Brigham Young University

BYU ScholarsArchive

1999-03-01

Resolving Problems in Engineering Ethics: Precept and Example

Joel C. Adair
Brigham Young University - Provo

BYU ScholarsArchive Citation

www.manaraa.com

RESOLVING PROBLEMS IN ENGINEERING ETHICS:
PRECEPT AND EXAMPLE

JOEL C. ADAIR

Resolving Problems in Engineering Ethics:

Precept and Example

by

Joel C. Adair

Submitted to Brigham Young University in partial fulfillment
of graduation requirements for University Honors

March 1, 1999

Advisor: Steven E. Benzley   Honors Dean's Representative: Perry W. Carter

Signature: _____   Signature: _____

Table of Contents

List of Figures and Tables

Acknowledgments

No thesis would be complete without an expression of gratitude to those who provided the support necessary to make it possible. It is interesting to note that convention dictates that this tribute be placed at the beginning of the work, as if to indicate that it was written first, before the author received all the requisite encouragement, love, patience, help with proofreading, support with children and housekeeping, etc. – the list continues, seemingly without end. The reader may rest assured that these "Acknowledgments" are the last words added to this work.

That said, I must express my gratitude to my advisor, Dr. Steven Benzley, as well as the other Engineering Ethics professors, Dr. Ron Terry and Val Hawks, for laying the groundwork of this thesis. I appreciate their examples, ideas, support, and patience while I finished this work.

My parents also deserve a note of thanks. They have made countless sacrifices to make my education possible. Certainly, much of the thinking that went into this thesis was shaped by their influence and example.

Finally, I could not say enough to express the gratitude I owe my wife, Kim. She has borne a tremendous responsibility in our home and family while the months of research and writing have passed away. Without her support, this thesis would never have reached its completion.

PART 1. BACKGROUND

1.1 Professional Ethics in Context

Recently, the subject of professional ethics has become a topic of heightened discussion among professionals, in academics and in the media. While some might say that this represents a new awareness of our moral responsibilities, others might justifiably conclude that the growing interest is due to the increasing contrast between ethical behavior and the downward spiraling societal norm. Rushworth M. Kidder notes this fearful trend in his book entitled *Shared Values for a Troubled World* with these words:

> So many voices from so many different backgrounds have spoken so earnestly about the world's moral situation that their warnings can't be brushed aside. Something, they are saying, is profoundly and globally amiss, not just economically, or militarily, or politically, but ethically. Something deep in the soul of our collective future seems out of balance, and the world appears to be in a long, slow drift toward moral recession. (1994)

At the heart of this "drift toward moral recession" seem to be the doctrines of relativism and situationalism. These philosophies corrupt society's moral code by proclaiming that there are no constant standards of acceptable behavior. Rather, they state that what is right in one instance is wrong elsewhere, and what is right for one person is wrong for another. Sociologist Alan Wolfe refers to these philosophies as the "new 11th Commandment: 'Thou shalt not judge'" (Bennett, 1998).

The acceptance of the philosophies of situationalism and relativism is clearly evidenced in the American public's reaction to the 1998 White House scandal, in which it was discovered that President Bill Clinton engaged in sexual relations with an intern, Monica Lewinski. Despite the impeachment by the House of Representatives for perjury

and obstruction of justice, the President's public approval ratings remained high. William J. Bennet, co-founder of Empower America, writes:

> The moral pendulum has swung too far in the direction of relativism. If a nation of free people can no longer make pronouncements on fundamental matters of right and wrong – for example, that a married 50-year-old commander-in-chief ought not to have sexual relations with a young intern in his office and then lie about it – it has lost its way. The problem is not with those who are withholding judgment until all the facts are in, but with the increasing number of people who want to avoid judgment altogether. Firm moral convictions have been eroded by tentativeness, uncertainty, diffidence. (Bennet, 1998)

With fewer people willing to judge the acceptability of others' behavior, the tolerance for corruption increases.

This moral decline is present in the professional world, just as it is in government. As the world is further demoralized, the few professionals willing to uphold high standards of responsible behavior become more noticeable. If Latter-day Saints are to practice our religion in our professions, it will require, more than ever before, being a "peculiar people."

With this challenge in mind, administration, faculty and students at Brigham Young University are placing greater emphasis on the study of professional ethics by researching, teaching and applying ethical philosophies that are in harmony with the gospel of Jesus Christ. To meet the need for a gospel-oriented approach to professional ethics, the College of Engineering and Technology currently offers several sections of Engineering Ethics taught each semester, each class focusing on a different engineering discipline and being taught by an appropriate engineering professor. The typical approach in these classes is to discuss how a person might develop Christlike character traits and apply them to situations that an engineer might expect to encounter in the

workplace. There is usually some discussion of classical ethical philosophy, but the emphasis is on a more direct application of gospel principles to engineering practice.

The purpose of the research leading to this thesis was to investigate ethics in the context of the engineering profession beyond that which could be studied in the Engineering Ethics course. As stated in the title, this text will discuss engineering ethics by "precept and example." The "precept" portion has a two-fold purpose: first, to discuss the ideologies upon which ethical behavior is built; and, second, to develop a methodical approach for resolving ethical dilemmas. The "example" portion of this text presents case studies in which professionals faced with moral choices reacted in an ethical manner, resolving their dilemmas appropriately.

1.2 The Need for Ethics in Engineering

When thinking of professional ethics, people typically think of lawyers and medical professionals. Lawyers, because of the nature of their work, must keep strict confidences with their clients while possessing the integrity to help ensure that justice is met. Often, it is the conflict between these responsibilities that creates ethical dilemmas among this group of professionals. Likewise, doctors must maintain a high level of ethical judgment, as their work has direct impact on their patients' health and lives. In medicine, ethical dilemmas are created when researchers choose suitable means by which to test a new drug or treatment, as disparities arise between those who can afford expensive treatment and those who need it, and as physicians consider treatment possibilities.

With legal and medical ethics at the forefront of many people's thoughts and media attention, the general public tends to forget the importance of ethical behavior among engineers. However, ethical behavior among this group is as crucial as in other professions. What is it that makes ethical behavior so critical in the professional world? As Frank Collins writes, looking to the factors that define a profession provides insight:

> The dictionary defines *profession* as 'a vocation or occupation requiring advanced training in some liberal art, or science, and usually requiring mental rather than manual work, as teaching, engineering, etc.
>
> The formal definition says nothing about the socioeconomic status of professionals nor about any special responsibility [to act ethically]. Nevertheless, there is a deeper meaning to professionalism that is worth exploring here. The definition implies that professionals, apart from any economic questions, have a definite responsibility for the quality and, more importantly, for the character of their work. (Schaub, 1983)

Thus, a professional is required to behave responsibly because she possesses knowledge that is not generally understood by her patients, clients, or the public in general. Those who have not spent years in the study and practice of medicine are entirely at the mercy of their doctor, who possesses knowledge that can both cure disease or end a life. We simply expect our doctor to use his knowledge benevolently (though not without compensation, of course) without causing harm to us either intentionally or erroneously. Similarly, a lawyer, because of her knowledge of the judicial system, possesses the ability to influence the "truth" that is perceived and the manner in which justice is meted out.

One might also conclude that professionals are to act responsibly simply because that is what is expected of professionals, both by professionals and non-professionals, alike. Responsible behavior is intrinsic to professionalism, just as faith is intrinsic to

religion. The Professional Activities Committee of the American Society of Civil
Engineers has captured this aspect of professionalism in their definition of a profession:

> A profession is a calling in which special knowledge and skills are used in a
> distinctly intellectual plane in the service of mankind, and in which the successful
> expression of creative ability and application of professional knowledge are the
> primary rewards. There is implied the application of the highest standards of
> excellence in the educational fields prerequisite to the calling, in the performance
> of services, and the ethical conduct of its members. Also implied is the conscious
> recognition of the profession's obligation to society to advance its standards and to
> prescribe the conduct of its members. (ASCE, 1995)

This definition places several significant constraints upon the professional. A profession
is a "calling," rather than merely a job. This is evidenced by the internal rewards that are
mentioned: "successful expression of creative ability and application of professional
knowledge." A professional, in the true spirit of professionalism, is not drawn to a
professional field for purposes of financial gain. Rather he feels the need to be of service,
to contribute to society. In this sense, the professional is motivated by similar factors as
those that inspire an artist, musician, philanthropist, or teacher.

Like other professional fields, the engineering disciplines possess all the
aforementioned aspects of a profession. An engineer possesses knowledge that is highly
technical, difficult to obtain, and constantly in flux. The engineer is also in a position to
provide service to others. This is felt, perhaps, even more keenly by the engineer than by
other professions, since an engineer is foremost responsible to protect the public as a
whole, while doctors and lawyers are primarily responsible to their clients, a small subset
of this larger group. The public, to whom the engineer is accountable, is characterized by
"innocence, helplessness and passivity.... [It is] 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" (Davis, 1987). Since the engineer's sphere of influence is greater than that of a doctor or lawyer, the potential for harm is proportionately larger, as is his ability to protect and assist.

1.3 Studies of Ethics

There have been many theories developed through the centuries concerning the principles and applications of ethics. Each has a unique approach to determining ethical behavior based on the ideology upon which the theory is founded. Some of the theories have their roots in religion, others in philosophy and logic. While a thorough study of the important ethical philosophies is far beyond the scope of this work, a short discussion of some of the more prominent theories is in order to assess some of the tools available for ethical problem solving in engineering applications.

1.3.1 Teleological Theories

Classical ethical theories can be categorized in two major divisions, the first being *teleological.* These theories measure the worth of an action by its results: The best action produces the greatest good for the most people. The emphasis is on determining what is good, rather than what is right (Ward, 1998). Consequently, it is possible to select a course of action which is harmful or unjust to an individual or group, as long as the benefits to others outweigh these negative effects. As long as the action produces more good than harm, it is ethically correct, according to teleological theory.

Evaluating an action based solely on its results creates difficulty, in that it is troublesome – often impossible – to ascertain all of the many consequences. The

complexities of an issue due to such considerations as the interrelationships between people and systems and uncertainties in the many variables make it problematic to predict accurately the consequences of an action. Thus, teleological theories are limited in their usefulness for guiding a person through an ethical dilemma.

Furthermore, adherents of these theories do not seek to evaluate the process used to reach a goal or outcome. The common philosophical question of "Do the ends justify the means?" is not an issue in teleological theories because the means are irrelevant. Since the results are the only measure of the value of an action, any methods, no matter how questionable, can be justified to achieve any desirable objective.

1.3.1.1 Act-Utilitarianism

Act-Utilitarianism, advocated by John Stuart Mill (1806-1873), is the most strict teleological theory. As explained by Edward Gehringer, professor at North Carolina State University, this theory states that the greatest good is achieved by the act that produces the greatest amount of happiness – the only intrinsically good thing – for the greatest number of people (1998). It stresses that in evaluating an action, a person must consider everyone affected, not just the person or people directly involved in the situation. For instance, the decision to use a particular energy resource requires a determination of the effects of its consumption on future generations, as well as those of the present-day society that will directly benefit from the use of the resource. Needless to say, accurately predicting these results can be extremely challenging.

A further difficulty with Act-Utilitarianism is its focus on the uniqueness of specific choices. Because each situation is different, actions that were ethical in situation "A"

might not be the proper choice for actions in situation "B," even though the scenarios could be nearly identical. If there is a small difference that has an effect on the amount of "goodness" produced, the proper course of action might be radically different. As Professor Martin of the Department of Philosophy at Chapman University explains:

> Everyday maxims like "Keep your promises," "Don't deceive," and "Don't bribe" are only rough guidelines. According to Mill, these maxims are useful rules of thumb that summarize past human experience about the types of actions that usually maximize utility. But, the rules should be broken whenever doing so will produce the most good in a specific situation. (Martin, 1996)

Thus, each situation must be analyzed, regardless of prior experience with similar situations.

1.3.1.2 Rule-Utilitarianism

Like Act-Utilitarianism, Rule-Utilitarianism seeks to obtain the greatest happiness for the most people, but it does this in an indirect manner. Rule-Utilitarianism requires that there first be an established set of rules, laws, or other behavioral standards. These might be commandments established by God, laws enacted by the people, or guidelines created by a professional society. Whatever the source, the objective of these standards is to prescribe behavior that will result in the greatest good for the people and proscribe behavior that does not promote happiness for the majority. Ethical behavior, then, is behavior which is in harmony with the established rules. The maxims that could only serve as general guidelines to the Act-Utilitarians are the basis for Rule-Utilitarianism. Thus, explains Professor Martin, according to the Rule-Utilitarians, "we ought to keep promises and avoid bribes, even when those acts do not have the best consequences in a

particular situation, because the general practices of promising and not bribing produce the most overall good (compared to other practices)" (1996).

Richard Brandt is one of the key contemporary promoters of Rule-Utilitarianism. In his theory, Brandt disagrees with Mill's opinion that happiness is the only intrinsically good thing, stating that certain "rational desires" are also good. These include such things as friendship, love, understanding and appreciation of beauty (Martin, 1996). Thus, an action is ethical if it increases any of these intrinsically good things better than other actions.

1.3.2 Deontological Theories

The other major category of ethical theories is *deontological* theory. Deontological theories are diametrically opposed to teleological theories in that they stress doing what is right, no matter what the consequences may be. Rather than measuring the value of an action by its consequences, deontological theories assert that an action is intrinsically right or wrong. The rightness of an action is usually felt more than it is measured or analyzed, as in teleological theory.

The following sections will explain the various standards used by each of the deontological theories to measure the "rightness" of an action. Though each has a unique motivation, each judges actions based upon their adherence to some critically important ideal. In each case, the principle around which the theory is based is seen as intrinsic and vital to humanity. Furthermore, because principles are intrinsic, it is usually a person's conscience that tells them when they have violated the ethical law. Thus, ethical behavior is seen as a fundamental ingredient of human existence.

1.3.2.1 Duty Theory

The first deontological theory to be discussed is Duty Theory, developed by Immanuel Kant (1724-1804). The characteristic argument of this theory is that ethical behavior is initiated by duty, or an undeniable sense of what ought to be done, as dictated by the conscience intrinsic to every individual. William Turner, contributor to *The Catholic Encyclopedia*, writes:

> [According to Kant,] the moral law is supreme. In point of certainty, it is superior to any deliverance of the purely speculative consciousness. I am more certain that 'I ought' than I am that 'I am glad', 'I am cold', etc. In point of insistence, it is superior to any consideration of interest, pleasure or happiness; I can forego what is for my interest, I can set other considerations above pleasure and happiness, but if my conscience tells me that "I ought" to do something, nothing can gainsay the voice of conscience, though, of course, I am free to obey or disobey. This, then, is the one unshakable foundation for all moral, spiritual, and higher intellectual truth. (1913)

Thus, the promptings of the conscience, though subtle, are more powerful than any physical or emotional stimulus. Turner explains further that the moral law is "universal and necessary." That is, a moral act will be moral no matter the time or the circumstances. While this statement is in agreement with the concept of a conscience given to all mankind by a God whose expectations of us are unchanging, Kant introduces an element of harshness and compulsion that we do not usually associate with a caring God. Turner writes:

> This quality of universality and necessity shows at once that the moral law has no foundation in pleasure, happiness, the perfection of self, or a so-called moral sense. It is its own foundation. Its voice reaches conscience immediately, commands unconditionally and need give no reason for its behest. It is not, so to speak, a constitutional monarch amenable to reason, judgment, or any other faculty. It exacts unconditional, and in a sense unreasoned obedience. Hence the "hollow voice" of the moral law is called by Kant "the categorical imperative." This celebrated phrase means merely that the moral law is a command

(imperative), not a form of advice or invitation to act or not to act; and it is an unconditional (categorical) command, not a command in the hypothetical mood. (1913)

Hence, the categorical imperative is unyielding and rigid. There are no exceptions. In a sense, there is no judgment – only an unbending directive of what is right – though one might argue that this is, in fact, judgment. This characteristic of Kant's theory is, on one hand, its strength; on the other, its weakness. Universal truths are unchanging, as the theory implies, but it is the purpose of man's existence to find them and voluntarily obey, not to have them irresistibly imposed upon us. While there is, in a sense, a categorical imperative, it is a fundamental part of the human experience to willingly submit to it, seek to understand it, and live so that we can be liberated by the Truth.

1.3.2.2 Justice Theory

Harvard philosopher John Rawls (1921-) has expanded upon Kant's philosophy to create another theory commonly referred to as the Justice Theory. To apply this theory, Rawls suggests:

> Imagine yourself in an original position behind a veil of ignorance. Behind this veil, you know nothing of yourself and your natural abilities, or your position in society. You know nothing of your sex, race, nationality, or individual tastes. Behind such a veil of ignorance all individuals are simply specified as rational, free, and morally equal beings.

> In this original position, behind the veil of ignorance, what will the rational choice be for fundamental principles of society? The only safe principles will be fair principles, for you do not know whether you would suffer or benefit from the structure of any biased institutions. Indeed the safest principles will provide for the highest minimum standards of justice in the projected society. (Kay, 1997)

Thus, Rawls sees fairness as the driving force behind ethical behavior. In making a judgement, we are to attempt to strip ourselves of all biases and make a decision that will provide for the most equitable results for everyone involved. In doing so, Rawls argues that all rational people will abide by two basic moral principles: "(1) each person is entitled to the most extensive amount of liberty compatible with an equal amount for others, and (2) differences in social power and economic benefits are justified only when they are likely to benefit everyone, including members of the most disadvantaged groups" (Martin, 1996).

Of course, the difficulty with applying this theory involves the fair amount of imagination needed to place one's self "in an original position behind a veil of ignorance." It is not simple to let go of one's biases, prejudices and attitudes to rationally determine the proper course of action that will ensure equitable results for everyone involved. However, if this difficulty can be overcome, this theory seems to have a considerable amount of power to produce ethical behavior.

1.3.2.3 Rights Theory

In the 1600's John Locke (1632-1704) first presented his Rights Theory. The theory quickly became popular, heavily influencing the American and French revolutions. In fact, the inalienable rights discussed in the Declaration of Independence – life, liberty, and the pursuit of happiness – are nearly identical to the rights that Locke considered essential – life, liberty, and the property generated by one's labor (Martin, 1996). According to P. Aarne Vesilind of Duke University, the theory has been the dominant

ethical ideology in the United States and most of Western civilization for 200 years. It has become so much a part of our culture that many people wrongly consider the study of ethics to be merely a discussion of human rights (1998).

Mike W. Martin of Chapman University explains that Locke's view of rights ethics was highly individualistic. That is, rights are entitlements that protect us from another's unwanted interference with our lives (1996). The most basic of these rights are given to us merely by virtue of our being human, but they require an organized society to uphold them. This implies a social contract between members of society to respect and honor an individual's rights. Creating such a contract forms an ethical society from what would be a chaotic collection of individuals each seeking his or her own personal welfare with no regard for others' rights (Vesilind, 1998). Thus, in seeking to secure our own rights – an individualistic concern – we simultaneously must promise to protect the same rights for others.

Unfortunately, the modern interpretation of rights ethics is probably not what Locke or any of the early subscribers to the theory intended. Locke maintained that natural rights are given to mankind by God (Vesilind, 1998). Coupled with this belief was a strong foundation in reverence for God and His creations and strong adherence to Judeo-Christian virtues. Today, society has departed from the connection to Diety and the associated moral standard, and rights ethics has been warped into a mindset that states, "I have the right to do anything I want." For rights ethics to be a useful guide, one must apply it in the manner in which it was originally intended, bounded by moral standards.

A. I. Melden (1910 – 1991) developed the theories of rights ethics along slightly different lines. In his version, he argues that "having moral rights presupposes the capacity to show concern for others and to be accountable within a moral community…. Melden's account allows for more 'positive' *welfare rights*, which he defined as rights to community benefits needed for living a minimally decent human life" (Martin, 1996). The support of this theory is evident in government welfare programs, the intent of which are to provide a minimum standard of living for those who cannot provide it for themselves. However, like Locke's version of this theory, it must be closely intertwined with virtue. If it is not, the systems of distributing welfare needs are certain to be corrupted.

1.3.2.4 Virtue Theory

All of the ethical theories discussed previously come from modern times; yet, the study of ethics as a philosophy has taken place for millennia. Looking back to ancient times, the writings of Aristotle (384 – 322 BCE) are the earliest secular treatises we have concerning ethical theory. Aristotle's Virtue Theory is a significant contribution to the study of ethics, and will receive considerable attention here.

At the center of Aristotle's theory is the concept of the "chief good." He explains this as "some end of the things we do, which we desire for its own sake." (Darwall, 1996). The chief good is not a means by which to achieve something else; it is an end unto itself. We desire the chief good simply because it is desirable. Stephen Darwall, professor of Philosophy at the University of Michigan, writes, "Aristotle remarks that there is broad agreement that the chief good is *eudaimonia*, which Ross translates

'happiness,' but is better understood as 'flourishing.'... Aristotle gives a general, positive

argument for the claim that the good life is a virtuous life" (1996).

The line of reasoning Aristotle uses to conclude that virtuous living allows one to

obtain the chief good is intriguing. He begins by noting that among all living things,

humans are unique, and, therefore, must have a unique function. This ability cannot be

merely living, since this is common to all living things. Our function is not perception,

since this is shared with the animals. Our one unique gift is the ability to reason, since

this is the one function of which mankind alone is capable. Aristotle then defines virtue

as "excellence in reason." Excellence in reason comes about when three components of

virtue are present: First, a person must exhibit virtue of thought, or be capable of

discerning right and wrong. Second, a person must exercise virtue of action and do what

is right. Finally, a person must then have virtue of feeling, or receive pleasure from

performing a virtuous action (Clancey, 1998). A person who characterizes these qualities

exhibits excellence in reason, according to Aristotle, and will, therefore, obtain the chief

good.

It is also of interest to note that Aristotle concludes that virtues are developed

through application. Interpreting Aristotle, Professor Darwall writes,

> Virtues are acquired by habituation. We are not born with them, nor do we
> acquire them by any natural process that does not involve our own activity, and,
> perhaps more important, the activity of parents and other elders. This is because
> "the virtues we get by first exercising them.... By doing the acts that we do in our
> transactions with other men we become just or unjust, and by doing the acts that
> we do in the presence of danger, and by being habituated to feel fear or
> confidence, we become brave or cowardly.... Thus, in one word, states of
> character arise out of like activities." Thus, we become virtuous only by doing
> virtuous acts. (1996)

This line of reasoning seems rational, though the process is opposite from what we usually consider to be right. Generally, we tend to think that a cruel person does cruel things, or a thoughtful person performs thoughtful actions. That is, the character trait precedes the action. Aristotle is claiming just the opposite – that a person who does cruel things will become a cruel person through habituation of cruel activity. With this in mind, it is easy to see why Aristotle places a high level of importance on upbringing. A child's mistakes left uncorrected can desensitize the conscience, leading to more malevolent actions. As a person continues to gain pleasure or satisfy base desires through ignoble means, his personality tends to become more corrupt. By correcting a child's errors, parents can help a child habituate virtuous actions, which will, in turn, produce an upright adult.

While Aristotle's theory explains learning to be virtuous as being somewhat akin to learning to play a musical instrument by practicing and habituating skills of musicianship, there is a notable difference. The value of playing an instrument is in the product – a beautifully played piece of music. The value of virtuous activity is in the action itself. Professor Darwall continues:

> A genuinely fair action, for example, must be one the agent himself conceives (knows) to be fair, and which he chooses to do for its own sake as fair, indeed is disposed to choose as a matter of firm character. Moreover, the genuinely virtuous person takes pleasure in her virtuous activity; she does not have to drag herself to undertake it, but actively enjoys it. Now all this means that in acquiring virtues, one does not simply acquire a certain knack or knowhow. One comes to know, desire, and enjoy virtuous activity for its own sake. (1996)

Thus, the fruits of virtuous living are intangible. They are the feelings of satisfaction we receive when we do something we know to be virtuous.

One other important point needs to be made regarding Aristotle's virtues: Virtue is the "mean" between two opposing vices. Any character trait, if carried to the extreme, becomes a vice. Virtue is the balance of character traits found between opposite extremes of vice. For example, Aristotle views courage as the mean of confidence and fear. A person may possess too much confidence, leading him to foolishly underestimate a threat to life or safety. Conversely, a person may possess too much fear, leading him to react to danger with cowardice. Courage is the virtue between the extremes of these two vices. The difficulty lies in finding the mean, rather than exhibiting the vices on either extreme. Aristotle says that this is possible by applying a "rational principle." However, this rational principle seems to presuppose that a person already possesses a foundation of moral virtue. This brings Aristotle back, once again, to the importance of upbringing. It seems that a virtuous lifestyle must be initiated by an outside source, usually a parent. Once the beginnings of virtue are inculcated into a person's mentality, the pattern of virtuous living is self-sustaining, assuming that the person recognizes rational principles and chooses to follow the virtuous path.

Alasdair MacIntyre, a contemporary ethicist, has renewed the interest in the application of virtue ethics in the realm of professional ethics. He states that the virtues that are important to the professional can be categorized in four groups. The first is *self-direction virtues*, such as self-understanding, humility, moral judgement, courage, self-discipline, perseverance and integrity. To these he adds the category of *public-spirited virtues*, such as beneficence, generosity, and compassion. The third category is *team-work virtues*, which include characteristics such as collegiality, loyalty, and leadership. The final category, entitled *proficiency virtues*, includes competence, diligence, creativity,

and self-renewal (Martin 1996). MacIntyre maintains that these virtues are the building blocks of professional ethics, and that a professional will seek to develop these if she seeks to be successful.

1.4   Ethics as an Application of Virtue

While the theories discussed each have their merits, there seems to be a renewed interest in the application of virtues as a basis for ethical conduct. It may be that a reestablishment of virtue ethics will be the only way to combat the general moral decline of modern society. Applying the Virtue Theory seems to be the only way to establish a system of ethics which is incorruptible, applicable to all situations, and acceptable to everyone. However, the theories proposed by Aristotle and MacIntyre are not in themselves perfect. To build upon them, it is necessary to place them within a framework of beliefs that is perfect. This context is the gospel of Jesus Christ.

By placing ethical philosophy within a foundation of religious principles, one can overcome many of the philosophical difficulties encountered. This is because the classical ethical philosophies are the product of imperfect, finite human thought, while the gospel of Jesus Christ is perfect and eternal. It is the only system of belief that is based on an infinite view of mankind, the interrelationships between people, and our purpose for existence. Moreover, we have in Christ the perfect exemplar of virtuous behavior. By following His example and applying His teachings, we can face any ethical challenge with confidence and moral courage.

PART 2. DEVELOPMENT OF A PROBLEM-SOLVING APPROACH FOR ETHICAL DILEMMAS.

2.1 Ethical Dilemmas

An engineer will undoubtedly face many decisions which have ethical ramifications during the course of his or her career. These decisions come daily as small opportunities to exercise engineering judgment or in determining how to interact with coworkers. Also, monumental decisions can arise that affect millions of lives and have career-altering significance. No matter what form or size in which the problems come, they are always significant because of the ethical component. How we respond to a given situation is important because our ethical response stems from the core of who we are and, conversely, molds who we are to become.

Given the importance of successfully resolving ethical dilemmas, it is prudent to work through problems in a systematic way that will increase our chances of successfully resolving them. In the following section, one possible methodology will be presented. The approach is an adaptation of a process designed by Professors Steven Benzley, Val Hawks and Ronald Terry at Brigham Young University. While the formal problem-solving process developed herein is designed for addressing difficult, complex ethical dilemmas, the principles that build the foundation are equally applicable to any ethical problem, no matter how small.

2.2   A Foundation in Virtue

A critical beginning to ethically resolving a dilemma is to form a set of virtues or core values by which to measure options and direct action. These values are the ideals which we consider the most essential for feeling satisfied with our lives. They are the most fundamental guides by which we may make self-evaluations of our thoughts, words, and actions.

For Latter-day Saints, the most significant resource for identifying important values is our religion. The gospel provides clear teachings of Christlike virtues, guidelines for developing them, and expectations for their application. These virtues include compassion, integrity, forgiveness, responsibility, courage, wisdom, and obedience, to name several. More importantly, we have the example of Jesus Christ to follow. Of course, not everyone adheres to the gospel of Christ or any other faith. This does not necessarily decrease the value of religion as a source for identifying significant values, even for the non-believer. Historically, the values advocated by the many religions of the world have had a tremendous impact on cultures everywhere. One will find that the most fundamental values are common to nearly all religions. These would form a good set with which to start for anybody.

In another method for identifying core values, Dr. Stephen R. Covey suggests in his book, *The 7 Habits of Highly Effective People*, that we imagine ourselves attending our own funeral. At the meeting, four people will speak: a family member, a friend, a coworker, and an associate from church or a community organization. Dr. Covey suggests that we imagine what we would like each of these people to say about us as they

reflect upon our associations with them. The character traits that each of these people speak of are likely those that we treasure most (1989).

Yet another way to begin identifying values that we might include in our list of core values is to ask the question, "If there could be a global code of ethics, what would it contain?" Rushworth M. Kidder asked this question of people around the world and reported the results in his book, *Shared Values for a Troubled World* (1994). In this work, Kidder identifies fundamental values that are common to people of all cultures, races, religions, and socioeconomic backgrounds, "a kind of global ethics neither invented nor imposed, but rather discovered and identified." Those values he names as common to all are: love, truthfulness, fairness, freedom, unity, tolerance, responsibility, and respect for life. These values or variations of them could serve as a good starting point in defining a set of core values. One should not simply accept this list without careful consideration, however. Perhaps there are other values which are of greater importance to an individual. Kidder himself states that these values are not *the* answer, but *an* answer to the question of what core values should be at the center of a global code of ethics.

One's profession, particularly the professional societies, are an additional resource for identifying important values. Many of these organizations provide guidelines for expected or ideal behavior on the part of members of that profession. Some, such as the American Society of Civil Engineers (ASCE) and the Institute of Electrical and Electronics Engineers (IEEE), go as far as to provide a detailed Code of Ethics for its members to follow. These documents detail specific behaviors which are expected and prohibited. While much of this information is presented as guidelines for practice, it is

possible to discern the underlying values which form the foundation for each of the guidelines.

After identifying a list of important values, it is necessary to distinguish those that are vital to an individual's life. One might ask, "Which of these values are intrinsic to my fundamental nature? Which capture the essence of who I want to be? Which have the power to influence every decision I make in home, professional, and personal matters? Which will allow me to develop characteristics by which I would want to be remembered?" It is these that form our core values.

Though it is acceptable to leave our core values in the form of a list, one may wish to refine these concepts further by developing a personal mission statement, as advocated by Dr. Covey. A person may find that this process makes it easier to cross the bridge from an abstract concept, such as "integrity," to everyday application. As Covey explains, "Principles are deep, fundamental truths, classic truths, generic common denominators. They are tightly interwoven threads running with exactness, consistency, beauty, and strength through the fabric of life" (1989). Transforming these abstract principles into a mission statement is not an easy task, as Covey points out:

> A mission statement is not something you write overnight. It takes deep introspection, careful analysis, thoughtful expression, and often many rewrites to produce it in final form. It may take you several weeks or even months before you feel really comfortable with it, before you feel it is a complete and concise expression of your innermost values and directions. (1989)

Struggling through this process can be valuable, however, since the required introspection helps us to determine more precisely how we feel about our values and how we wish to apply them, producing a document that provides directly applicable guidelines for everyday decision-making.

Regardless of whether a person creates a mission statement or simply identifies several essential virtues by which to live, the importance of starting with basic, fundamental virtues cannot be stressed enough. It is vital that a person be aware of guiding principles that are of personal importance before facing an ethical challenge. Without this principle-centered foundation, it is easy to be lured by the philosophies of relativism and situationalism, a course which will likely lead to unethical behavior.

2.3   A Process

Once we have identified a set of core values, it becomes necessary to determine how to best apply them when faced with an ethical dilemma. Such situations are similar to other types of problems faced by engineers, but with an ethical component. Thus, problem-solving techniques used to resolve technical or managerial problems can be applied in these types of situations, as long as the technique employed allows a person to direct the problem-solving process within a framework of important core virtues.

Many volumes have been written on problem-solving techniques. Consequently, a careful study of the available techniques that could be used to resolve an ethical dilemma will not be presented here. A prototypical method will be presented in this thesis, but this is only to provide one possible process for resolving a dilemma. A person faced with an ethical dilemma is encouraged to adapt the process developed herein to create a technique tailored to the specific problem and the individual's personal problem-solving style.

It should also be noted that the process described here is suited particularly to difficult, complex problems. Since the process is likely to be time-consuming, it may not

be practical to apply it to simpler situations.   In these common, less-complicated dilemmas, one may find it more reasonable to apply a simplified process in determining a suitable course of action to take in resolving the situation.

2.3.1   Define the Problem

Essential to determining an appropriate course of action is, first, formulating an accurate picture of the problem.   Also, it is necessary to have a clear image of the qualities that should exist in the situation after it has been resolved successfully.   Arthur VanGundy suggests that creating a detailed assessment of the gap between "what is and what should be" is a helpful means by which to define a problem (1988).   This involves making an appraisal of the present and the goal states.   In doing so, it is advantageous to be as detailed as possible, identifying as many aspects of the problem that are not in their desired state.   This will help to determine the expected effectiveness of the generated solution possibilities.

To illuminate the differences between the present and goal states, it is important to accurately determine the stakeholders – those who are affected by or who have an investment in the situation.   In most problems, there will be several obvious stakeholders, but there may also be many more whose relationships to the problem are obscure.   Like determining the consequences of an action, assessing the stakeholders in any given situation can be a difficult task.   This is particularly true in engineering situations, since many projects can be in use for a generation or more.   Predicting all those who will be impacted by a decision becomes a difficult, if not impossible, task.   However, an engineer

should make every attempt to adequately determine the stakeholders and their relationship to the problem.

Once the stakeholders have been identified, it is important to discern their expectations for the resolution. Oftentimes, it is possible to describe each stakeholder's primary interest with one or two key expectations. While it is impossible to accurately describe any individual or group as being interested only in obtaining a certain outcome, it may be fair to say that one or two expectations are controlling what a particular stakeholder would want to achieve in a specific situation. For instance, a driving motivation for a structural engineer may be safety, while that of an architect might be functionality, and that of the building owner, economy. These desired outcomes do not completely describe each stakeholder, yet they adequately describe the driving value that is governing what each person might hope to achieve in an effective resolution of a dilemma.

While gathering information about a problem, it is crucial to carefully judge the value of each piece of data uncovered, since the process will undoubtedly yield a quantity of invalid information along with that which is accurate. Separating fact from opinion is essential to understanding a problem. This is especially important when a dilemma is emotionally charged, with conflicting stakeholders feeling strongly about a given course of action. In such situations, emotions and opinions can heavily influence the interpretation of the facts. At times, a strong emotional bias can inhibit a person from recognizing relevant data or interpreting it correctly. Consequently, great care must be maintained to view information objectively.

Another helpful technique for addressing complex problems is to divide them into small, manageable units. Oftentimes, a problem seems so overwhelming that we do not know where to begin, and we leave the problem unresolved. We may try to justify or ignore the problem, hoping that it will go away or resolve itself. In many ethical dilemmas, however, failure to take action can be as unethical as choosing the wrong course of action.

To avoid this pitfall of being frightened into inactivity by a problem, one can divide the problem into subproblems that are easier to manage. In doing so, one might divide the problem according to the facets of the problem affecting each of the various stakeholders, by seriousness of the issues involved, by amount of time required to resolve the problem facet, or some other logical means. Dividing a problem in this manner can help to bring focus to an otherwise complex and confusing situation. It is also simpler to see interrelationships between the facets of the problem, possibly making it possible to form a logical sequence of tasks that will resolve the problem as a whole.

In addressing a difficult problem no one has ever stated that an engineer must face an ethical decision alone. It is always a good idea to talk to others to get their perspectives on a problem. A spouse, trusted friend, or coworker might be a good place to start. If none of these people can provide a needed engineering perspective, many professional societies have resources for obtaining advice regarding ethical dilemmas. Whether the opinion of another engineer is needed, or if it would be better to hear the advice of someone outside the profession, speaking with another person about a problem is always advisable. A trusted person who is not in the midst of the dilemma can often provide objective insight, seeing information or courses of action that we cannot see

ourselves. Even if the person is unable to provide counsel, speaking through a problem with another person can help to organize thoughts and possibly recognize options that were previously unnoticed.

Not every dilemma a person faces is completely new. Many times we have faced situations with many of the same conditions. If a person has not faced a similar dilemma, it is likely that an acquaintance has. Analyzing the similarities between the current dilemma and those of the past can provide valuable help in determining an appropriate resolution. Additionally, identifying the differences between the present and past situations can bring clarity to the current problem definition. Highlighting similarities and differences can help to clarify how a solution to the former problem might be adapted to fit the current situation.

To complete the problem definition, write a clear, concise problem statement. This should explain the conditions present that have created the dilemma, the expected consequences of doing nothing to resolve the situation, the stakeholders and their relationships to the issue, and any schemes for subdividing the problem. Having this statement will help to focus the search for a resolution.

2.3.2 Identify Needed Assumptions

For every problem there are assumptions that must be made to arrive at a solution. This need arises because not all information is readily obtainable, and especially not in the time frame or with the resources available. Therefore, it becomes necessary to make certain assumptions about various aspects of a problem. Missing information will likely be manifest in the problem statement, and might include such things as characteristics,

attitudes, or desires of some of the stakeholders and relationships between problem elements. Needed assumptions might also include technical data, economic factors, or legal aspects of the problem. In making these assumptions, it is desirable to err on the conservative side, as is often the case in other engineering problems. This will assure that the problem can be resolved in a satisfactory manner. If solutions are based on unconservative assumptions that are later discovered to be inaccurate, additional work will be required to completely solve the problem.

2.3.3   Identify Fundamental Principles

The next step in resolving an ethical conflict is to identify fundamental laws, principles and values that are relevant to the problem. The core values provide the ideal starting place for this step. However, it may be that every value that is important to us may not be directly applicable to a specific situation. We should select those values that are applicable and use them to drive our search for a resolution.

After determining the values that are of significance to the problem, it is helpful to identify laws and principles that employ these values. This is useful because laws and principles are more easily applied than are abstract values, since they serve to provide a more tangible link between thought and action. For instance, if a value that is of importance in a given situation is *honesty*, an engineer might look to her professional society's code of ethics for canons and guidelines that apply this value. Such a canon might be, "Engineers shall not permit the use of their name or associate in business ventures with any person or firm that they believe are engaged in fraudulent or dishonest enterprise" (National Society of Professional Engineers, 1996). Identifying this canon

helps a person apply the value of honesty because it clearly prescribes behavior that is in harmony with the abstract concept.

A professional society's code of ethics is just one of many sources of laws and principles to which a person can turn for guidance. There are other references, such as government-mandated laws, religious commandments, societal expectations and industry regulations. Any of these can be useful tools for understanding what manner of problem resolution might be acceptable.

2.3.4 Formulate Possible Solutions – The Divergence Phase

Once we are prepared with a clear understanding and an accurate definition of the problem we must set out to solve it. The procedure of finding a solution is comprised of two phases. The first phase is a divergent one, in which we generate several possible solutions. In this first process, no effort is made to evaluate the solution possibilities. We simply identify possible courses of action with no thought for whether they will be effective, efficient, or ethical.

The goal in this phase of the solution process is quantity, not quality. Arthur VanGundy explains that it is important to "really push yourself to seek quantity." Quality is not important during the divergent phase, but takes on importance later, during the convergent phase. "Whenever you are diverging, purge your mind of whatever idea pops up and write it down. Then, after you have listed all possible ideas, you can evaluate them to look for quality" (1987). The extent to which it will be possible to diverge depends, largely, upon the nature of the problem. For some problems, there may be fifty or more possible solutions, while for others, there might be fewer than five. The object is

simply to discover all of the possibilities, so the optimal solution can be chosen during convergence.

2.3.4.1 Brainstorming

One of the most common divergent processes for generating possible solutions is brainstorming. Alex F. Osborne, the man credited for the creation of this technique, began using it in his advertising agency in 1939 and wrote about it in his 1953 book entitled *Applied Imagination* (Olsen, 1982). Many volumes have since been written about this process which provide a more thorough explanation than will be presented in this thesis. Only some basic guidelines will be provided here.

Brainstorming is especially suited to complex problems in which a creative solution, rather than a rational approach, is required for proper resolution. To foster creativity, the process takes the "shotgun" approach to problem solving. That is, many possible solutions are generated that are all aimed in the general direction of the problem with hope that one of them will hit the mark. This is accomplished by quickly recording as many solutions as can be conceived in a specified amount of time.

A key element of the brainstorming process is deferred evaluation. During the process, no analysis is made of a solution's potential for solving the problem. As possible solutions are generated, it is understood that most of them will not be selected for even casual study, and that of the several possibilities that are studied carefully, only the one will be chosen for implementation that will most effectively solve the problem. Returning to the shotgun analogy, a hunter, having fired a round at a target does not (in fact, cannot) selectively recall several of the shots as they speed toward their target

because he can see that they are going to miss. Rather, it is understood that much of the shot will completely miss the target, that a portion may graze the target, but only one ball will deal the fatal blow. Such it is with brainstorming.

The principle of deferred evaluation applies to positive as well as negative evaluation, as Arthur VanGundy explains:

> It sometimes can be just as harmful to make an untimely positive evaluation as a negative one. For example, you might train yourself to stop commenting on how terrible someone's idea is as soon as you see it. However, if you also loudly exclaim how wonderful an idea is upon first hearing it, you would be just as guilty of violating this principle (1987).

Premature judgment is detrimental because it short-circuits the brainstorming process, limiting the creativity of the solutions generated. A solution which initially seems unreasonable may later be refined into the perfect fix. Conversely, if the first solution that looks adequate is accepted, it may lend poor results when it is discovered not to be the optimal solution.

Failure to defer judgment limits creativity in several other ways. An important part of the brainstorming process – particularly when it is performed in groups – is "hitch-hiking" or "piggy-backing." This happens when one idea, whether it is good or bad, leads to another. If a solution is immediately discredited, it will also eliminate all of the permutations of that idea which might have been generated. On the other hand, if an idea is praised, it may heavily influence the direction of the process, so those involved only create variations of that one particular solution. Limiting the brainstorming process in this manner undesirably diminishes the solution possibilities both qualitatively and quantitatively.

2.3.4.2 Looking at the Extremes

Marvin Levine describes another useful technique for studying a problem as "looking at the extremes" (1988). This process involves "manipulation of the problem space," or redefining the problem variables, to see if setting them to extreme values provides any insight into obtaining the solution. In his book, Levine demonstrates several mathematical and geometric problems that are solved in this manner.

The process of looking at the extremes can also be applied to problems in ethics. First, minimize the problem – make it far less serious than it really is. In this scenario, the consequences are minimal, the complexities of interpersonal relationships are greatly simplified, and the problem of insufficient resources is eliminated. Now, determine if the problem in this simplified state has an obvious solution. Next, perform the opposite problem transformation – make the situation far more serious. The decision now carries with it enormous consequences that will affect many people's lives, including having serious career-related ramifications. Is there a clear solution to the problem in this scenario? Looking at the extreme cases of the problem can provide valuable insights into an appropriate solution.

After visualizing the extreme scenarios, consider the situation in which both extremes suggest a single course of action. In this case, it is likely that the solution is appropriate for the actual problem, and one should study the implementation of this solution. Are there complexities that would make the extreme solution inadequate in the actual situation? If not, a satisfactory solution may have been found.

Next, consider the situation in which each extreme case suggests different courses of action. Though this situation is not as clear cut as the previous case, there are still

valuable insights to gain. An appropriate question one might ask is, "Is my decision-making process being too heavily influenced by the consequences of the situation?" In other words, am I reacting differently when the situation is dire than I would when the ramifications of my decision are not so tremendous? If this is the case, it would serve well to take a close look at what is motivating the action: Is it being driven by core values or outside influences? If our decision-making in ethical dilemmas is being steered by external powers, we are being led into a potentially dangerous situation in which we are being reactive, rather than proactive. When we allow ourselves to be influenced in this manner, we tend to practice situational ethics, which are inconsistent, since they are not guided by a set of core values. Thus, obtaining this result from evaluating the extremes may not provide the answer, but it provides a valuable check to determine if we are being properly motivated in our decision process.

2.3.4.3   Incubation

Often, it is not clear how to proceed in resolving a problem. No matter how much effort we put into finding the solution, an appropriate resolution continues to evade us. In times such as this, the search for solutions can be benefited by incubation. Marvin Levine describes this process:

> A problem resists solution because we have the wrong approach.... The recommendation is that we put the problem aside and become involved in other activities. This frequently has one of two results. The first is that the solution will later occur to us when we least expect it. It is as though the mind has been unconsciously working on the problem while we have been going about our daily routine. The second effect of taking a break is not only that the problem-solving process "incubates," but that our mind has changed when we return to the problem. We are less dominated, controlled, by the incorrect set we had several

hours earlier. We are now more likely to think of new approaches. (Levine, 1988)

In complex problems that require days or weeks to resolve, there will naturally be a considerable amount of time for incubation. The trick is to allow one's self to benefit from this time. This requires an open mind that is not controlled by habits or preconceived notions of how to handle the situation. We must continually look at a problem from different perspectives, trying to understand its many intricacies. If we are willing to evaluate and make adjustments to our mindset, we can benefit from the subconscious thought process that takes place during incubation.

2.3.5   Evaluate Proposed Alternatives – The Convergence Phase

Once we have diverged to generate as many solutions as is possible, we must begin the convergence process to discover which solution is optimal. Now, quality becomes the driving force, rather than quantity. It is in this process that we evaluate the solutions for such properties as effectiveness, efficiency, longevity, cost, quality, and adherence to our code of ethics.

This section will present several methods for comparing solutions, though there are certainly other processes by which a person might make helpful comparisons. Depending on the size and complexity of the problem and the number of solution possibilities generated during the divergent stage, it may be appropriate to select one of the convergence processes here or use several or all of them.

If many solutions have been generated, it may be helpful to narrow down the choices by making a preliminary evaluation, allowing one to focus on only the best

possibilities during the final comparison. It may be possible to eliminate the solutions that have obvious deficiencies, leaving only the ones that merit more thorough consideration. Arthur VanGundy warns, however, that during the process we should avoid the "killer instinct" that leads to hasty elimination of solution alternatives. An elimination approach that tends to look more positively at the options allows the problem solver to explore the possibilities – at least, on a superficial level – of even the worst ideas. It is often possible to turn a terrible idea into a very good one by altering it or combining it with another solution (1987). Once the solution choices have been narrowed down to the several that exhibit the most promise, the following evaluation schemes can be used to thoroughly compare the courses of action.

2.3.5.1 Congruity with Core Values

The most important evaluation to make of a solution is through the filter of our core values. If there is a solution that is not in harmony with our core values or the principles espoused in our mission statement, it is not an acceptable solution. This is the most effective means by which to separate out those solutions which might outwardly look promising, but upon deeper inspection, are not viable. Though this is the most important test and the most effective, it is by no means the simplest. Measuring an action against fundamental principles such as honesty, courage, responsibility, and love requires careful thought and deep introspection.

Dr. Stephen Covey in his book entitled *The Divine Center* writes of an experience in which the solution to a difficult situation came as the parties involved took a moment to sincerely listen to what their consciences were telling them, rather than clinging to

incorrect, unprincipled viewpoints. Covey explains that we often choose improper courses of action because our minds have been educated with ideologies based in incorrect principles. By ignoring this education momentarily, we can see the correct course to take in a given situation. The challenge, then, is to turn from our previous behavior in the present situation, then work to retrain our minds to consistently listen to the conscience and act appropriately (1982).

Covey's situation illustrates an important point: in measuring a choice against our core values, the answers are often more emotional and spiritual than they are logical and rational. This makes the evaluation particularly challenging because we must train ourselves to pay attention to signals that are far more subtle than those coming from external forces. However, the key to ethical problem resolution and consistent ethical conduct lies in acting upon the internal evaluations made as we measure our choices against correct values.

2.3.5.2   The "Front Page Test"

The "Front Page Test" is somewhat easier to implement than purely studying a problem in the context of our core values. In the end, a similar evaluation is made, but in this test, the application of core values is made in a more indirect manner. The test is performed by asking, "How would I feel if a report of this action appeared on the front page of the local newspaper tomorrow?" (Whetten, 1995). This question is a simple way to begin a thorough, introspective study of a possible problem resolution.

Asking one's self this question can be helpful because it creates an imagined external impetus for thought. Initially, we might study such questions as "Would I be

embarrassed? Would it be harmful to my family or business?" After these first questions that deal with the superficial evaluations made by others, our thoughts turn to the more important questions of "Would I be portrayed as being honest? Would I be happy with the person described in the article? Should I have acted differently?" Ultimately, these questions address our application of core values to the situation, but by applying the test, we attempt to look at ourselves from an outside perspective.

2.3.5.3   Application of Classical Ethical Theories

In the approach for resolving ethical issues developed by the Markkula Center for Applied Ethics at Santa Clara University, proposed alternatives are evaluated using classical ethical theories. This is accomplished by asking the questions: "Which alternative best protects the moral rights of individuals? Which alternative would be most just? Which alternative would lead to the best overall consequences? Which alternative best promotes the common good? Which alternative would help one develop and maintain a virtuous state of character?" (Markkula, 1998). As previously discussed, providing answers to these questions is not a simple task, as it is difficult to accurately determine the consequences of an action or the extent to which it protects others' rights. Still, it is helpful to look at a problem from these perspectives to gain better insight as to which solution is the most suitable. At the very least, evaluating a solution on these terms will point out a solution that obviously fails to meet the standards of one of the classical ethical theories. If a solution has blatant deficiencies in one of these areas, it is not likely to be a viable solution.

2.3.5.4   Comparison of the Resultant State With the Goal State

In our evaluation of possible solutions to a problem, let us not forget that a solution must not only be ethical, it must work. A solution that does not work is not a solution at all, even though it may handle the situation in an ethical manner. A good way to measure the effectiveness of a solution is to compare the expected results with the goal state that was defined during the problem definition stage. This is why it is important to clearly, thoroughly and accurately establish the differences between the present state and the goal state. The better one defines these differences, the more precisely the effectiveness of a solution can be evaluated.

Our evaluation of the differences between the present and goal states will include the obvious factors that are creating the disparity in the first place, be it a safety concern, a breach of confidentiality, the use of a proprietary product, or the like. Ideally, the comparison will go much further than this, however. It is important to consider such factors as how the solution affects interpersonal relationships with others involved in the situation, its precedent for future decisions, its possible side effects, and other more obscure facets of the problem. These factors may be difficult to analyze, but they should be included for a complete evaluation of the solution's effectiveness.

2.3.5.5   Decision Grid

With the several means by which to evaluate the proposed solutions, a problem-solver needs a way to organize the information and make comparisons. He can accomplish this by using a decision grid, a tool that engineers and others have widely used for many years. This simple tool is set up as shown in Figure 1.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Total
Solution 1						
Solution 2						
Solution 3						
Solution 4						
Solution 5						

Figure 1. Layout of a decision grid.

The first step in using the decision grid is to select appropriate criteria with which to evaluate the proposed solutions. The selection of evaluation methods chosen will impact what criteria are used. For example, if a person desires to compare the solutions solely by how they apply particular virtues, each of the criteria would be a different virtue. Similarly, if a person wants to apply several of the classical ethical theories, each criteria could be a different theory. Or if it is desirable to apply one classical theory – say, the Justice Theory – each criteria might represent a stakeholder in the problem, with columns of grid cells comparing how well the solution resolves the problem for that individual or group in a just manner. Of course, any combination of these or other criteria – for example, cost, longevity, or efficiency – could be used to create a useful comparison between alternatives. The point is to select criteria that compare the solutions in a meaningful manner.

Once the criteria have been selected, performing the comparisons proceeds by ranking each solution according to how well they meet the criteria and assigning points to each solution, the best solution receiving the greatest number of points. Thus, if five potential solutions are being considered, for each criterion they will be ranked one

through five, with five being the best. The process continues until a comparison has been made according to each of the criteria.

2.3.6 Select the Best Alternative

If the decision grid is used, selection of the best alternative is direct – one must simply pick the solution that received the highest total of points. Engineers, in particular, are drawn to this method of choosing a solution, because it seems to be rather objective. It should be noted, however, that selection of the criteria and evaluation of the solutions is an extremely subjective process. One must be careful to compare the alternatives without bias, since it is easy to "make the data fit" the solution we prefer. If the decision grid is not used in making comparisons of the alternatives, another suitable method for choosing the best alternative should be chosen.

2.3.7 Seek a Confirmation

Many people would conclude that after the decision is made as to which alternative to select, all that remains to do is to implement the solution. There is, however, an intermediate step that is vital to the process: to seek a confirmation from God as to whether the solution chosen is truly the correct one. In the Book of James, we read, "If any of you lack wisdom, let him ask of God, that giveth to all men liberally and upbraideth not; and it shall be given him" (KJV 1:5). God wants us to communicate with Him about our challenges. Furthermore, He is willing to provide assistance when our knowledge and experience are lacking if we will do all that we can and ask for His help to compensate for our inadequacies.

There is an experience recorded in the Doctrine and Covenants from which we can learn about this process. After some time of serving as a scribe to Joseph Smith during the translation of the Book of Mormon, Oliver Cowdery desired to perform some of the translation himself. God granted permission, and Oliver tried, but failed in his attempt. Subsequently, Oliver and Joseph asked the Lord why Oliver had failed. The Lord responded:

> Behold, you have not understood; you have supposed that I would give it unto you, when you took no thought save it was to ask me.

> But, behold, I say unto you, that you must study it out in your mind; then you must ask me if it be right, and if it is right I will cause that your bosom shall burn within you; therefore, you shall feel that it is right.

> But if it be not right you shall have no such feelings, but you shall have a stupor of thought. (D&C 9:7-9)

From this, we learn two important principles: First, we must do all we can to determine the solution to the problem using our own reasoning ability, conscience, and talents. The Lord gave us these for a purpose, and we can only learn and grow by exercising them. Throughout the problem-solving process we should petition the Lord for guidance, but we cannot neglect the requirement to make a sufficient personal effort. Second, if we do our part, the Lord will bless us with a confirmation of our decision, either in the positive or the negative. He has committed to this, but only after we fulfill our part of the commitment.

It is important to note that those who are not religious can apply a similar process for obtaining a confirmation with equal success. After performing the labor necessary to determine a solution, if a person will take time to meditate on the decision, a similar confirmation to that described previously can be obtained. This is possible if a person

will ponder over the decision, thinking about how it fits with his or her core values and listening to the subtle voice of the conscience. If a person is sincerely trying to resolve a problem in an ethical manner, and the solution chosen is a good one, there will be a clear confirmation that the solution is right.

2.3.8   Implement the Solution and Adjust for Unseen Complications

Once we have received a confirmation – either from divine sources or through sincere introspection – we have the responsibility to do what we now know to be right. This step can sometimes be extremely challenging, as it can require a great deal of courage. Resolving a problem mentally is far different from actually implementing the solution. After an engineer has worked hard to determine a proper course of action, his conscience gives him little choice but to act on it.

Implementing the solution requires careful monitoring to ensure that the solution will be successful. If we have performed the problem-solving process well – particularly, if we received a confirmation of the appropriateness of our decision – the likelihood of success is great. However, we must realize that unforeseen complications often arise, and we must always be prepared to reevaluate and adjust the solution process when the situation warrants.

2.3.9   Learn from the Experience

As we properly resolve a difficult dilemma, we should look back to analyze what we have done with the intent of learning from the experience. Those who subscribe strictly to teleological philosophies would argue that a person cannot apply the solution to

one problem to another, since the parties involved and the resulting consequences are different. Furthermore, those who follow deontological theories might argue that evaluation of the consequences is unnecessary, so long as we have done what is right. While these arguments may be true in the most strict sense, there are many opportunities to learn from an experience resolving an ethical dilemma.

Often, similarities between problems will allow us to modify the solution from a previous problem to fit a later dilemma. Even better, we may learn to discern the events and situations that led us into the dilemma in the first place. If we can learn to recognize and avoid such situations, it may be possible to elude having to resolve similar problems in the future.

One of the greatest things to be gained from a successful resolution to an ethical dilemma is a sense of satisfaction for having completed it in the proper manner. This knowledge is empowering, as it will strengthen us in times of future difficulty. As we successfully resolve ethical dilemmas, our confidence grows in our ability to face them, and we will begin to feel comfortable in resolving larger, more complex problems in the future.

2.4 Worksheets

Contained in the Appendix are worksheets designed to guide a person through the problem-solving process. These may be reproduced and used as an aid in resolving a dilemma. They are intended to provide general guidance, so space is provided for completion of all the problem-solving techniques described in this thesis. Since all of

these steps may not be necessary or desirable in a given situation, the engineer should feel

comfortable enough with the process to adjust it to fit the problem as deemed appropriate.

PART 3. CASE STUDIES

It is common practice to use case studies in the classroom and professional practice to provide examples of ethical and unethical behavior in given engineering situations. This method of teaching has its merits, as well as its drawbacks. The greatest merit is that there is a tremendous amount to be learned from other people's successes, as well as their mistakes. On the other hand, the greatest drawback is that most ethics cases are far more complicated than could ever be presented in any written case study of a reasonable length. Another significant drawback is that the emphasis of most case studies is on the problem and what a person did about it, rather than how the person came to decide upon a particular course of action. Consequently, case studies are valuable tools for teaching applications of ethical principles, but they do little to teach techniques of problem solving in such situations.

Using cases to teach ethical problem-solving principles, then, requires effort on the part of the reader to assess how problem-solving techniques could have been used in the particular situation described in the case. If one will place himself or herself in the position of the protagonist in the case study, it may be possible to determine how an organized problem-solving process may have led to the action chosen – or how it would have yielded different results.

This brings us to another shortcoming of problem cases: there seems to be a plethora of cases readily available in which the protagonist made the wrong choices, yielding unfortunate results. It seems to be a "Don't make this person's stupid mistake" approach to ethics education. The problem with this approach is that it is easy, once we know the outcome, to see the mistakes that were made and say vehemently, "I would

never be so dumb as to do that." Unfortunately, real life ethical dilemmas do not afford us the opportunity to know the outcome of an action before we choose it. It is, therefore, much easier to be swept by workplace pressures into unwise choices.

To answer this problem of ethical case studies, the ones printed here are all situations in which the protagonist made the right choices. Much can be learned from the successes of others. Perhaps even more important is the strength that a person can gain from simply knowing that others have faced other difficult dilemmas and responded with moral courage, technical proficiency and creativity. When ethical challenges face us, having the example of a moral leader to emulate can empower us to act with similar virtue. In studying these cases, then, the effort on the part of the reader should be to look at the response of the protagonists and the underlying principles of ethics and virtue that they exhibit.

Furthermore, to illustrate how the problem-solving process could have been used to resolve the dilemmas presented in the cases, there will be a brief commentary following each case. Rather than completing the entire procedure for each case, the commentaries will provide examples of how two or three steps of the process might have been used in the given situation. Following the case entitled "Citicorp Tower," the commentary will discuss the steps of "Defining the problem" and "Identifying Needed Assumptions." The discussion after the "Navy Sonar System" case will examine the application of the "Identify fundamental principles" and "Brainstorm possible solutions" steps. Following the "Coal Slot Storage Facility" case, the commentary will focus on the steps of "Looking at the extremes," "Incubation," and "Congruity with core values." The "Front page test" and the use of classical ethical theories will be illustrated following the

"Coal Combustion Research" case. Finally, the commentary following "Malden Mills" will discuss "Comparison of the result state with the goal state" and using the Decision Grid. Thus, the application of each step of the problem-solving process will be illustrated. To gain greater proficiency with the steps of the problem-solving process, it may be desirable to determine how steps other than those discussed in the commentaries following each case might have been used in the particular situation.

3.1   Citicorp Tower

In the summer of 1978 repairs took place on the 59-story, 914-foot-tall Citicorp

Center in New York City. At the time, all that the press reported of the work was that its

purpose was to give the building the ability to withstand a 1000-year storm, or a storm of

such intensity that it occurs only once every 1000 years (ENR, 17 Aug 1978). In a 1995

New Yorker article, however, the project's structural engineer, William J. LeMessurier

(pronounced "Le-Measure"), revealed his account of what actually happened. The story

that he unfolded has come to be one of the most respected examples of ethical behavior in

the engineering community.

Figure 2. William J. LeMessurier (From Plosky, 1996).

The Citicorp Center, completed in 1977 at a cost of $175 million, employs an

innovative design, with its first floor sitting atop massive "stilts" nine stories tall. Even

more unique, architect Hugh Stubbins placed these columns at the center of each face of

the structure, rather than at the corners, as shown in Figure 3.

Figure 3. The Citicorp Tower (From Guise, 1985).

This unusual concept was created to accommodate Saint Peter's Lutheran Church, which would not sell its property, but granted Citicorp air rights above its corner lot in return for a major rebuild of the church. Church officials required that the new church be a free-standing structure, so the Citicorp tower could not have corner columns, which would come down through the church's space.

William LeMessurier made this architectural concept a structural reality. On a napkin in a Greek restaurant in Cambridge, Massachusetts, LeMessurier conceived a braced frame which gave the structure unusual stiffness to resist wind forces, while weighing 18 percent less than a conventional frame. His concept divides the structure into 8-story modules, each with giant diagonal members which channel loads into the central columns. These enormous columns then transmit all the forces to the ground.
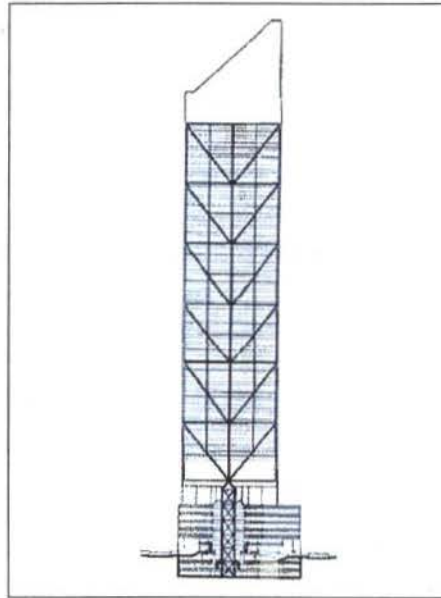
Figure 4. Framing of Citicorp Tower (From Stubbins, 1976).

To further reduce wind-induced sway and compensate for the light structure, LeMessurier placed a tuned mass damper (TMD) on the 59th floor. This 400-ton block of concrete, shown in Figure 5, sits on a film of oil and is forced to move opposite to the building's direction of motion to counteract the sway. This was the first time that a building was designed to be mechanically assisted in this manner, representing an engineering marvel in itself.

Figure 5. The Tuned-Mass Damper. (From Plosky, 1996).

At the time of its completion, the Citicorp tower was the 11th tallest building in the world (Gerometta, 1998). In New York, it was overshadowed only by four other structures. Citicorp now owned a place in the New York skyline held only by the most elite corporations. Furthermore, architects were praising Hugh Stubbins for creating a graceful solution to a difficult architectural problem, and LeMessurier was elected to the National Academy of Engineering, the highest honor the engineering community can bestow.

A short time later, however, LeMessurier discovered that the building could collapse in a relatively small storm, and that it was in need of urgent and costly repairs. This came to LeMessurier's attention soon after the structure was completed, when he was considering his brace design for a project in Pittsburgh. In this proposal, others were criticizing the welds on the huge diagonal braces, which had to be welded at the site. This prompted LeMessurier to contact his design office to solicit testimony regarding the success and economy of the welds. In doing so, however, he discovered that the connections on the Citicorp Tower had been redesigned as bolted connections at the request of Bethlehem Steel, the steel fabricator, who had offered Citicorp a $250,000 rebate to make the switch, since it would allow them to build the structure more quickly and at lower cost.

Alone, the discovery of the change was not cause for alarm. Bolted connections are often substituted for welded connections when the high strengths of welded connections – often much higher than that required for the design – are not necessary. The critical blow came several weeks later, when an architecture student called to get information on the building for a class. The conversation prompted LeMessurier to

perform some further calculations to settle his curiosity about the strength of the structure in quartering winds, those coming at the building from 45 degrees. He had not previously calculated this because the critical load condition occurred with the wind blowing perpendicular to the face of the building. LeMessurier now found a surprise – quartering winds increased the strain in half of the braces in each tier by 40 percent. With welded connections, this would have posed no problem. However, LeMessurier became concerned that this had not been taken into account in the design of the bolted joints.

On July 24th, LeMessurier confirmed that the forces induced by quartering winds had not been considered in the design of the connections. Further, in the configuration of the connection, a 40 percent increase in member tension resulted in a 160 percent increase in the force that each bolt must resist. To make matters worse, he found a conceptual error in the design. When LeMessurier had designed the diagonal braces, he had considered them columns. When LeMessurier's office redesigned the connections, they defined the diagonals as truss members. Though merely a matter of semantics, this redefinition eliminated a building code requirement for a safety factor applicable to columns, and further reduced the number of bolts required in the connection.

Realizing the seriousness of the situation, LeMessurier decided to speak with Alan Davenport, the director of the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario, who had performed wind tunnel testing on a model of the Citicorp tower during its design stage. Retrieving and reanalyzing the data from the tests only made the situation worse. The calculated 40 percent increase of stress in the

diagonals was theoretically correct, but in the real world this figure could approach 60 percent, given resonance effects.

Having obtained all this information, LeMessurier set out to determine the calculated risk of failure. Analyzing each connection, he discovered the weakest point to be at the building's thirtieth floor. Failure of a connection there would bring catastrophic failure to the entire structure. Applying data from New York City weather records to the analysis of the structure, LeMessurier calculated that a storm with a statistical probability of occurrence once every 16 years would bring the building down. "This was very low, awesomely low," LeMessurier said to the author of the *New Yorker* article (Morgenstern, 1995). Looking at this statistic from another perspective, it means that in any given year there is a 1 in 16 chance of a storm severe enough to bring the building down. Clearly, these odds are unacceptable.

LeMessurier could take some solace from one design detail – the tuned mass damper. With the TMD operational, the storm bringing disaster was effectively increased to a 55-year storm. But if power became unavailable – a likely event in a major storm – the TMD would cease to work, and the building would fail.

It was at this moment that LeMessurier realized what he must do. He understood that he must take responsibility for the situation, inform Citicorp, and set repair crews to work resolving the problem. LeMessurier told the *New Yorker* , "I almost said, 'Thank you, dear Lord, for making this problem so sharply defined that there's no choice to make'" (Morgenstern, 1995).

With the height of hurricane season approaching, LeMessurier had to act quickly to bring the structure up to safe standards. On the morning of July 31st, he began the

process of informing everyone involved in the crisis. He first faced a battery of lawyers from his professional liability insurance provider. After convincing them of the danger, another structural engineer, Leslie Robertson, was brought in to assess the problem. With these people aware of the situation, all that was left was to inform Citicorp.

August 2nd, LeMessurier and architect Hugh Stubbins met with Citicorp executives, chairman Walter Wriston and executive vice-president John Reed, to inform them of the danger. To LeMessurier's relief, Citicorp was amazingly composed at the news. Wriston offered his full support in getting the building fixed, giving authorization to begin repairs immediately, and began drafting a press release. He assigned two vice-presidents who had overseen construction of the Center, Henry DeFord III and Robert Dexter, to supervise repairs and assured LeMessurier that he could reach Citicorp top management at any time of the day or night when management decisions needed to be made.

The next morning, August 3rd, LeMessurier and several engineers from his design office met with DeFord, Dexter and Leslie Robertson to outline a plan for making the repairs. The strategy was to reinforce the connections by welding two-inch-thick steel plates over each of the connections -- more than 200 total. After exposing a connection and determining that the design would indeed work, Karl Koch Erecting, the New Jersey-based firm responsible for constructing the World Trade Center, was contracted to perform the repairs.

Other groups were also brought into action. MTS Systems Corporation, manufacturers of the tuned mass damper, were contracted to have a technician available to keep the device operating perfectly. A California firm was brought in to instrument

the entire structure with strain gauges so the building's every movement could be monitored from Robertson's office, 8 blocks away. A special team of meteorologists was assembled to provide regular weather forecasts and warning of sudden weather events that could threaten the structure. Robertson also worked with the Red Cross to form an evacuation scheme for the building and its surrounding area, so the proximity could be cleared of people in a threatening storm. This meant preparing to mobilize between 1200 and 2000 workers in an emergency.

Finally, they contacted the city's Department of Buildings to inform them of the problem and obtain the necessary permits. The department was very cooperative, even complimenting LeMessurier on his honesty and courage in handling the situation. They offered to test and certify more welders to alleviate the city's shortage of certified structural welders and asked to be kept informed of the progress of the repairs.

With the large number of people involved, Citicorp had to prepare for intense media coverage and possible hysteria from frightened employees who lacked the technical background to understand the nature of the problem. To minimize the alarm, Citicorp released a notice to the press that was purposely bland. For example, *Engineering News Record* reported of the incident:

> LeMessurier maintains that the... tower has well over the structural support it requires to withstand anticipated wind loads and that the purpose of the extra bracing is simply to supplement it. By adding a small amount of additional steel, the wind-load capacity of the tower's primary structural members will be increased exponentially. It will "mobilize strength that's already inherent in the building," he says, in a step that he calls a state-of-the-art refinement of wind bracing technology.

> LeMessurier declines, however, to specify whether he feels the bracing is necessary or optional. "I advised the bank and they listened to me," he says. "As the bank put it, 'we'd like to have belt and suspenders.'" (1978)

Though this report was not entirely truthful, LeMessurier justifies the falsehood and understatement. After all, he says, the researchers at the University of Western Ontario had said that the new wind records for New York City indicated that there would be a slight increase in building stresses. When he originally learned of this, LeMessurier felt the detail only compounded the problem, but now it provided a convenient way to justify the repairs to the public. He explained in a lecture given at the Massachusetts Institute of Technology, "White lies at this point are entirely moral. ... You don't want to terrorize people in the community that don't need to be terrorized" (1995).

Wednesday, August 9th, LeMessurier's wife told him that a reporter from the *New York Times* had been trying to reach him all day. LeMessurier, afraid that the reporter would seek to sensationalize the story and cause a panic, spoke with Hugh Stubbins' attorney before returning the phone call. They agreed that there was really no choice but to speak with the reporter, but to be as careful as possible. To everyone's relief, when LeMessurier called the *Times*, he was greeted by a recording stating that the *Times*, along with the other major newspapers in the city, had just been shut down by a strike. This lasted throughout the repairs, so Citicorp never had to face the media beyond the initial, uninformative press release.

As soon as LeMessurier's office could produce the design drawings, welders went to work, advancing through the building joint by joint at LeMessurier's direction. To avoid causing the tenants alarm, drywall crews and carpenters worked from 5:00 to 8:00 PM, tearing away the wallboard to expose the connections and building small plywood enclosures in which welders could work. Welders then worked to repair joints from 8:00 PM to 4:00 AM, after which cleanup crews worked to have the offices orderly by the

time the first secretaries arrived. As repairs proceeded, the engineer frantically performed calculations to determine the order in which to repair the joints, seeking to direct welders to each subsequent connection that would most dramatically increase the safety of the building.

Friday morning, September 1st, panic struck when weather reports indicated that Hurricane Ella was off of Cape Hatteras, heading toward New York. With the progress of the repairs to that point, and if the tuned mass damper remained operational, LeMessurier reported that the structure could withstand a two hundred-year storm. Even with this assurance, everyone was extremely concerned. Nobody wanted to suggest evacuation, so they waited on pins and needles to watch the storm. A few hours later, to everyone's relief, Hurricane Ella turned and headed out to sea.

September 13th, LeMessurier and Robertson deemed the building safe enough to call off the constant weather watch and inform the Red Cross that the evacuation plans would no longer be needed. In October, welding was complete. The structure could now withstand a seven hundred-year storm without the TMD and a one thousand-year storm with it functioning, making it one of the safest structures ever built.

Only one thing remained – the bill. Costs had run higher than LeMessurier's original estimate of $1 million. Citicorp wanted to be reimbursed for $4.3 million, according to LeMessurier. A noteworthy point is that Citicorp did not pursue LeMessurier in the normal litigious fervor of the business world. LeMessurier offered to pay Citicorp $2 million – the limit of his professional liability insurance, and Citicorp accepted. The bank never pursued litigation against Hugh Stubbins' or LeMessurier's firms.

A short while later, LeMessurier's insurance provider informed him that his premiums would be raised due to his large liability claim. At this news, LeMessurier's associate traveled to Chicago to give an impassioned speech, convincing them that not only should they not raise the rates, but they should lower them. He claimed that LeMessurier, upon discovering a problem that no other engineer would have found, acted ethically, responsibly and quickly to resolve it. In doing so, he avoided what could have been one of the greatest insurance disasters of all time. This sounded reasonable to the insurers, so they lowered his rates.

The Citicorp case has become one of the best known examples of proper, ethical engineering behavior. LeMessurier acted responsibly in a very difficult situation. Leslie Robertson says of him, "I have a lot of admiration for Bill, because he was very forthcoming. While we say that all engineers would behave as he did, I carry in my mind some skepticism about that" (Morgenstern, 1995). It should be noted that others involved behaved in an exemplary manner, as well. Walter Wriston and the Citicorp management, the city's Department of Buildings, the insurance company, the steel fabricators and others all acted in a manner that illustrated their desire to solve the problem, rather than making the problem worse by protecting only their own interests. Through their concerted effort, the "Fifty-nine-story Crisis" did not become the "Fifty-nine-story Catastrophe."

3.1.1 Defining LeMessurier's Problem

To begin to define LeMessurier's problem, it is helpful to compare the characteristics of the problem state with those of the desired result state. Though a

detailed comparison is expedient, only several basic comparisons will be made herein to serve as an example of how to complete this step. The results are shown in Table I below.

Table I. Comparison of the Problem and Result States.

Problem State	Desired Result State
Building has 1 in 16 chance of collapse in design wind storm.	Structure is safe – at least meeting minimum requirements of building code, but, preferably much more safe.
Nobody knows about problem except LeMessurier.	All stakeholders know about problem and its successful resolution.
Business relations with Citicorp are good.	Business relations with Citicorp are even better than what they are before discovering the problem.
Connections of braces are inadequately designed.	Connections are repaired to achieve necessary strength.

From these comparisons, it is clear that deficiencies exist in the problem state that LeMessurier must resolve. One may also notice that at the outset of the problem, not all of the comparisons reveal deficiencies – LeMessurier's relationship with Citicorp is good. The solution, then, must resolve the deficiencies without damaging this relationship or creating other problems.

The next step in defining the problem is to identify the stakeholders in the situation and determine what factors are of importance to them in a successful resolution of the problem. Table II identifies some of the key stakeholders and their motives:

Table II. Stakeholders and their motives.

Stakeholder	Motivations
LeMessurier	Safety, preserving the image of himself and his firm, maintaining a relationship with Citicorp, economics
Citicorp	Economics, prestige, usefulness of building
Hugh Stubbins, architect	Maintaining a relationship with Citicorp, client satisfaction, liability
The general public	Safety, assumption that structures are designed to safe standards

The final illustration of defining the problem that will be made here is a brief look at how the problem could be subdivided into more manageable parts. One such logical division would be to separate the engineering aspects of the problem from those that deal with business considerations, interpersonal relationships, economics, and liability issues. This division would serve to isolate the engineering design for retrofit of the structure from influences that might put pressure on LeMessurier to create anything but an optimal solution. The issues that deal with factors other than engineering concerns could then be further subdivided according to their influence upon the stakeholders involved. Dividing and subdividing the problem in this way or in a similar manner could help to simplify this difficult and overwhelming situation.

3.1.2   Identifying Needed Assumptions for the Citicorp Dilemma

From our standpoint looking back on a problem, it is difficult to identify what assumptions may have been needed to resolve the situation. Nevertheless, we might gain some ideas as to what information LeMessurier may have had to assume.

One notable assumption that made the problem less intimidating was the assumption that, eventually, all the financial concerns of the problem would be resolved.

Making this assumption allowed LeMessurier to move forward with the solution, concerning himself primarily with the engineering concerns. Without making this assumption, it would be easy to conclude that the financial burden of the resolution would destroy his career just as surely as could a structural failure. This conclusion could, in turn, lead to a feeling of hopelessness that any satisfactory solution could be possible. This does not place a person in the proper frame of mind for creative problem-solving, so the quality of the resolution decreases.

Perhaps equally notable is what LeMessurier did not assume. His thorough approach to collecting needed information before informing anyone of the nature of the problem is one of the factors that led to the successful resolution of the problem. When he began speaking to his insurance company, the architect, and Citicorp, he already had the answers to the questions he knew they would ask. His careful collection of data allowed him to win the support of other key stakeholders. This support, then, made the problem much more manageable.

3.2 Navy Sonar System

Note: This section is an adaptation of Chabries, 1997.

In the mid-1970's Dr. Douglas M. Chabries, pictured in Figure 6, worked as a civilian research engineer for the United States Navy, working at the Naval Oceans Systems Center. During this time, the center was heavily involved in

Figure 6. Dr. Douglas M. Chabries. (From Chabries, 1998)

developing, testing, and improving sonar systems. Sonar, used to locate submarines and underwater hazards, operates by emitting a pulse of sound and recording the amount of time it takes for it to be reflected back from an underwater object. The system then calculates the distance to the object and couples it with the direction from which the echo came to locate the object. The device is often housed in a bulb on the bow of a ship, as pictured in Figure 7.

Figure 7. Sonar dome visible on a ship in dry dock. (From "Image," 1998)

On one occasion, Dr. Chabries was required to install a system on a ship that would make its sonar more sensitive. As a part of the normal routine, Dr. Chabries conducted a test of the sonar system before installing the new enhancement. In this test, he lowered a sound source from the side of the ship to a position a few feet from the sonar dome and listened for the tone in the sonar system. To his surprise, the sound was not audible.

Concerned that the sonar was unusable, Dr. Chabries felt it was necessary to stop the ship from proceeding to its next mission. This is done by issuing a "casualty repair." This is a serious step, since it places the ship and all its crew out of commission. In wartime, a casualty repair is issued when a ship is seriously damaged, and the ship is withdrawn from service for repairs.

With the issuance of the casualty repair, the Navy brought in some technicians to test and repair the sonar system. Following the procedure outlined by General Electric, the sonar's manufacturer, they tested the system and determined that the system was functioning properly, so they gave notice to clear the casualty repair. Once again, however, Dr. Chabries lowered the sound source over the side of the ship to discover that the ship's sonar was still silent.

The next step was to call General Electric and have technicians of their own investigate the problem. Like the Navy's technicians, the ones from GE performed their tests and concluded that the sonar was functioning properly. Once again, Dr. Chabries lowered his device over the side of the ship and demonstrated that the sonar was not working. He issued yet another casualty repair.

The naval laboratory engineers who had designed the system were the final group that could possibly provide an explanation for the sonar's behavior. After performing their tests, this final group, like those before, concluded that the sonar was performing correctly. Still, Dr. Chabries's simple test demonstrated that this was not the case. He was forced to file another casualty repair.

This was more than Navy officials could tolerate. Every test performed on the sonar showed that it was functioning properly, but Dr. Chabries refused to proceed with his installation because his test did not agree with the other, more technical diagnostics performed on the system. The Navy informed him that they would be launching the equivalent of a court marshal hearing, but for civilians. His work would be reviewed by a tribunal, and he would have to defend it. If he failed to provide a satisfactory

explanation, though his civilian status would protect him from going to prison, he would be removed from the project, and his career would be tarnished.

At the tribunal, representatives from the Navy technicians, General Electric and the naval laboratory were all present to testify against Dr. Chabries before the admiral who was hearing the case. Each of them gave long, technical explanations to defend their position that the sonar was functioning within specifications. After they concluded, the admiral turned to Dr. Chabries for his rebuttal. Realizing that most admirals are not well versed in technical matters, Dr. Chabries sought to give the admiral a simple explanation that anybody could grasp. He played a tape recording of his sound source that he had used in his test, then a recording of what the sonar heard. In this second tape, only noise was audible. He then set up an oscilloscope and demonstrated that the noise was not random, but was, in fact, the sound of a sixty-cycle pump. All the sonar could hear was the sound of the ship's own power source. To Dr. Chabries's relief, the admiral stated, "Any fool can see that this sonar is broken."

With the tribunal over, it was now time to determine why the sonar was not functioning, when all diagnostic tests indicated that it was. The search for answers led to an electrical cabinet in which 576 leads from the sonar system's transducers met. In an effort to organize the wires in the cabinet to ease maintenance, the person who had wired it laid out the wires as illustrated in Figure 8. With the wires in the configuration shown, the electrical cabinet behaved as a transformer, amplifying any nearby electrical field. This produced a buzz in the sonar that made it impossible to hear the sonar echoes. The room's fluorescent lights, a floor buffer, even a soldering iron, could be heard in the sonar when they were in use.
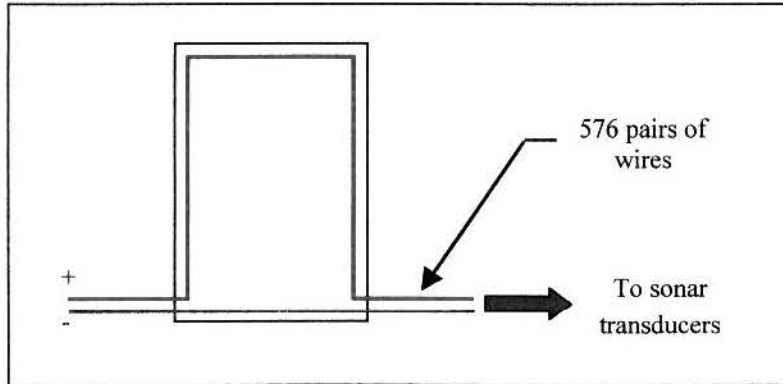
Figure 8. Wiring through electrical cabinet.

The problem with the sonar had never been discovered because the first step performed when testing the sonar is to short the wires between the cabinet and the transducers, so the sonar is isolated from the rest of the system. The test then proceeds on the transducers and the associated electronics. The electrical cabinet was never included in the section of the system being tested, so its effect on the system went undetected.

Once the problem was found, a message was sent to the entire U.S. fleet instructing them to look at the wiring in the cabinet to see if they had a similar situation. The word soon began coming back – every vessel in the fleet had the problem. It had not been discovered because the United States had not been at war in a long time, and there had not been a need to use the sonar. Orders were quickly issued to repair the entire fleet.

Dr. Chabries, instead of being court-marshaled, was given an award. The letter accompanying the award said, "Thank you for maintaining your courage and integrity in the face of assurances by GE, by the naval designers, and by the naval personnel that you

were wrong." Integrity, in this case, remedied a problem that could have cost billions of dollars and people's lives.

3.2.1 Identifying Fundamental Principles in the Sonar Case

Looking at the Navy Sonar case, there are several important principles to which Dr. Chabries had to adhere to resolve the problem successfully. These principles include, but are not limited to:

- *Integrity:* Dr. Chabries was required to defend what he knew to be true, when others seemed to have proof that he was wrong.

- *Responsibility:* He knew that he was responsible to ensure that the sonar system was working properly, even though the Navy would not likely hold him responsible if they discovered the flawed system at a later time.

- *Respect for life:* He understood that failure of the sonar system would place the lives of all those aboard the ship in jeopardy. It was unacceptable to let the ship leave port while the system was not functioning, no matter what the cost to his reputation.

- *Courage:* Facing a tribunal that had the power to destroy his career took a great deal of courage. Without this attribute, the successful resolution would have been impossible.

A failure to adhere to any of these principles would likely have resulted in a failure to resolve the problem in an ethical manner.

3.2.2 Brainstorming Possible Solutions for the Sonar Case

The following list illustrates several of the ideas for possible solutions that might be generated in a brainstorming session. Notice the unpolished nature of the list, as well as the presence of both good and poor solutions.

- Accept the results of the other technicians, assuming the test performed personally was inaccurate

- Hire an independent company to test sonar system

- Resign from position

- Remain steadfast in belief that the sonar system is defective

- Design comprehensive set of diagnostic tests for system

- Test system on another ship to see if similar results are obtained

- Take results to other officials

- Tell story to news media, exposing problem with defective system

- Knowing that the system is defective, install system enhancement, anyway, and let the military resolve the problem some other time

- Recommend installation of a new sonar system

This list serves to illustrate several important aspects of brainstorming. First, all ideas are recorded, even if they are obviously deficient. Furthermore, the sentence fragments in the list are symbolic of the incomplete nature of the ideas. There has not been any thought at this stage of the process regarding the efficacy of the solutions or the details of their implementation. These considerations are reserved for the convergence phase of the problem-solving process.

3.3   Coal Slot Storage Facility

Note: The information for this section was obtained from Jones, 1998.

In 1975, the Atlantic Richfield Company (ARCO), working with design engineers H.K. Ferguson, was developing a design for a new coal mine, the Black Thunder Mine, and the associated handling and loading facilities near Gillette, Wyoming. An important feature of the facility was a "slot" storage area, where coal would be stored in a large slot cut into the ground surface, rather than in vertical silos, as was often the storage choice. This type of storage facility could be constructed for approximately $7 million, as opposed to $16 million for silo storage. Additional savings would also be realized due to the fact that a slot storage facility had been designed for another ARCO site that had been abandoned due to permitting problems, so a design was already available, assuming it could be adapted to the new site.

The design consists of an 800-foot long slot 70 feet deep with sloped sides. A typical cross-section of the slot is illustrated in Figure 9. As shown in the figure, the sides of the slot are steeply sloped – a slope of at least 50 degrees is required – to allow the dumped coal to slide down the sides to the conveyor system housed in the reclaim tunnel at the bottom. The sides are protected with concrete and the slot is covered with a roof structure to shelter the coal from weather.
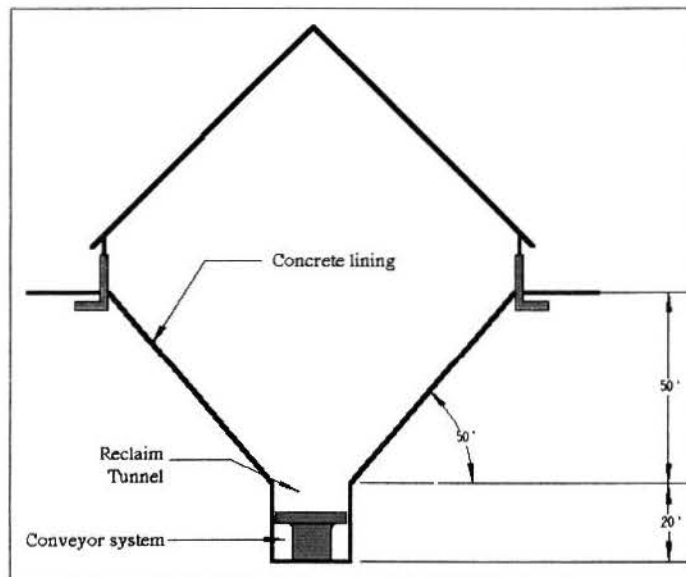
Figure 9. Cross-section of the coal storage slot. (From Jones, 1982)

ARCO selected Northern Testing Laboratories as its geotechnical consultants responsible to adapt the storage facility design for the soil conditions at the Gillette site, and the project was assigned to Walter V. Jones, P.E., ("Walt").

After performing a typical geotechnical evaluation of the site, Walt determined that the conditions were not favorable for this type of storage facility. The water table was high, and the facility would be situated partly within a weak carbonaceous shale. The geologic conditions posed at least three problems that could seriously undermine the viability of the project: 1) The combination of the weak carbonaceous zone and the high water table made the possibility of a massive slope failure in the structure high, 2) the high water table would create seepage into the coal which would create shipping and handling difficulties, and 3) most of the slot was situated in a Claystone shale, which would degrade when exposed to the environment, making it difficult to place a concrete topping on the sides without performing major slope rehabilitation (Jones, 1982).

Walt took these concerns to ARCO and recommended that they consider a silo storage facility for the site. ARCO did not want to consider silos unless it was absolutely necessary, however. The added construction costs would be significant, and the silo facility would need to be designed, whereas the slot design was already complete, allowing them to get the facility into operation more quickly. ARCO officials responded by saying, in effect, "The site may not be well suited to the slot storage, but can you make it work?" Walt, wanting to meet their needs, told them that he could.

To better understand the underlying conditions, Walt decided to excavate a large test section within the proposed slot area. From the information gathered in this test, he was able to adapt the design to the site. The final design, shown in Figure 10, was constructed by, first, excavating to the dashed line, then placing the filter fabric and drain rock. The lime-stabilized engineered fill was placed, compacted, and trimmed to form a smooth slope. The reclaim tunnel was then excavated at the bottom. With the excavation complete, the walls could be covered with a layer of shotcrete, the roof structure built, and the conveyor system installed.
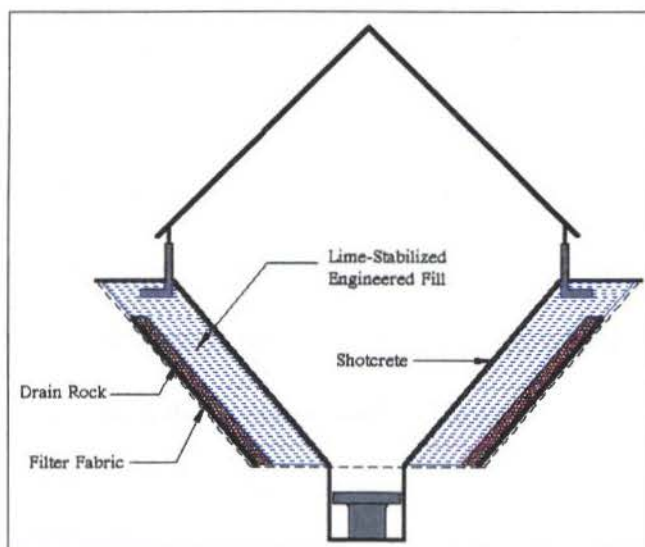
Figure 10. Cross-section through storage facility. (From Jones, 1982)

With the design details worked out, construction began at the site. Everything was progressing smoothly – the lime-stabilized material had been placed without any problems. The excavation for the reclaim tunnel was nearly complete when problems arose. Walt was away from the office working at another site when he got word one Friday afternoon of a disaster out at the Black Thunder Mine. Information was very limited, and it was not known whether anyone had been hurt or killed, or even the extent of the damage. As Walt drove back to the office, his stomach churning, he went over again and again in his mind the factors that had led him to his design. He realized the responsibility that would be placed on him as the Engineer of Record if his design was faulty. Walt explained, "This could be very disastrous for the company if somebody had been killed or if they couldn't proceed with the project after they'd gone this far. Personally and to the company it could've been a real crisis for us."

As soon a Walt returned to his office in Boise, Idaho, he chartered a plane to Gillette for Saturday morning. He also contacted two other people at his firm, an engineering geologist and another man who was "a real good sound thinker," and asked them go with him out to the site.

When the team reached the mine Saturday morning, the situation looked serious, but, luckily, nobody had been injured. There was a geologic anomaly that had caused a section of the wall of to collapse. The section was approximately 60 feet long by 12 feet high and 8 feet back into the face of the wall. As the material collapsed, it had partially covered a Back-hoe and scared the operator badly. There were also cracks developing at the ground surface, some of which had widened to 2 inches in just a few days. These

indicated that the engineered fill was sliding into the reclaim tunnel and a massive slope

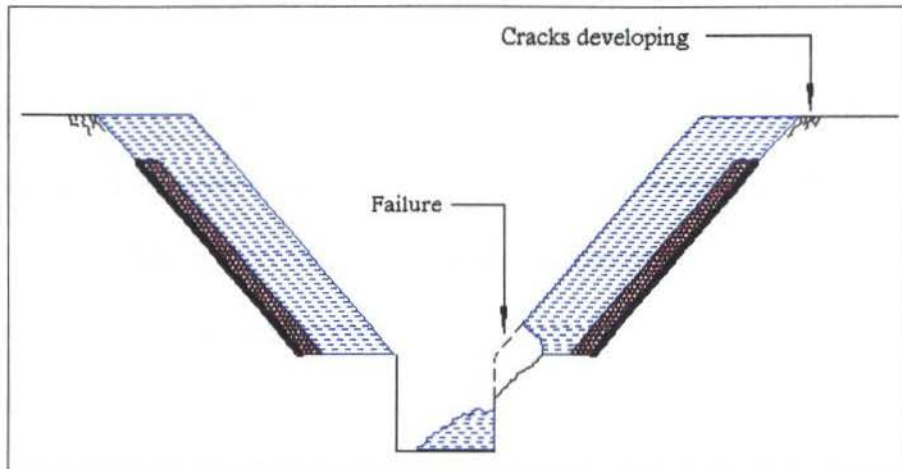failure was eminent. This situation is illustrated in Figure 11.

Figure 11. Section through storage facility showing failure. (From Jones, 1982)

The team immediately set out to determine the extent of the problem and look for

possible remedies. After a closer investigation, they realized that the geologic anomaly

that had caused the collapse was fairly isolated, and did not appear to pose a significant

threat to the remainder of the wall. The cracks still concerned them, but they indicated a

slow failure that would not likely cause a sudden collapse and endanger workers. With

this type of failure, they could place instrumentation in the wall and closely monitor it for

signs of an impending collapse. With this information, they formulated a plan to repair

the collapse and safely complete the construction.

Monday morning, Walt and his companions met with the project manager. They

knew going into the meeting that it would be a tense situation, but they were prepared

with a solution that they felt could save the project. Walt explained, "We got there a little

before they did, and we were sitting at this conference table in a trailer out by the project.

Three of them came in – and the project manager had this really dark look on his face – and sat down. We tried to have some cordial conversation, but the first thing he did was slam his fist down on the desk and said, 'I thought you told us we could safely build this, and here we are now looking at a $5-10 million loss! What are you gonna do about it?'" The engineers' careful preparation paid off at this critical moment when the future of the project and the relationship between them and their client hung in the balance. As they explained their approach, they were able to change the project manager's attitude from one of criticism to one of support and trust. He gave his approval to go ahead with their plan and set crews to work implementing it.

Critical to the success of the plan was rebuilding the confidence of workers down in the hole. Walt was confident that the anomaly that had caused the collapse was limited in size and did not pose a threat to the remainder of the project. Furthermore, the slope failure of the walls was slow and did not pose an immediate threat. Walt had the walls heavily instrumented to measure their movement and make certain they did not become a more urgent concern. To ensure the safety of the workers, an engineer would monitor the instrumentation and meet with the foreman daily to give approval to go ahead with that day's work. To more directly win the confidence of the workers, Walt and his coworkers spent a lot of time in the excavation taking measurements. He explained, "We tried to be very visible so they knew [it was safe]. We wouldn't have one of our guys [in the excavation] if we didn't feel it was very safe."

To further convince ARCO management of his desire to safely and successfully complete the project, Walt had a third party geotechnical engineer come in to perform a peer review of his work. It soon became clear to ARCO managers that Northern Testing

Laboratories was just as interested in saving the project as they were. Their approach turned a situation that was initially hostile into one that was very positive.

This transformation did not come easily, however. It required hard work by Walt and his colleagues, and a proportionate amount of stress. Walt relates this experience:

> For months, every time I got a call from Wyoming, my stomach churned and my heart started beating, my palms would get sweaty. You know, it was just that close. The pressure of this project got so great on me after so many months of it – so much worry and concern with 100 people working down in this hole and the possibility of anything going wrong. I'd just really had it…. One night… I stayed in a motel there at Casper, … and I just prayed and prayed and prayed. It's the longest I'd ever been on my knees in my life. As I was praying, … I felt like I didn't need to worry any more, and that the Lord had put his hands out and was just holding that thing up.

Consistent with Walt's affirmation, the project was completed successfully and without further incident. All told, the repair of the collapse added about $500,000 to the cost of the project and delayed it a month. More importantly, the manner in which Walt and his colleagues handled the situation resulted in a very positive relationship between ARCO and Northern Testing Laboratories. From that time on, whenever ARCO had a problem on a project, no matter where it was, they would call Walt to come take a look at it. This high level of trust could only result from technical skill coupled with ethical behavior in the face of a difficult challenge.

3.3.1 Looking at the Extremes of the Coal Storage Problem

As explained previously, looking at the extremes is accomplished in two steps. The first is to minimize the scope of the problem. In the coal slot storage scenario, the minimized version of the problem might have the following characteristics:

- The slot is only 20 feet deep and 80 feet long.

- When the slope failed, nobody was in the trench.

- The soil conditions make the chance of a massive slope failure very small.

- ARCO places no blame on Northwestern Testing Laboratories.

- The cost to repair the damaged wall is insignificant.

Reducing the pressures and consequences of the decision in this manner may suggest this course of action: Since the failure is small, the means required to repair it are similarly insignificant. Walt could design a solution for the repair and offer it to ARCO free of charge, since his time spent designing it would be relatively small. This would ensure that his relationship with ARCO remained positive. Furthermore, Walt could offer to have an engineer or technician present for the remainder of the trenching operation to immediately solve any additional problems that might arise. This small extra effort to serve his client would likely win ARCO's trust, and they may become regular clients of Northwestern Testing Laboratories, since they could be assured that the engineers will be responsive and helpful in facing a project crisis.

Having performed the previous transformation and determined a suitable course of action, it is now necessary to analyze the opposite scenario:

- The storage facility is 200 feet deep and 5000 feet long.

- When the slope failed, 10 workers were killed.

- The soil conditions make an impending massive slope failure likely.

- ARCO is threatening to take legal action against Northwestern Testing Laboratories for criminal malpractice.

- Estimated repair costs are $100 million.

Imagining the situation in this challenging extreme might suggest the following resolution: Given the severity of the problem, Walt would need to begin at once designing a means by which to mitigate the immediate threat to safety. Because his first responsibility is to the public, which includes the workers, eliminating this threat would be expected of him, regardless of any questions of fault. Next, given ARCO's heated, litigious response, it would be in the engineers' best interest to resolve the problem themselves, rather than to have ARCO look to another geotechnical firm for a solution. Though Walt feels comfortable with his design and confident that he would not be found guilty of any malpractice, it would still be less expensive for Northwestern Testing Laboratories to devote resources to solving the problem than to later be caught in an expensive legal proceeding. Thus, Walt should use whatever time and resources that are necessary to solve the problem, offering this to ARCO without cost. If he is successful in solving the problem, it may be possible to preserve his relationship with ARCO, though this is a minor concern, compared to restoring safety and protecting the company from litigation.

Having determined solution possibilities for both extreme scenarios, it is now necessary to determine what insights we can gain about a successful resolution of the actual problem. In this case, both extremes prompt similar courses of action, though the motivation in each extreme is different. This suggests that in the actual situation, Walt ought to help ARCO by taking responsibility and determining a way to stabilize the slope.

3.3.2 Letting the Coal Storage Problem Incubate

It is virtually impossible to understand the value of incubation when we are looking back upon on a successful resolution of a problem. However, one particularly important incubation period is evident in this case. This is the time between Walt's Saturday morning visit to the site with his coworkers and their Monday morning meeting with the project manager. During this time, we can be certain that their minds were working non-stop to determine a solution that would successfully solve the problem. They knew that their Monday meeting with ARCO would be tense, and that they needed to be able to assure the oil company that they could solve the problem, so the project could be completed. This period of incubation proved to be invaluable, as they were able to design a solution that would save both the project and their relationship with ARCO.

3.3.3   Measuring Proposed Solutions Against Core Values

To illustrate the process of evaluating solution possibilities in light of core values, suppose the following three possibilities are being evaluated:

- Blame ARCO for the failure, stating that it occurred because they required the use of the slot storage at a site that was not suitable for this type of structure.

- Return any paid fees to ARCO and tell them to find another geotechnical engineer.

- Accept responsibility for the failure and find a way to stabilize the slope.

Let us now determine how well each of these solutions apply several important core values.

The first value we shall consider is *love*. The first two solutions do not seem to apply this principle well. Placing blame on ARCO or leaving them without a consultant during this critical time in which an additional failure is likely is certainly not an example of compassion or love. The third solution, on the other hand, shows love by indicating to ARCO the level of concern that Northwestern Testing Laboratories has for them. Just as a friend would not desert a friend in a time of crisis, so should Walt support ARCO through this crisis.

Next, we can turn to the value *integrity*. The first solution does not exhibit the application of this attribute. If Walt was pressured into using the slot storage design at a site where he thought it would not work, he should have indicated that before starting the design. To withdraw now would be dishonest and irresponsible. Earlier in the scenario, the second solution could have been one that applied integrity – sometimes the only thing a person with this trait can do is to get out of a bad situation. However, Walt is now too far involved to escape the situation. As the Engineer of Record for the project, it is his responsibility to resolve the problem. This leaves us with the third solution – the only solution which demonstrates integrity.

A third value important to this situation is *loyalty*. An engineer's first loyalty is to the public as a whole, but as the engineer hired by ARCO for the project, Walt owes a great deal of his loyalty to them, as well. As long as ARCO's interests are not in conflict with those of the general public, he has a responsibility to be loyal to them. Clearly, the third solution is the only one of the three that demonstrates Walt's loyalty to ARCO.

In solving this problem, evaluations of the solution possibilities for each core value important to the situation would continue in a manner similar to these. Other

values which could be important include responsibility, respect for life, service, wisdom, and courage. After evaluating the options for these values and any others, it should be possible to discern which solution best conforms to our most important ideals.

3.4 Coal Combustion Research

Note: This section was adapted from Smoot, 1997.

Dr. L. Douglas Smoot, professor of Chemical Engineering at Brigham Young University, has many years of experience studying the combustion of fossil fuels and the control of wastes produced in the process. From the time he joined the BYU staff in 1967, he has led the university's research in combustion.

Figure 12. Professor L. Douglas Smoot (From ACERC, 1998).

In 1986 he founded the Advanced Combustion Engineering Research Center (ACERC), which has since become an internationally-recognized leader in the study of fossil fuel use. As an academic center as well as a center for research, ACERC contributes to the scientific community and industry in two very important ways: First, the center conducts important research into the more effective use of fossil fuels. Second, the center provides

opportunity for students to perform research applicable toward advanced college degrees, thus preparing them to continue providing valuable service to industry.

In the mid nineteen-eighties, a graduate student, Kyle Simpson (the name used here is fictitious), became a research assistant to Professor Smoot, with the intent of earning a Master's degree in chemical engineering. He was given a research assistantship that required him to work part-time during the school year and full-time during the summer months. For his work, he earned approximately $13,000 per year, which he used to support his family, consisting of his wife and four children.

In concert with his research at ACERC into the measurement of oxidation rates of coal char particles, he helped to construct a laboratory-scale drop-tube reactor. He used this device to complete a series of experiments, the results of which were published in his thesis and in a technical journal. Kyle completed the requirements for his Master of Science and was awarded this degree in 1985.

Following the completion of Kyle's Master's degree, Professor Smoot suggested that Kyle continue on and complete a doctoral degree. Kyle accepted this challenge and began his work, earning about $15,000 per year for his research assistantship. Kyle and Dr. Smoot presented a research proposal to the United States Department of Energy (DOE) and secured a four-year research contract for $180,000 in 1986.

Kyle's research dealt with the effects of coal and coal-char chemical and physical structure on the oxidation rates of carefully prepared coal chars. To complete the work, he had to design and construct a more sophisticated laboratory reactor than that which was required for his Master's work. This device needed to produce higher temperatures and use laser technology to make advanced measurements. To learn about the necessary

technologies, Kyle spent several months at Sandia National Laboratories in Livermore, California. With this information, he then designed and assembled the reactor, procuring a $30,000 plasma generator to preheat the combustion air to a desired temperature.

Designing and building the reactor was only a portion of the work, however. Kyle had to also organize an exhaustive testing program, determine which coals to study, carefully measure their physical and chemical characteristics, and prepare the samples for testing. Samples were also sent to outside labs for advanced testing. All of this was done under the scrutiny of the DOE, which required quarterly progress reports.

Research progress was steady, but not without difficulty. There were challenges in getting the new reactor to operate properly, particularly with the plasma generator. After several months of trouble with this component, it was finally abandoned and replaced with a more reliable gas heater, though this could not heat the air to as high of a temperature.

After two years of working with the reactor, the research had not progressed as far as Kyle would have hoped. Frustrated, he indicated to Professor Smoot that he was ready to give up. Including the time spent in obtaining his Master of Science, he had been in graduate school over five years. His family had grown, and he was feeling pressure from them and about their financial situation. In December 1989, he informed Professor Smoot that he was going to abandon his research and accept a job. Troubled by this decision, Dr. Smoot worked hard to change Kyle's mind. Kyle's coursework was complete, over 85 percent of the research was done, about that same amount of the budget had been spent, and only eight months remained in the contract to complete the work. Furthermore, it would be nearly impossible to find another student to take Kyle's

place to complete the work in the remaining contract time. After much persuasion, Kyle agreed to remain at the university through the remainder of the contract.

During the next several months, Kyle completed the oxidation tests, analyzed the data, and wrote his dissertation. The contract final report, which was primarily composed of Kyle's dissertation, was sent to the DOE. Kyle also presented his work at an international coal conference in England and published it in a journal. With Kyle's responsibility to the university and the DOE fulfilled, the university awarded his doctoral degree in 1990, and Kyle accepted a position with a prominent company in New Jersey.

Shortly after Kyle left the university, two more graduate students working with other faculty members started follow-up research to Kyle's. The reactor Kyle had assembled was an expensive piece of equipment useful for research far beyond that which Kyle had performed. After making a few minor modifications to the device, they set out to duplicate some of Kyle's tests before beginning their own. When met with difficulty in reproducing the results, the students sought help from their graduate advisors, Dr. Smoot and Kyle. Still, they could not produce the same data. As far as was possible to ascertain, however, their tests appeared to be both accurate and precise. Over several months, questions began to arise concerning the accuracy of Kyle's tests and even whether he had actually performed all of the tests which he had reported in his dissertation.

As these questions arose, faculty members were faced with some difficult decisions. Approaching Kyle with their suspicions would be a delicate task, particularly if their allegations proved to be wrong. If they were correct, however, it would be necessary to determine the appropriate consequences and implement them.

First, the graduate students and faculty directly involved with the work compiled a packet of materials documenting the evidence for their suspicions. As Kyle's advisor, Professor Smoot was assigned the responsibility of contacting Kyle directly, which he did in the Fall of 1991. In their conversation, Dr. Smoot, being as professional and courteous and possible, outlined their concerns and invited Kyle to respond to each of the evidences documented in the written packet, which he would mail. Kyle vehemently denied any wrong-doing and took offense at being accused. Professor Smoot politely invited him to respond to the packet of materials when he received it, indicating that if Kyle would provide satisfactory explanation for each point, the university would pursue other rationale for the discrepant data.

The day after this telephone conversation, Kyle called back in tears to confess his fabrication of the oxidation test data. He exhibited a repentant attitude and offered to help in any way to resolve the problem.

Following Kyle's confession, Dr. Smoot immediately contacted the DOE officer responsible for the project to inform him of the situation. They arranged a meeting between Professor Smoot, who was to represent the university, and DOE attorneys, administration, and the project officer. The university was understandably concerned about how the DOE would proceed, as it was within their rights to pursue a criminal prosecution. Faculty members, particularly Kyle's graduate committee, and administration met to determine a strategy that would defuse a potentially disastrous situation with the DOE, address the necessary consequences of Kyle's action, and most ethically resolve the dilemma.

Since Dr. Smoot had a conflict of interest as both the dean of the college and Kyle's graduate advisor, he gave all college decision-making responsibility to an associate dean. This allowed him to separate the interests of the college from those of his own, as Kyle's advisor.

The first penalty recommended by the dissertation committee was to revoke Kyle's doctoral degree. This was implemented immediately. In addition, it was necessary to inform Kyle's employer of the loss of his degree. Kyle was given the opportunity to inform his employer firsthand, and Professor Smoot followed up with a letter. As one might expect, Kyle's employer fired him.

The next facet of the problem the committee had to address was Kyle's dissertation. First, they recovered the six bound copies that were in circulation and destroyed them. It was also necessary to notify Dissertation Abstracts Services at the University of Michigan of the problem. As a distributor of U.S. dissertations, they were requested to remove the dissertation from their database and retrieve any copies that they had previously distributed.

Besides Kyle's dissertation, the information had been published in the DOE final contract report and in a professional journal. The DOE agreed to retrieve the copies of the final report that had been circulated. Dr. Smoot notified the technical journal of the problem, and they printed a disclaimer notification in the next issue.

To set things right with the DOE, Kyle revised the final contract report, removing the falsified data and the related discussion and conclusions. The DOE accepted this report, but never published it. The department also required the university to repay them for contract money spent from December 1989 to the conclusion of the contract in the

Fall of 1990 – the approximate time that the fabrication of test data was taking place. This sum, plus interest, amounted to approximately $35,000. To pay this bill, Professor Smoot received approval from the university to use a portion of the funds in his internal research account. Because the university immediately informed the DOE of the problem once it was known and cooperated fully to achieve a resolution, the DOE did not press criminal charges.

The situation was now resolved with the DOE and at the university level. All that remained was for Kyle to complete his personal closure of the situation. To help him accomplish this, Dr. Smoot discussed with him the possibility of his return to the university to complete the research. After several conversations about this possibility, Kyle elected not to choose this course, and sought instead to continue professional work. Though he no longer possessed a doctoral degree and his reputation had been tainted, he still had B.S. and M.S. degrees and valuable experience to offer a company. He found an employer in Michigan interested in his abilities and accepted a position there. As of September 1997, seven years after the incident, Kyle was doing very well in his career and seems to have recovered from the many difficulties that the situation created for him.

The results of ethical conduct on the part of Professor Smoot and the university in this case are obvious: Kyle, though his life was upset, was able to continue on to a successful career. The university continues to receive research contracts from the DOE and is still respected for its quality of education and integrity of its research. These outcomes would have been impossible without the virtues of honesty, responsibility, integrity and humility employed in the solution.

3.4.1 Using the "Front Page Test" in the Combustion Research Problem

The "Front Page Test" can be used to evaluate possible resolutions in the coal combustion research case. Suppose Dr. Smoot was choosing between the following courses of action:

- Ignore the implications of the conflicting data and simply provide the government with new data.

- Provide the DOE with new data, indicating that there had been a miscalibration of the test apparatus or a procedural error that had invalidated the previous data.

- Reveal to the DOE that a portion of the data had been fabricated and assume responsibility for the consequences.

Either of the first two solutions might seem to pass this test upon casual review, but they fail after taking careful thought. A nonchalant explanation and a quiet substitution of data does not seem particularly embarrassing, but if the imagined newspaper reporter sensed any effort to cover a misdeed, a little investigative journalism could cause the situation to erupt into an embarrassing scandal. Even if the cover up was not discovered, knowing that the newspaper story is inaccurate would cause Dr. Smoot's conscience to prompt him to find an alternate solution. On the other hand, the third solution seems to initially fail the test, since it makes public Kyle's wrongdoings, embarrassing the university and exposing it to possible reproof. In the end, however, the readers of the newspaper would be impressed with the forthright manner in which the university dealt with a problematic situation.

3.4.2 Applying Classical Ethical Theories to the Combustion Problem

The possible courses of action listed previously could also be evaluated for their application of classical ethical theories. Illuminating any deficiencies in satisfying any of these theories can help to eliminate solution possibilities and steer one's decision-making toward a solution that is likely to be acceptable. For the purpose of brevity, in applying this technique to this case, we shall only discuss the impact of each solution upon three stakeholders: the DOE, the university, and Kyle.

To evaluate the options according to the Act-Utilitarian theory, we need to ask the question, "Which of the solutions will produce the best overall consequences?" Either of the first two solutions protects Kyle from the immediate consequences by not blaming him for the incorrect data. This may seem like the best option from Kyle's perspective. However, seeking protection only addresses the immediate consequences – what of the eternal consequences? When considering eternal ramifications, it is better for Kyle's mistakes to be uncovered now, so he can face them, accept the consequences, and repent. The third solution, then, produces the best overall consequences for Kyle. Does this solution also bring about the best consequences for the DOE and the university? Certainly, the DOE benefits from this solution, since it is the only one which provides the department with the truth. Furthermore, addressing the problem in this manner allows the university to clearly indicate which data are accurate and which are fabricated. Merely providing new data would tend to bring all of Kyle's work into question. From the university's standpoint, this solution brings upon it the worst immediate consequences, in that the university is subjected to shame and possible legal action. In the long run, however, this solution produces the best consequences for the university,

because it has the greatest potential for preserving its good relationship with the DOE. Providing new data in the manners suggested by the other solutions would cause the DOE to question the university's quality of research.

The application of the concepts of Rule-Utilitarianism is more straightforward in this case. The third option is the only acceptable possibility because it applies the rule, "One should tell the truth because telling the truth generally produces the best consequences for everyone." The other two solutions do not conform to this rule, and would, therefore, be rejected.

The deontological theories also clearly suggest the acceptance of the third option. Duty Theory would suggest to Dr. Smoot, "You ought to provide the DOE with an accurate account of what has happened." Justice Theory suggests that it is not fair to protect Kyle or the university from the consequences of fabricating data when others would be expected to accept punishment for similar infractions. Rights Theory would suggest that by funding the university research the DOE has the right to accurate data. Finally, Virtue Theory would suggest that the third solution is the best simply because it is honest. Being honest allows a person to live happily, whereas the other solutions do not promote happiness, because Dr. Smoot's conscience would remind him that he has not been honest in his approach to the situation.

3.5 Malden Mills

December 11, 1995 is a day that Aaron Feuerstein and his employees at Malden Mills will never forget. It was on this date that fire erupted, destroying most of the textile manufacturer's plant in Lawrence, Massachusetts. The fire started on the company's "Flock" line, where they produced an inexpensive upholstery covering for furniture. In the process, finely-chopped nylon particles, "flock," were chemically treated and blown onto fabric coated with adhesives and electrically charged (Butterfield, 1996). The combination of heat, chemicals, dust and electricity made the environment especially volatile.

This was explosively illustrated as flames shot through the Monomac building, severely burning several workers and starting a blaze that would quickly transform the entire complex into an inferno.

Figure 13. The late-night fire engulfs Malden Mills. (From Boston Globe, 1995)

From the Monomac building, the fire spread to the Process Mill, the Main Mill and the Dye House, destroying valuable processing equipment with the buildings that housed it. Finishing Two was the only production building to survive, though it was damaged and

without power. Though it only represented about 20 percent of the finishing operation, this tiny bit of remaining life was significant – it was enough to convince owner Aaron Feuerstein to rebuild.

Figure 14. A view of the mill a week after the fire. (From Boston Globe, 1995)

Rebuilding the mill may not seem so significant, however, if one does not consider the market forces working in the textile industry. Malden Mills is among the last of the textile manufacturers left in New England, where the industry in the U.S. began. Though the area's economic history has been influenced enormously by textiles, most manufacturers have left the area in search of cheaper labor.

Malden Mills, however, has stayed. The maker of the expensive, high-tech fabrics, Polartec and Polarfleece, stayed in Massachusetts when the competition fled south or overseas. Owner Aaron Feuerstein feels strongly that to produce a product like his, he needs skilled laborers with an unfaltering work ethic who take pride in their product and in the company. To reward these laborers, Feuerstein pays the highest wages in the textile industry. They return his high wages and fair treatment with hard work that has made Malden Mills successful, bringing $400 million in 1994 sales. This is

especially significant when one considers that Malden Mills filed for bankruptcy protection in 1982. Now, with the fire, Feuerstein had much more to deal with than marketing his product and staying ahead of the competition. He had to reconstruct his business literally from the ground – and do it quickly before he lost his customers.

Figure 15. Aaron Feuerstein and his wife, Louise. (From Boston Globe, 1996)

Feuerstein made the announcement that Malden Mills was going to rebuild, going against everything corporate America has come to expect. For one thing, Feuerstein was 70 years old at the time. By most standards, he should have been enjoying a comfortable retirement even before the fire. After the disaster, nobody would have been surprised if he had taken the insurance money, retired, and left his 2,320 employees jobless. Paul Coory, president of Local 311 of the Union of Needletrades, Industrial and Textile Employees, said of the fire, "I was standing there seeing the mill burn with my son, who also works there, and he looked at me and said, 'Dad, we just lost our jobs.' Years of our lives seemed gone" (Wulf, 1996). Aaron Feuerstein looked at the burning mill and had a different response, however. "No, I'll not weep," he declared, quoting King Lear

(Butterfield, 1996). He later told the New York Times, "I was telling myself I have to be creative.... Maybe there's some way to get out of it" (Wulf, 1996).

In the days after the fire, even Malden Mills' own executives doubted Feuerstein's confidence in their ability to get the company back on its feet. Everyone -- even Louise Feuerstein, Aaron's wife – doubted that there would be a post-fire Malden Mills. The night of the fire, Louise cautioned her husband, "So much is gone. You may not be able to bring it all back" (Butterfield, 1996). It was in this time of hopelessness that Aaron Feuerstein truly lived up to the principles taught during his orthodox Jewish upbringing. He realized that he must be a "mensch." This term comes from a Yiddish proverb that states, "When all is moral chaos, this is the time for you to be a mensch." A "mensch" is a person who exhibits exceptional moral courage, a person who does the right thing when nobody else would (Auerbach, 1995). The determination to live up to this standard guided the decisions he would make in the months following the fire, as Malden Mills rebuilt. Every choice was measured against this standard -- if an option did not meet the criteria, Feuerstein discarded it, sometimes meeting intense opposition from corporate leaders who lacked his vision.

One of the first decisions Feuerstein made after the decision to rebuild was also one of his most noteworthy. In a crowded meeting at a local high school on December 14th – just three days after the fire – he announced that he would continue to pay his workers for at least 30 days, despite when they were actually able to return to work. The limit of 30 days was a compromise between Feuerstein and his executives. Aaron had originally planned on announcing 90 days of pay, but at a cost of about $1.5 million per week, the other executives wanted to be more cautious. Feuerstein, however, had no

intention of ending the pay at 30 days. He had told his managers, "Well, it doesn't make any difference. I'll announce at the end of the first 30 days another 30 days, and at the end of that another" (Butterfield, 1996). Not only would pay be extended, but full insurance coverage would also continue for 3 months.

Though generosity and the desire to act as would a "mensch" motivated this decision, it also served an important business purposes: It ensured that Malden Mills would be able to keep its employees. This was critical if the mill was going to be up and running in the short time that Feuerstein demanded. Quick recovery was vital to keeping their buyers happy and the continued success of the business, but a rapid recovery would have been impossible with new workers requiring training. Thus, continuing to pay his employees was not only compassionate, but, arguably, a sound business choice, as Thomas Teal of *Fortune* magazine explained (1996).

Feuerstein realized that the best thing he could do, both for his business and for his workers, was to resume production as quickly as possible. This was his primary focus, since all other goals for the success of the business relied on this. Resuming production would not only allow Malden Mills to keep its share of the market, but it would combat the employees' feeling of hopelessness, so destructive to success. Feuerstein made numerous public assurances that all mill employees would still have jobs. He was determined not to lay off anyone. "I can't shirk my duty," he would say. "There's a lot I have to do. Because there's somebody out there who's not working if I don't come through" (Jerome, 1996). Still, while making these statements to the public, behind office walls he had to continually reassure mill executives that he had not decided to run Malden Mills as a non-profit organization.

It may have been hard to get his executives to believe him when he continued his benevolent traditions despite the company's crisis. Each employee's first paycheck after the fire contained a $275 Christmas bonus. Feuerstein also made his annual Christmas trip to several local homeless shelters, soup kitchens and charities, leaving a $20,000 check at each (Butterfield, 1996).

It was most critical to get Polartec back in production. Not only is the lightweight, warm fleece Malden Mills' most profitable product, but halted production lines in Methuen meant similar stoppages at two of the mill's other plants, which provide the Massachusetts plant with unfinished goods. Feuerstein gave this task to Patti Fitzpatrick, the production manager for the product. Working a miracle, she got Polartec started in three days, using one of the two intact buildings left in the mill complex. By the end of December, Polartec production was at 20 percent of normal, by February, 25 percent, and by May, 85 percent (Butterfield, 1996).

Figure 16. Polartec fabric. (From Boston Globe, 1996)

To further complicate the mill reconstruction, executives also sought to improve it and bring its technology up to date. This meant making whirlwind decisions about

equipment, buildings, and processes. "We're making decisions involving millions of dollars so fast, it's frightening," explained Fitzpatrick (Butterfield, 1996). However, in the already tense situation, some of these improvements created conflict within Malden Mills leadership. While several executives pushed for more automated processes, which they felt would improve quality control, Feuerstein remained vehemently opposed to this shift, stating that it was the workers' skill that produced a superior product and that going to more automated systems would displace workers to whom he had promised jobs. The dichotomy of viewpoints created serious conflict, but in the end, Feuerstein's paternalistic care for his workers prevailed, and the factory today relies heavily on worker involvement in the manufacturing process.

While incredible progress was being made in restoring production of many of the mill's products – Polartec, most notably – there was one product line that lagged behind. This was Flock, the production line where the explosion took place that started the fire. With millions of dollars of equipment on order, there was still not a place to put it, and Feuerstein was furious about delays in getting the product back on line. In the end, Flock would be delayed long enough that Feuerstein was forced to lay off 400 employees. Of these, all would be given a priority rehire status, and 68 of them would be rehired a few weeks later. Despite the enormous success of the rest of the reconstruction, this one small failure cast a pall on the entire process for Feuerstein. In explanation of what he calls his "profound mistake" to the laid-off workers, Feuerstein said, "I'm depressed about the fact that you guys have such a rough road ahead of you in the future. You people can go home and cry because you have a good reason to cry. But it's not going to help you. You have to get on with your lives" (Butterfield, 1996). Though Feuerstein

feels like a failure, workers applaud him for his efforts to protect their jobs. Of the 2,320 employees in Lawrence, 2,000 were able to continue working for the mill after the fire.

Feuerstein's example of corporate responsibility has earned him numerous awards, public praise, special recognition from the President of the United States, and – most important to him – the love of his employees. Still, he claims, "I haven't really done anything. I don't deserve credit. Corporate America has made it so that when you behave the way I did, it's abnormal" (Wulf, 1996). When Feuerstein was presented with George Washington University's 1996 "CEO of the Year" award, he explained,

> In 1866, Arlington Mills built its first plant. Just a year later, a conflagration destroyed the entire mill. The proprietors then were determined to rebuild, without publicity and without celebrity status. At that time, it was normal to care about your business and community. The value system of 130 years ago is the same value system that my grandfather and father taught me; nothing's changed. So why all of a sudden this celebrity status? Perhaps it's a reflection on some of the modern CEOs of today. As a CEO, it is my responsibility to make sure our employees' spirit isn't broken and their American dream isn't crushed. They're not just a pair of hands and a cut-able expense. Without them we can't succeed. (George Washington University, 1996)

Many corporate executives would consider this philosophy outdated. Aaron Feuerstein has proved through his example at Malden Mills, however, that moral courage in the face of a crisis and in day-to-day business practice is both profitable and ethically correct.

3.5.1   Comparing the Result and Goal States at Malden Mills

To obtain an image of what would likely be Aaron Feuerstein's goal for the resolution of the problem, one needs to look at the manner in which he ran his business and his personal conduct. Possibly, the greatest concern he had in all his business affairs was for his workers. Consequently, a successful resolution to the problem would be one which would treat his employees with the greatest compassion. Additionally, as a

businessman, a successful resolution would necessarily result in the greatest success of his company. While this image of a goal state for a successful resolution is in no way complete, it provides sufficient insight to evaluate several resolution options here.

Consider that Aaron has the following options after the destruction of the mill:

- Collect the insurance money, close his mills, and retire.

- Place the company for sale and sell it to any firm willing to rebuild the mill and operate the new facility.

- Rebuild the mill and hire workers as soon as construction is complete.

- Rebuild the mill, keeping workers employed during the reconstruction.

Let us consider the first option. This option obviously does not result in a state anything similar to Feuerstein's goal state. The workers would be abandoned, and the company would no longer be in existence. Given Aaron's expectations for the business, this would be a grossly unacceptable option.

The second solution could have the result Feuerstein seeks, but it places the implementation of the solution completely out of his control. While it is possible that the new management would run the business in a fashion similar to Feuerstein's, there would be no guarantees of this. For someone possessing Aaron's compassion for people and concern for the business, this risk would be too great. This option, then, would be discarded because of the uncertainty of its success.

The third possibility could produce acceptable results for the business, except that it does not guarantee that Malden Mills will be able to hire back the same workers, since many of them would seek alternative employment during the reconstruction. While this option saves the company millions of dollars in employee wages, retraining new workers

after the mill reopens would cost the company in decreased productivity and workmanship. Furthermore, this option does not meet Feuerstein's level of commitment to his workers. Any resolution that does not satisfy this primary concern would be unacceptable.

The final solution, then, is the only one which fulfills Aaron's vision of the goal state. Both the workers' needs and the company's expectations are met. Based upon this evaluation, this solution would be the one most likely to succeed.

3.5.2 Using the Decision Grid in the Malden Mills Problem

As a final illustration of how to apply the steps of the problem-solving process, let us consider how a decision grid created by Aaron Feuerstein might have looked. Given his personal motivation, which is largely a result of his religious upbringing, it seems reasonable that he would select important core values as the criteria for evaluating the solution options. With this assumption, Table III illustrates a possible decision grid for choosing between the options presented in the previous section.

Table III. A Possible Decision Grid for the Malden Mills Case.

Solution	Compassion	Responsibility	Industry	Loyalty	Service	Courage	Total
Collect insurance and retire	1	1	1	2	1	1	7
Sell mill	3	2	3	1	3	2	14
Rebuild, hiring workers after construction	2	3	2	3	2	3	15
Rebuild, keeping workers employed throughout construction	4	4	4	4	4	4	24

The decision grid clearly indicates that the final option is the best.

Of course, there are countless decision grids that Feuerstein could have used. This is just one example that demonstrates how the decision grid might have been applied using values which seem to be important to Feuerstein as the criteria. He could have also applied classical theories, performance-related business criteria, or any combination of these.

PART 4. CONCLUSION

This thesis has served to accomplish several objectives. First, a foundation was laid for the consideration of ethical factors in an engineering context. This was done by first establishing the need for ethical judgment in the engineering disciplines. A summary of several significant classical ethical theories followed, providing several tools with which to evaluate decisions that have ethical implications. Finally, the conclusion was made that the best framework for making ethical decisions is found in the application of the virtues espoused by the gospel of Jesus Christ.

With the foundation for ethical thought in place, the next objective was to present a problem-solving process for resolving ethical dilemmas in an engineering context. This process is a synthesis of several common problem-solving techniques, guided by virtue, as discussed in Part 1 of this thesis. A formalization of the approach is presented in the Appendix, which contains general-purpose worksheets that guide an engineer through the problem-solving procedure. These worksheets are intended to be reproduced and used by interested individuals.

Finally, this thesis has presented several actual cases that demonstrate positive resolutions of ethical dilemmas. Following each case, a brief commentary has illustrated how a portion of the problem-solving process could have been applied in that situation.

Having accomplished these objectives, it is hoped that readers of this thesis will close this volume possessing a greater understanding of ethical thought and problem-solving processes. Hopefully, the case studies have also provided inspiration for ethical conduct and insight into the success that a person can achieve through a symbiosis of ethical behavior, creative thinking, and technical proficiency. More importantly,

however, is for the reader to leave with a heightened sense of the necessity of ethical behavior, a greater desire to apply ethical principles in a professional setting, and a deeper love for the virtues which are the basis for ethical conduct.

References

Advanced Combustion Engineering Research Center. "ACERC History." Online. Internet. 15 Sep. 1998. Available HTTP://www./~acerc.byu.edu/structure.html.

American Society of Civil Engineers, Professional Activities Committee. "Visioning for the Future." (Oct. 1995). Online. Internet. 10 Dec. 1998. Available HTTP://www.asce.org:80/peta/prof/pcvision.html.

Androshick, Julie. "Kaboom!" Forbes 18 Nov. 1996: 18+.

Applied Ethics Case of the Month Club. "Nine Basic Steps to Personal Ethical Decision Making." Online. Internet. Available HTTP://www.engr.washington.edu/~uw-epp/Pepl/Ethics/ethics4.html.

"At New York's Citicorp Center, a structure of masterly invention underlies the urbane face of a skyscraper in the grand manner." Architectural Record Mid-August 1976: 66-70.

Aucoin, Don and Pamela Ferdinand. "In Lawrence, Hope Goes Up in Smoke." The Boston Globe 13 Dec. 1995: Metro 37. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Auerbach, Jon and John Milne. "Methuen's Unstoppable Hero Aaron Feuerstein Tempered by Fire." The Boston Globe 15 Dec. 1995: Metro 1. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

"Basic Concepts and Methods in Ethics." Online. Internet. 11 Nov. 1998. Available HTTP://ethics.tamu.edu/ethics/essays/basics.htm.

Bennett, William J. "Does Honor Have a Future?" Imprimis. Dec. 1998: 1-4, 8.

Boston Globe Online. "A photographic essay of the Malden Mills fire." Online.

Internet. 1 Oct. 1997.

Butterfield, Bruce. "Test by Fire: The Story of Malden Mills." The Boston Globe 8-11

Sep. 1996. The Boston Globe Online. Online. Internet. 1 Oct. 1997.

"A Brief Discussion of Aristotle's *Nichomachean Ethics*." Online. Internet. 12 Nov.

1998. Available HTTP://www.cco.caltech.edu/~rclancey/tech/hum10a_1.html.

Carden, Stephen. "Lecture Notes on Background to Kant." Online. Internet. 12 Nov.

1998. Available HTTP://www.occ.uky.edu/stevecarden/kant/notes-bg.htm.

Chabries, Douglas M. Digital image. Online. Internet. 6 June 1998. Available

HTTP://www.ee.byu.edu/faculty/chabries/biography.html

Chabries, Douglas M. Presentation given to Engineering Ethics (Religion C 491/492)

class. Brigham Young University. Provo, UT, 1 Oct. 1997.

"Citicorp Center." Online. Internet. 10 Sep. 1997. Available

HTTP://www.arch.usyd.edu.au/kcdc/caut/html/Citi/CC.htm.

Covey, Stephen R. The 7 Habits of Highly Effective People. New York: Fireside, 1989.

Darwall, Stephen. Lecture notes for Philosophy 361, University of Michigan. Online.

Internet. 12 Nov. 1998. Available HTTP://www-

personal.umich.edu/~sdarwall/361a196.txt.

Darwall, Stephen. Lecture notes for Philosophy 361, University of Michigan. Online.

Internet. 12 Nov. 1998. Available HTTP://www-

personal.umich.edu/~sdarwall/361k196.txt.

Dowdy, Zachary R. "Company Saw a Resurgence." The Boston Globe 12 Dec. 1995:

Metro 34. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

References

"Engineer's afterthought sets welders to work bracing tower." Engineering News Record
17 Aug. 1978: 11.

Flood, Robert Louis. Solving Problem Solving: A Potent Force for Effective
Management. Chichester: John Wiley and Sons, 1995.

Gehringer, Edward F. "Ethical Principles Index." Online. Internet. 12 Nov. 1998.
Available HTTP://courses.ncsu.edu:8080/csc379/readings/principles/study.html.

George Washington University. "International Textile Manufacturer Aaron Feuerstein
Named CEO of the Year." Online. Internet. 1 Oct. 1997. Available
HTTP://www.sbpm.gwu.edu/perspcfa/Feuerste.htm.

Gerometta, Marshall. "The World's Tallest Building Page." Online. Internet. 8 Oct.
1998. Available HTTP://www.dcircle.com/wtb/96.

Goldstein, Stanley H. and Robert A. Rubin. "Engineering Ethics." Civil Engineering
Oct. 1996: 41-44.

Guise, David. Design and Technology in Architecture. New York: John Wiley and Sons,
1985.

Hayes, John R. The Complete Problem Solver. Philadelphia: Franklin Institute Press,
1981.

Healy, Tim, et al. Ethical Issues and Earthquake Risk Reduction. Oakland, CA:
Earthquake Engineering research Institute, 1998.

"Image of the Sonar Dome in the Yards." Digital image. Online. Internet. 6 June 1998.
Available HTTP://pvia2.caverns.com/~ddg54/thumb2.htm.

Jerome, Richard and Stephen Sawicki. "Holding the Line." People Weekly 5 Feb. 1996:
122+.

References

"John Locke and Natural Law Ethics." Online. Internet. 12 Nov. 1998. Available

    HTTP://www.onu.edu/user/FS/mdixon/336/summary-locke.html.

Jones, Walter V. Personal interview. 5 March 1998.

Jones, Walter V. "Unique Slope Stabilization with Lime Treatment." Ms. for Geotech II.

    28 Apr 1982.

"Kant: The Categorical Imperative." Online. Internet. 12 Nov. 1998. Available:

    HTTP://www.cco.caltech.edu/~rclancey/tech/hum10a_html.

Kay, Charles D. "Justice as Fairness." (20 Jan. 1997). Online. Internet.

Kidder, Rushworth M. Shared Values for a Troubled World: Conversations with Men

    and Women of Conscience. San Francisco: Jossey-Bass Publishers, 1994.

Korman, Richard. "Critics grade Citicorp confession." Engineering News Record 20

    Nov. 1995: 10.

Korman, Richard. "LeMessurier's confession." Engineering News Record 30 Oct. 1995:

    10.

"Legs centered under each face carry diagonally braced tower." Engineering News

    Record 24 June 1976: 68-70.

Levine, Marvin. Effective Problem Solving. Englewood Cliffs, New Jersey: Prentice

    Hall, 1988.

Lorant, Richard. "Rebuilding Corporate Compassion." The Seattle Times 11 Dec. 1996.

    Online. Internet. 24 Sep. 1997. Available

    HTTP://www.seattletimes.com/extra/browse/html/mald_121196.html#top.

MacKinnon, Donald M. A Study in Ethical Theory. London: Adam and Charles Black,

    1957.

References

MacQuarrie, Brian. "Community Rallies to Rebuild." The Boston Globe 15 Dec. 1995:

Metro 48. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

MacQuarrie, Brian. "Quiet Heroes Help Pick Up the Pieces." The Boston Globe 13 Dec.

1995: Metro 37. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

MacQuarrie, Brian. "Workers Recall Fire's Fury." The Boston Globe 14 Dec. 1995:

Metro 37. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Marchetti, Michele. "Rising from the Ashes." Sales and Marketing Management Aug

1996: 30+.

Markkula Center for Applied Ethics. "An Approach to Ethical Decision Making."

Online. Internet. Available

HTTP://www.scu.edu/Ethics/practicing/decision/framework.shtml.

Martin, Mike W. and Roland Schwinzinger. Ethics in Engineering. New York:

McGraw-Hill Companies, 1996.

"Methuen's Good Fortune." Editorial. The Boston Globe 13 Dec. 1995: 14. The Boston

Globe Online. Online. Internet. 2 Oct. 1997.

Michelmore, Peter. "One Boss in a Million." Reader's Digest Oct. 1996: 94-99.

"Mill to Draw on Old, New to Rebuild." The Boston Globe 34 Dec. 1995: Metro 34.

The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Milne, John. "Mill Owner Says He'll Pay Workers for a Month." The Boston Globe 15

Dec. 1995: Metro 50. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

"Moral Concepts and Theories." Online. Internet. 11 Nov. 1998. Available

HTTP://ethics.tamu.edu/ethics/essays/moral.htm.

References

Morgenstern, Joe. "The Fifty-Nine-Story Crisis." The New Yorker 29 May 1995: 45-53.

Nyhan, David. "The Mensch Who Saved Christmas." The Boston Globe 17 Dec. 1995: A20. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

O'Brien, Ellen and John Milne. "Explosion, Fire Destroy Methuen Textile Complex. More than 30 Injured, Six Critically; Nearby Residents Evacuated." The Boston Globe 12 Dec. 1995: Metro 1. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Olsen, Shirley A., Ed. Group Planning and Problem-Solving Methods in Engineering Management. New York: John Wiley and Sons, 1982.

Plosky, Eric and Caroline Whitbeck. "The Citicorp Tower and William LeMessurier." Online. Internet. Available HTTP://www.cwru.edu/affil/wwwethics/LeMessurier/lem.html.

"Problem Solving: Identify the Problem, Identify the Solution." Online. Internet. 26 Mar. 1998. Available HTTP://www.businessconnections.bt.com/guides/c34/index.html.

Saltus, Richard. "Team Effort Saved Burn Victims." The Boston Globe 17 Dec. 1995: Metro 45. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Smoot, L. Douglas. Presentation given at the College of Engineering and Technology Ethics Forum. Brigham Young University. Provo, UT, 6 Nov. 1997.

Stein, Charles. "Firm Revived Flagging Industry." The Boston Globe 13 Dec. 1995: Metro 38. The Boston Globe Online. Online. Internet. 2 Oct. 1997.

Stubbins, Hugh. Architecture: The Design Experience. New York: John Wiley and Sons, 1976.

Teal, Thomas. "Not a Fool, Not a Saint." <u>Fortune</u> 11 Nov. 1996. Online. Internet. 20 Sep. 1997. Available HTTP://www.pathfinder.com/@@n8I6kgQADhgCO*yX/fortune/1996/961111/fea.html.

Thiroux, Jacques P. <u>Ethics: Theory and Practice</u>. New York: Macmillan Publishing Company, 1990.

"Tuned mass dampers steady sway of skyscraper in wind." <u>Engineering News Record</u> 18 Aug. 1977: 28-29.

Turner, William. "Philosophy of Immanuel Kant." <u>New Advent</u> (1996). Online. Internet. Available HTTP://www.knight.org/advent.

VanGundy, Arthur B. <u>Creative Problem Solving: A Guide for Trainers and Management</u>. New York: Quorum Books, 1987.

VanGundy, Arthur B. <u>Techniques of Structured Problem Solving</u>. New York: VanNostrand Reinhold Company, 1988.

Vesilind, P. Aarne and Alastair S. Gunn. <u>Engineering, Ethics, and the Environment</u>. Cambridge: Cambridge University Press, 1998.

Viehman, John. "From Ashes to Fleece." <u>Backpacker</u> Mar. 1996: 5.

Ward, Jennifer. "Ethical Theory." Online. Internet. 11 Nov. 1998. Available HTTP://ng.netgate.net/~embier/libr200/jen.html.

Whetten, David A. and Kim S. Cameron. <u>Developing Management Skills</u>. New York: Harper Collins College Publishers, 1995.

Wulf, Steve. "The Glow from a Fire." <u>Time</u> 8 Jan. 1996: 49+.

"300 Malden Mills Workers Return." The Boston Globe 23 Dec. 1995: Metro 21. The

Boston Globe Online. Online. Internet. 2 Oct. 1997.

APPENDIX

The Problem Solving Process

- Define the problem
- Identify needed assumptions
- Identify fundamental principles
- Formulate possible solutions
  - Brainstorming
  - Looking at the extremes
  - Incubation
- Evaluate proposed alternatives
  - Congruity with core values
  - The "Front Page Test"
  - Application of classical ethical theories
  - Comparison of the resultant state with the goal state
  - Decision grid
- Select the best alternative
- Seek a confirmation
- Implement the solution and adjust for unseen complications
- Learn from the experience

Define the problem

Characteristics of the present state	Characteristics of the goal state

Who are the stakeholders and what are their motivations?

- Define the problem
- Identify needed assumptions
- Identify fundamental principles
- Formulate possible solutions
    - Brainstorming
    - Looking at the extremes
    - Incubation
- Evaluate proposed alternatives
    - Congruity with core values
    - The "Front Page Test"
    - Application of classical ethical theories
    - Comparison of the resultant state with the goal state
    - Decision grid
- Select the best alternative
- Seek a confirmation
- Implement the solution and adjust for unseen complications
- Learn from the experience

Define the problem

Should this problem be divided into sub-problems? How might I divide it?

Who might be able to provide me with advice or insight?

How is this problem similar to other problems I have solved? How is it different?

Define the problem

Problem statement:

Identify needed assumptions

What information is unavailable? What assumptions must I make in order to proceed?

•Define the problem

•Identify needed assumptions

•Identify fundamental principles

•Formulate possible solutions

   •Brainstorming

   •Looking at the extremes

   •Incubation

•Evaluate proposed alternatives

   •Congruity with core values

   •The "Front Page Test"

   •Application of classical ethical theories

   •Comparison of the resultant state with the goal state

   •Decision grid

•Select the best alternative

•Seek a confirmation

•Implement the solution and adjust for unseen complications

•Learn from the experience

Identify fundamental principles

Core values that are important to consider in this situation:

Laws, principles, guidelines that apply the important core values:

- Professional society code of ethics
- Commandments of religion
- Laws
- Expectations of society
- Industry regulations

Formulate possible solutions

Brainstorm possible courses of action here.

Important aspects of brainstorming:

• Defer evaluation   • Create as many solutions as possible   • Build on, modify and combine other ideas

Formulate possible solutions

Looking at the extremes

What solutions become apparent when the scope, consequences and complexity of the problem are minimized?

What solutions become apparent when the scope, consequences and complexity of the problem are maximized?

Formulate possible solutions

What new possibilities become apparent after letting the problem incubate for a period of time?

Evaluate proposed alternatives

Looking back at the core values important to the problem, are there any alternatives that do not exhibit all values?
Are there alternatives that apply the values particularly well?

Evaluate proposed alternatives

Look at each alternative and ask, "How would I feel if a story about this action appeared on the front page of the local paper tomorrow?"

Which alternative best protects the moral rights of individuals?

Which alternative would be most just?

The Problem Solving Process

- Define the problem
- Identify needed assumptions
- Identify fundamental principles
- Formulate possible solutions
  - Brainstorming
  - Looking at the extremes
  - Incubation
- Evaluate proposed alternatives
  - Congruity with core values
  - The "Front Page Test"
  - Application of classical ethical theories
  - Comparison of the resultant state with the goal state
  - Decision grid
- Select the best alternative
- Seek a confirmation
- Implement the solution and adjust for unseen complications
- Learn from the experience

Evaluate proposed alternatives

Which alternative would lead to the best overall consequences?

Which alternative best promotes the common good?

Which alternative would help one develop and maintain a virtuous state of character?

The Problem Solving Process

- Define the problem
- Identify needed assumptions
- Identify fundamental principles
- Formulate possible solutions
  - Brainstorming
  - Looking at the extremes
  - Incubation
- Evaluate proposed alternatives
  - Congruity with core values
  - The "Front Page Test"
  - Application of classical ethical theories
  - Comparison of the resultant state with the goal state
  - Decision grid
- Select the best alternative
- Seek a confirmation
- Implement the solution and adjust for unseen complications
- Learn from the experience

Evaluate proposed alternatives

Examine each alternative to determine how effectively it resolves the problem.
Compare the expected result with the goal state.

Characteristics of the result state	Characteristics of the goal state

•Define the problem

•Identify needed assumptions

•Identify fundamental principles

•Formulate possible solutions

   •Brainstorming

   •Looking at the extremes

   •Incubation

•Evaluate proposed alternatives

   •Congruity with core values

   •The "Front Page Test"

   •Application of classical ethical theories

   •Comparison of the resultant state with the goal state

   •Decision grid

•Select the best alternative

•Seek a confirmation

•Implement the solution and adjust for unseen complications

•Learn from the experience

Evaluate proposed alternatives & select the best one

Choose a set of suitable criteria with which to compare the alternatives and rate the solutions.
For each criterion, assign the highest number to the solution that best meets the criterion.
After completing the comparisons for all the criteria, total the rows and select the solution with the highest score.

CRITERIA

TOTAL

SOLUTION ALTERNATIVES

Seek a confirmation

Seek a confirmation from God regarding the correctness of the decision.

Implement the solution

As the solution is implemented, adjust for unseen complications that could affect the resolution.

Learn from the experience

After a successful resolution has been realized, look back at the experience to determine:

- What can I learn from this experience?
- What got me into this problem in the first place? How could I avoid such situations in the future?
- What, if anything, would I do differently if faced with the same dilemma again?
- How do I feel about having resolved this dilemma?