social Theory and Practice* 21 (Spring 1995): 31-60.

4. For an example of the philosophical approach to engineering ethics, see Nigel G.E. Harris, "Professional codes and Kantian duties" in *Ethics and the Professions,* edited by Ruth F. Chadwick (Avebury: Aldershot, England, 1994) pp. 104-115.

5. For a good example of the casuistic approach, see Ken Alpern, "Moral Responsibility for Engineers," *Business and Professional Ethics Journal* 2 (Winter 1983): 39-48; or Eugene Schlossberger, *The Ethical Engineer* (Temple University Press: Philadelphia, 1993).

6. For a good example of the technical approach, see the use Mike W. Martin and Roland Schinzinger make of the concept of engineering as social experimentation in *Ethics in Engineering,* 2nd ed. (McGraw-Hill: New York, 1989); or Timo Airaksinen, "Service and Science in Professional Life" *Ethics and the Professions,* edited by Ruth F. Chadwick (Avebury: Aldershot, England, 1994), pp. 1-13.

7. I can't think of a clear case of a philosopher using the social

approach in engineering ethics. I list it here because it seems to pop up regularly in discussions with engineers. For a philosopher who used it in medical ethics, see Robert M. Veatch, "Medical Ethics and the Grounding of Its Principles," *Journal of Medicine and Philosophy* 4 (March 1979): 1-19.

8. This is not to deny that there are, now and then, moments resembling direct negotiation between society and engineering; it is merely to acknowledge how rarely society,

whether through government or through newspaper editorials or other non-governmental pressures, takes an active part.

9. For a text in engineering ethics that takes the professional approach, see Charles Harris, Michael Pritchard, and Michael Rabins, *Engineering Ethics: Concepts and Cases* (Wadsworth: Belmont, 1995).

10. For an example of how hostile to codes a devotee of the philosophical approach can be, see John Ladd, "Collective and Individual Responsibility in Engineering: Some Questions" in *Beyond Whistleblowing: Defining Engineers' Responsibilities,* edited by Vivian Weil (Center for the Study of Ethics in the Professions, Illinois Institute of Technology) pp. 90-113.

11. For a rare (but welcome) example of what could be done, see Peter Whalley, "Negotiating the Boundaries of Engineering: Professionals, Managers, and Manual Work," *Research in the Sociology of Organizations* 8 (1991) 191-215.

12. Walter G. Vincenti, *What Engineers Know and How They Know It* (Johns Hopkins University Press: Baltimore, 1990).

13. For another good example of what can be done, see Bruce Seeley, "The Scientific Mystique in Engineering: Highway Research at the Bureau of Public roads, 1918-1940," *Technology and Culture* 25 (October 1984): 798-831.

14. Tracy Kidder, *The Soul of a New Machine* (Little Brown: Boston, 1981)

15. I would offer the same qualified praise for Kathryn Henderson's work, for example, "Flexible Sketches and Inflexible Data Bases:

Visual Communication, Conscription Devices, and Boundary Objects in Design Engineering," *Science, Technology, and Human Values* 16 (Autumn 1991): 448-473.

16. Interestingly, at least some sociologists, noting this advantage of the historians, simply adopted their methods. See, for example, Peter Meiksins, "The `Revolt of the Engineers' Reconsidered," *Technology and Culture* 29 (1986): 219-246. One of the good features of science and technology studies is that disciplinary boundaries remain relatively unimportant. So, "historian" must be read here as "someone functioning as a historian" rather than as "someone of that profession."

17. Edwin Layton, *The Revolt of Engineers* (Case Western Reserve University Press: Cleveland, 1971)

18. For a rare example of what such work might look like, see Eva Kranakis, "Social Determinants of Engineering Practice: A Comparative View of France and American in the Nineteenth Century," *Social Studies of Science* 19 (February 1989): 5-70.

19. *Report of Investigation into Allegations of Retaliation for Raising Safety and Quality of Work Issues Regarding Argonne National Laboratory's Integral Fast Reactor Project* (Office of Nuclear Safety, U.S. Department of Energy: Washington, D.C., December 1991).

20. Although he had a Ph.D. in metallurgy, his bachelor's degree was in metallurgical engineering (Colorado School of Mines, 1978) and his job description at Argonne was "associate engineer and experimenter." *Report of Allegations*, 19: 7. The report does not make clear whether his graduate training and other job experience was in engineering or science (though what it does say is at least

consistent with his graduate training being in an engineering department).

21. Among the most important exceptions are Robert Perrucci and Joel E. Gerstl, *Profession without Community: Engineers in American Society* (Random House: New York, 1969); much of the work of Edward W. Constant II; and Robert Zussman, *Mechanics of the Middle Class: Work and Politics Among American Engineers* (University of California Press: Berkeley, 1995).

22. See, for example, Richard DeGeorge, "Ethical Responsibilities of Engineers in Large Organizations," *Business and Professional Ethics Journal* 1 (1981): 1-14.

23. Carl Mitcham, *Thinking through Technology: The Path between Engineering and Philosophy* (University of Chicago Press: Chicago, 1994) pp. 103-105.

24. While the editorial boards of many of these journals do mix scholars in professional ethics with those in science and technology studies, I take that fact to indicate original hopes rather than present reality. The present separation of the fields is, I think, due not to a failure of the journals' founders to understand the connection between professional ethics and science and technology studies but a failure to realize that vision in daily practice. A choice of editor-in-chief here, the weight of submissions there, slowly turned journals with a distinct vision into journals much like others in their disciplinean interesting subject for a monograph or two on the sociology of the social sciences.

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