Changing the Paradigm for Engineering Ethics

Jon Alan Schmidt, PE, SECB
Associate Structural Engineer, Aviation & Federal Group
Burns & McDonnell Engineering Company, Inc.
P.O. Box 419173, Kansas City, MO 64141-6173 USA
Phone: 01-816-822-3373 / Fax: 01-816-822-3415
Email: JonAlanSchmidt@gmail.com

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ABSTRACT

Modern philosophy recognizes two major ethical theories: deontology, which encourages adherence to rules and fulfillment of duties or obligations; and consequentialism, which evaluates morally significant actions strictly on the basis of their actual or anticipated outcomes. Both involve the systematic application of universal abstract principles, reflecting the culturally dominant paradigm of technical rationality. Professional societies promulgate codes of ethics with which engineers are expected to comply (deontology), while courts and the public generally assign liability to engineers primarily in accordance with the results of their work, whether intended or unintended (consequentialism). A third option, prominent in ancient philosophy, has reemerged recently: virtue ethics, which recognizes that sensitivity to context and practical judgment are indispensable in particular concrete situations, and therefore rightly focuses on the person who acts, rather than the action itself. Beneficial character traits—i.e., virtues—are identified within a specific social practice in light of the internal goods that are unique to it. This paper proposes a comprehensive framework for implementing virtue ethics within engineering.

INTRODUCTION

All engineers are familiar with the codes and standards that govern their work. For structural engineers, this includes the International Building Code (ICC 2012) and its referenced standards for minimum loads (ASCE 2010), concrete design (ACI 2011) and steel design (AISC 2010). Printed editions require a considerable amount of paper—nearly four thousand pages just for these four publications—and additional volumes provide the design criteria for additional materials and situations. Other disciplines of engineering are similar; the amount of relevant technical information is far beyond what any individual could reasonably be expected to memorize. As a result, engineers must refer to such documents on a regular basis, reflecting their importance for engineering practice.

Engineers are also generally familiar with the codes of ethics that various professional societies have promulgated, such as the one adopted by the American Society of Civil Engineers (ASCE 2006). Consisting of four fundamental principles, seven canons and various guidelines to practice, it fits on a total of just six pages. Perhaps it would be reasonable to expect engineers to memorize it—if not in its entirety, then at least the core statements that appear on the first page. However, it is doubtful that very many engineers have taken this step; in fact, it seems unlikely that very many engineers even feel the need to refer to the code of ethics on a regular basis. Does this reflect its (un)importance for engineering practice?

The eyes of a lot of engineers probably glaze over when they read or hear the words, "engineering ethics." Many jurisdictions require a certain amount of continuing education in ethics for every renewal, and anecdotal evidence suggests that many engineers find this to be annoying, tiresome and a waste of time and money. Perhaps at least part of the problem is confusion about what is meant by engineering ethics. Is it simply a set of rules to follow or a group of behaviors to avoid? Or could there be more to it than that?

As the title of this paper indicates, I advocate changing the paradigm for engineering ethics. The goal is to develop a way of thinking about and implementing ethics that is more consistent with the realities of engineering practice than what is found in much of the current literature.

I begin by explaining what a paradigm is and examining the current paradigm for philosophy in general. I then question whether its emphasis on technical rationality produces an accurate picture of engineering. Next I cover the current paradigm for ethics in particular, which includes two modern approaches: deontology and consequentialism. At that point I introduce an alternative with ancient roots, virtue ethics, and argue that it is much better suited for application to engineering. Finally, I lay out a specific framework for engineering ethics that I have developed accordingly, by exploring what it means to be virtuous engineers.

PARADIGMS IN PHILOSOPHY

The notion of a paradigm should be at least somewhat familiar to most people; in particular, the concept of a "paradigm shift." Kuhn (1962) gave the term its modern sense, defining a paradigm as a specific way of viewing reality—a set of assumptions shared by all practitioners within a particular discipline that effectively dictates what will be observed, what questions will be asked and answered, how such investigations will be carried out, and how their results will be interpreted.

What Kuhn called "normal science" proceeds in strict accordance with these presuppositions. Well-integrated members of the discipline are so immersed in the dominant paradigm that the mere possibility of alternatives is summarily dismissed, if it ever occurs to them at all. This is especially true when there seems to be overwhelming experimental evidence confirming the paradigm. However, if there are anomalies—new phenomena that are inconsistent with the paradigm—then a tension begins to develop in the field.

The first response is usually to make minor adjustments to the paradigm to account for the anomalies. Eventually, though, this may become untenable. Scientific revolutions happen when someone introduces a radical new way of looking at the world that better fits the available data. A paradigm shift takes place when the discipline as a whole embraces this change. A standard example is the transition from Newtonian physics to the theory of relativity in the early 20th century, even though—as Kuhn later acknowledged—this account is a bit oversimplified; after all, Newtonian physics is still quite useful to most engineers, since they generally deal with velocities that are a tiny fraction of the speed of light.

Addis (1990) applied the same approach to the history of engineering. He identified several "design revolutions," including the ancient Greek orders, Gothic cathedrals, truss analysis and plastic design. Structural engineers in the United States are still in the midst of a paradigm shift today, from allowable stress design (ASD) to load and resistance factor design (LRFD).

So what is the currently dominant paradigm in philosophy? That might seem like a rather esoteric inquiry, but it turns out that modern philosophical thought has had considerable influence on modern society and culture—including the engineering profession. Some helpful context is provided by going all the way back to the ancient Greeks. They generally identified three different kinds of knowledge:

- *episteme*, which is the root of the words epistemic (of or pertaining to knowledge) and epistemology (the study of knowledge), and designates knowledge-that something is the case;
- *techne*, which is the root of words like technique, technical and technology, and designates knowledge-how to achieve a predetermined outcome; and
- *phronesis*, which has not found its way into English at all, and designates knowledge-how to behave in a manner that is contextually sensitive and appropriate.

Each of these pertains to a specific sphere of human activity:

- *theoria*, which is contemplation or thinking;
- *poiesis*, which is production or making; and
- *praxis*, which is (inter)action or doing.

As such, *episteme*, *techne* and *phronesis* also correspond with certain forms of rationality and judgment. However, for the sake of clarity, they will be translated here as theoretical knowledge, technical rationality and practical judgment, respectively. These terms succinctly capture the most fundamental aspects of each category, and defining them in parallel helps to highlight the key distinctions among them.

Theoretical knowledge is propositional in nature and aims at eternal truth. It consists of conceptual beliefs that count as facts when possessed by a person of understanding, who is characterized as intelligent and makes decisions on the basis of evidence grounded in data. It applies primarily in the mental realm, resides in one's memory, and is imparted to a student by a process of instructing.

Technical rationality is procedural in nature and aims at external success. It consists of instrumental abilities that count as proficiencies when possessed by a person of skill, who is characterized as competent and makes decisions on the basis of method grounded in rules. It applies primarily in the physical realm, resides in one's habits, and is imparted to an apprentice by a process of training.

Practical judgment is personal in nature and aims at internal integrity. It consists of ethical dispositions that count as virtues when possessed by a person of wisdom, who is characterized as prudent and makes decisions on the basis of intuition grounded in experiences. It applies primarily in the social realm, resides in one's conscience, and is imparted to a disciple by a process of mentoring.

Many scholars have argued that today's culture has largely collapsed theoretical knowledge and practical judgment into technical rationality, with the result that the latter is widely regarded as the *only* legitimate form of reasoning. It might seem natural to associate theoretical knowledge with science and technical rationality with craft. However (Dunne 1993, p. 175):

> productive know-how ... is now brought into alignment with the new science, which therefore no longer retains the contemplative aspiration of the old theory. Henceforth the only type of knowledge that really counts ... is precisely that which is given to us by science. Scientific information about the world contains technical imperatives: the formulae for the new technology and modes of production no longer reside in the rules of craftsmen but rather in the corroborated findings of scientists. And so the gulf which had separated theory and production for the Greeks is now eliminated.

Likewise, practical judgment has largely been discredited (Dunne 1993, pp. 187-188):

> The extension of the technical form of rationality has been pursued on the basis of a claim to value-neutrality ... An orientation to efficiency and economy in the organization of means, which is the core of technique, does not in fact, as is often claimed ... stand ready to serve any set of values which is otherwise (non-rationally) decided upon. Rather, by a deeper, though unacknowledged, decision, this orientation is imposed on the organization of practical life as itself the *only* value—even though it is not conceived as a value at all but is granted a privileged status because of its seeming coincidence with the structure of rationality itself.

The upshot is that technical rationality has established a "hegemony" in modern societies. Its allure comes from its perceived objectivity and the apparent mastery over matter that humans have accomplished by employing it, as exemplified by today's technology. Because of this, "it is no longer seen as *a* form of rationality, with its own limited sphere of validity, but as coincident with *rationality as such*" (Dunne 2005).

THE NATURE OF ENGINEERING

On the surface, "technical rationality" with its "orientation to efficiency and economy" sounds like exactly the kind of thinking that engineers utilize all the time. The popular perception—even among engineers themselves—is that engineering is precisely the rational solution of technical problems. There is indeed a rightful place for technical rationality; in fact, "one can grant the validity and indeed the desirability of technicising—even in practical domains—everything that can without loss be technicised" (Dunne 2005).

However, technical rationality is only adequate to the task when the assignment at hand consists of following a detailed series of steps in order to achieve an already specified outcome. Something more is necessary because life "often present[s] us with a problematic situation where there is no discrete problem already clearly labelled as such, so that we might better speak of a difficulty or predicament rather than a problem." When confronting such circumstances, "one is not calculating the efficiency of different possible means towards an already determined end. Rather, one is often deliberating about the end itself: about what would count as a satisfactory, or at least not entirely unacceptable, outcome to a particular 'case'" (Dunne 2005).

This invokes the concept of "satisficing" (Simon 1977) and is relevant because the formulation of engineering problems and their solutions is inherently indeterminate; it routinely involves selecting a way forward from among multiple options when there is no one "right" answer (Addis 1997). Intentionality, rather than rationality, is the operative conscious process (Schmidt 2013). Furthermore, engineering involves reconceptualizing a complex situation to facilitate analysis. In other words, engineering includes problem definition, not just problem solution. Engineers have to convert all of the relevant design criteria—which are often dictated by clients, codes and other external authorities—into the "language," so to speak, of engineering. How do they accomplish this?

One answer is that they use *heuristics*, defined as "anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible" (Koen 2003, p. 28). Classic examples of engineering heuristics include rules of thumb and factors of safety. Why do structural engineers consider the stress in a material that corresponds to 0.2% strain to be its yield strength and base most of their designs on this value? Why do they then typically divide it by 1.67 to determine a member's capacity to resist service loads? The short answer to both questions is: Because it usually works.

In other words, heuristics cannot be "proven" in the absolute sense, but their utilization is legitimately warranted, frequently on the grounds of successful past implementation. In fact, each individual engineer has a unique collection of relevant heuristics at his or her disposal. When these are combined to facilitate "causing the best change in a poorly understood situation within the available resources" (Koen 2003, p. 7), they constitute what Addis (1990) called a "design procedure."

This term is somewhat misleading, because a design procedure does not lead inevitably to a particular outcome. Addis (1990, pp. 45-46) noted "that it is possible to produce very similar structural designs using different design procedures and that similar design procedures can lead to significantly different structures—there is no logical connection between the two." He likened the "acts of creation" in which structural engineers routinely engage to the composition of music, because both involve arranging a limited number of building blocks—for structural engineers, "the beam, the arch, the tie, the shell and so on"—that can be combined in a nearly infinite number of ways.

What, then, guides an engineer to select the appropriate heuristics in a given set of circumstances? The ultimate effect of technical rationality is "disembedding the knowledge implicit in the skillful performance of the characteristic tasks" of an endeavor such as engineering, so that "what is essential in the knowledge and skill can be abstracted for encapsulation in explicit, generalisable formulae, procedures, or rules" (Dunne 2005). This tendency is evident in the trend toward ever more detailed and prescriptive codes and standards, a well-meaning but misguided attempt to ensure competent engineering by providing an increasingly elaborate set of instructions. Can engineering really be reduced to rule-following all the way down?

Research into the nature of genuine competence suggests otherwise. Using a phenomenological approach to study "unstructured" problem areas that, like engineering, "contain a potentially unlimited number of possibly relevant facts and features" produced a plausible model of skill acquisition that includes five distinct stages (Dreyfus and Dreyfus 1986, pp. 20ff):

- The *novice* complies with strict rules based on context-free features of the task environment.
- The *advanced beginner* recognizes situational aspects of the task environment and follows maxims to adjust his or her actions accordingly.
- The *competent* performer does not try to account for all discrete elements of the task environment, but instead selects a plan, goal or perspective for establishing which of them are relevant and which may be safely ignored.
- The *proficient* performer no longer reflects on the task environment as a detached observer, but sees what needs to be done without having to evaluate multiple options, and then chooses how to go about doing it.
- The *expert* intuitively perceives both what needs to be done and how to do it, making especially subtle and refined discriminations in a variety of task environments that are sufficiently similar to those previously encountered.

The higher levels can only be attained through extensive experience and are characterized by less rational deliberation and greater emotional involvement. "When things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works" (Dreyfus and Dreyfus 1986, pp. 30-31).

A standard example is driving a car. The novice shifts gears based strictly on speed as conveyed by the instrument panel, while the advanced beginner also pays attention to less obvious cues like engine sounds. The competent driver, aware of multiple factors, may *determine* that he is going too fast, and then must decide what to do about it; while the proficient driver *senses* that he is going too fast. Finally, "The expert driver becomes one with his car, and he experiences himself simply as driving, rather than as driving a car" (Dreyfus and Dreyfus 1986, p. 30).

The Dreyfus model is consistent, up to a point, with Koen's heuristics and Addis's design procedures. Formal education primarily imparts rules for the novice, like how to calculate the maximum moment on a simply supported, uniformly loaded beam. Engineer interns become advanced beginners during the first few years of their careers by picking up on maxims such as "least weight does not equal least cost" and their implications.

Over time, engineers develop conscious and unconscious ways of decomposing and solving problems based on what has and has not worked for them. These are not necessarily processes that the engineers can communicate in words; they have become integral to who they are and how they operate. Competence is achieved when an engineer is capable of focusing intuitively on what really matters and converging relatively quickly on a viable solution.

An important constraint to acknowledge is that competence is domain-specific. Even experts inevitably revert to the behavior characteristic of novices and advanced beginners when confronted with unfamiliar circumstances. They must fall back on rules and maxims, because they lack the kind or amount of experience that would enable them to discern the appropriate course of action on their own.

PARADIGMS IN ETHICS

Perhaps this is what happens when engineers encounter the one branch of philosophy that they ordinarily cannot avoid: ethics. As mentioned above, it is typically manifested in *codes of ethics* with which engineers are expected to comply. These relatively straightforward formulations tend to focus on specific things that engineers should and (especially) should not do when carrying out their professional responsibilities. This is probably because the two major types of modern ethical theories are grounded in the dominant philosophical paradigm of technical rationality, and are largely concerned with a person's outward behavior.

First, *deontology* prescribes adherence to particular rules or fulfillment of particular duties or obligations. A commonly cited example is the "categorical imperative" of Kant (1993): "Act only according to that maxim whereby you can at the same time will that it should become a universal law." In other words, one should only take a particular action if it would be beneficial for everyone else to do the exact same thing under comparable circumstances.

An engineering code of ethics usually represents a clear application of deontology, since it explicitly spells out the relevant rules, duties, and obligations. First and foremost is holding paramount the safety, health, and welfare of the public. Other common provisions include performing services only in areas of one's competence, being objective and truthful in public statements, avoiding conflicts of interest, competing fairly, pursuing professional development, and—more recently—embracing sustainability. (ASCE 2006)

Second, *consequentialism*, as its name implies, evaluates a morally significant action on the basis of its actual or expected consequences. Perhaps the most famous version is the utilitarianism of Mill (1906), which advocates always doing whatever will produce the greatest amount of happiness for the greatest number of people. Sustainability may be seen as a more specific form of consequentialism (Elms 1999).

Engineers are frequently judged by society on the basis of the consequences of their work, whether intended or unintended. Furthermore, technical codes and standards are often geared toward consequence-based risk assessment and management, whether explicitly or implicitly. Even so, uncertainty is unavoidable in engineering design, requiring the use of fallible heuristics; yet engineers are still subject to criticism and liability when their judgment calls occasionally, and unfortunately, lead to failures.

Is there an alternative approach that might be better suited to the unique nature of engineering? A third school of thought has ancient roots but is now returning to prominence: *virtue ethics*. It differs from deontology and consequentialism by focusing on the person who acts, rather than the action itself; the emphasis is on *being* good, rather than just *doing* good. Where deontologists argue about which set of commandments to follow and consequentialists debate how various outcomes should be weighted, virtue ethicists have diverse lists of the character traits that they consider to be desirable; in other words, *virtuous*.

There are at least three reasons why virtue ethics is preferable to deontology and consequentialism for engineering ethics. First, the latter are both algorithmic in nature and attempt to impose universal principles that are supposed to govern actions in every situation, while virtue ethics is more heuristic and focuses on developing attitudes. "The combination of character and context does not generate criteria for definitive decisions ... It gives space to personal and professional responsibility, instead of insisting on general outcomes of calculated data" (Procee 1997). Again, engineering is itself heuristic and non-deterministic, requiring creativity and skill to make choices from among multiple options. If engineering practice cannot be reduced to merely following a set of rules, then surely the same is true of engineering ethics.

Second, deontological and consequentialist ethics are "preventive," with a negative orientation; in an engineering context, they are geared toward avoiding professional misconduct and technological disasters, respectively. By contrast, virtue ethics is "aspirational," with a positive orientation; it advocates "the use of professional knowledge to promote the human good." Detailed guidelines and prohibitions "cannot adequately account for the place of discretion, judgment, and background knowledge in meeting some professional obligations," let alone the "internal, motivational, and often idealistic element present in professional life" (Harris 2008).

Third, engineers are in constant danger of forgetting that their primary goal is not technical ingenuity in itself, but helping people: "At its best, engineering changes the world for the benefit of humanity" (Bowen 2010). The problem is that both space and time often separate engineers from those affected by their work, who are thus perceived as populations, rather than individuals; and accountability is commonly diffused within an organization, rather than vested in a single person. Impersonal ethical systems like deontology and consequentialism only exacerbate this disconnect.

Recognizing the potential desirability of applying virtue ethics to engineering, how should one go about doing so? Most contemporary proponents hold that virtues can only be properly identified within the context of a particular *practice*. By this is meant "any coherent and complex form of socially established cooperative human activity through which goods internal to that form of activity are realized in the course of trying to achieve those standards of excellence which are appropriate to, and partially derivative of, that form of activity" (MacIntyre 1981, p. 187). Along similar lines, a practice may be described as follows (Dunne 2005):

> a coherent, complex set of activities that has evolved cooperatively and cumulatively over time, that is alive in the community who are its practitioners, and that remains alive only so long as they remain committed to sustaining—and creatively developing and extending—its internal goods and its proper standards of excellence (this commitment constituting them *as* a community).

It is important to note that according to both of these definitions, a genuine practice—consistent with the ancient Greek category of *praxis*—must have a significant social dimension, as well as internal goods that are pursued as ends in themselves. However, the reputation of the engineering profession is such that most people would likely assume that it does not meet either of these requirements. The common perception—even among engineers—is that engineering is primarily a matter of technical problem-solving and design by solitary individuals, and that the chief function of an engineer is to devise the most efficient means to achieve an end that is specified by someone else.

THE SOCIAL ASPECT OF ENGINEERING

Trevelyan (2010) challenged the first of these misconceptions, instead characterizing engineering as fundamentally a "human social performance" that "relies on harnessing the knowledge, expertise and skills carried by many people, much of it implicit and unwritten knowledge. Therefore social interactions lie at the core of engineering practice."

Trevelyan's research consisted primarily of interviews with and observations of "engineers in all major disciplines, experience levels, and types of business." He was surprised to discover how frequently they were "relying on others to perform some work or provide information ... These were mostly one-on-one situations with little or no formal authority ... [which] led to the conclusion that securing willing and conscientious cooperation is an important part of coordination" (Trevelyan 2010). Separately, Trevelyan also surveyed 180 novice engineers and found that they spent about sixty percent of their time engaging directly with other people, a figure that is remarkably consistent with results from similar studies of seasoned veterans.

Despite this, engineers persistently label tasks like performing analysis and preparing calculations as "doing engineering," and generally marginalize other aspects of practice. This is important because "people tend to devote more effort to activities congruent with their current identity" (Trevelyan 2010), and engineering failures can usually be traced to social breakdowns, rather than technical mistakes. Engineers constantly face time, information, and resource constraints, and thus must routinely make rapid and difficult choices in an effort to satisfy many diverse demands. In doing so, they confront not only the uncertainties inherent in nature and materials, but also the often greater unpredictability of their fellow human beings.

This is precisely why engineering requires the exercise of practical judgment—not just theoretical knowledge and technical rationality, although those are also indispensable. In fact, engineering seems like a good candidate to serve as an example of a field that clearly encompasses all three categories. The problem is that modern societies are increasingly attempting to organize and regulate human behavior strictly in accordance with technical rationality—and engineering is by no means exempt from this trend. This raises an important rhetorical question (Dunne 2005):

> In certain respects technical rationality seems to accord with the fabric of the material universe ... However, does the attempt to impose it on the very different reality of human practices spring from a considered understanding of this reality itself, or from an *a priori* enthusiasm (even obsession) to have in these areas the same kind of standardisation and control which, partly through technical rationality, we have in our dealings with some aspects of the material universe?

The implied answer is the second option. The same subconscious desire may also explain why engineers largely relegate the social aspects of their professional lives to "non-engineering" status. Analysis and calculations clearly fall within their "comfort zone," where they normally feel like they have a firm handle on things. The same is true even for more creative tasks like conceptualization and modeling.

Dealing with people is a different story. A person then encounters "volatile constellations of human passions and motivations" and "intervenes in a field of forces or immerses herself in a medium in which she seeks to bring about a propitious result." Our actions are "inserted in a web of interaction, with its own power and limits conditioned by its capacity to mesh with—without manipulating—the actions of *other* agents." Furthermore, "To acknowledge these points is to recognize the frailty and intricacy of human affairs—or, what amounts to much the same thing, the non-sovereignty of the single agent" (Dunne 2005).

Along similar lines, Trevelyan (2010) further described the engineering enterprise as "a combined performance" carried out by a wide variety of stakeholders in which "the engineer's role is both to compose the music and conduct the orchestra." This is a helpful metaphor, because composers and conductors provide definitive guidance to those who actually play the instruments, but cannot directly dictate precisely how they do so once the baton is raised.

Likewise, "an engineer has to ensure that everyone involved has sufficient understanding of the essential features that will create value to ensure that they are faithfully implemented and reproduced by other people" (Trevelyan 2010). This last comment is interesting, because it implies that the engineer is the one who best knows how to "create value" and is then responsible for communicating this to "everyone involved"—again suggesting that engineering has a significant social dimension, in this case involving those outside the profession as well as those within it.

THE PROPER PURPOSE OF ENGINEERING

What about the second criterion for engineering to qualify as a practice or *praxis*? *Internal* goods are precisely those ends that are specific to a practice, can only be fully understood by those who participate in that practice, and generally benefit the entire practicing community. A *virtue* is then "an acquired human quality the possession and exercise of which tends to enable us to achieve those goods which are internal to practices and the lack of which effectively prevents us from achieving such goods" (MacIntyre 1981, p. 191). By contrast, *external* goods can be attained in a variety of ways, including different practices, often involving competition that leaves both winners and losers. Familiar examples include money, power, and status.

Although any practice requires a set of technical skills and the existence of institutions to sustain it over time, it is identical to neither of these. Every practice has its own history that goes beyond merely improving technical skills and serves as a tradition from which anyone who enters it must learn. Institutions are generally concerned with acquiring and distributing external goods, which is why virtues are so important—without them, the institutions' pursuit of external goods will eventually supplant the practice's pursuit of internal goods, corrupting and ultimately destroying the practice (MacIntyre 1981).

This relationship between practices and institutions is especially relevant to engineers. Technology and innovation are generally dominated by market-driven value judgments, rather than technical knowledge. Even when managers or clients are engineers by training, the decisions that they make inevitably reflect the agendas and priorities of the organizations that they serve—not necessarily the capabilities and limitations of the engineers that they supervise or retain. As a result, engineering tends to be *instrumental* in nature; it is exploited by non-engineers as a convenient means of achieving their own objectives, which may be quite arbitrary (Goldman 1991).

Engineers might be able to escape this "social captivity," at least partially, by focusing on the goods that are internal to their practice. These are ends "whose intended achievement defines them as the particular practices that they are," including "both competencies proper to each practice and virtues of character that transcend any particular practice." The latter are essential to ensure that the former are not treated merely as means for acquiring external goods, such that "the practice [is] made instrumental to the point that violation of its internal fabric is allowed." A practice is thus "something that can succeed or fail in being true to its own proper purpose" (Dunne 2005).

What does it mean for a practice to have a proper purpose? It turns out that there are actually two different kinds of practices (Miller 1984):

> There is an important distinction to be drawn between practices which have no *raison d'etre* other than the particular excellences and enjoyments which they allow to participants (I shall refer to such practices as 'self-contained') and practices which have a wider social purpose (I shall refer to these as 'purposive'). Games, from which much of MacIntyre's thinking about practices seems to be drawn, are the main exemplars of the first category ... On the other hand, in the case of a

> productive activity ... there is an external purpose which gives the practice its point and in terms of which it may be judged.

In other words, MacIntyre's rigid classification of all goods as either internal or external to any given practice is difficult to maintain if it is one that could be described as purposive. Such a practice has an end that is intrinsic in a way that a strictly external good cannot be; and yet that end also does not qualify as an internal good, since its benefits extend well beyond the boundaries of the practicing community.

Combining the terminology of Dunne (2005) and Miller (1984), what is the proper purpose of a purposive practice? Perhaps the answer is something analogous to, or perhaps equivalent with, the fundamental ideal for which the practice strives; something that its members treat as an end in itself. Physicians pursue health; if humans ever attain perfect health, then doctors would be out of a job. Attorneys pursue justice; if humans ever attain perfect justice, then lawyers would be out of a job. Engineers pursue ... what, exactly? What perfection would humans have to attain in order for engineers to be out of a job?

Mitcham (2009) argued that engineering has no such ideal that is "good in itself" and is well-embedded in its curriculum and practice, characterizing the profession as "philosophically inadequate" on that basis. Although engineers are explicitly charged with holding paramount the safety, health, and welfare of the public, they are not especially qualified to determine exactly what satisfies that obligation. Goldberg (2009) responded to this assessment, claiming that Mitcham was merely reacting to the ethical complexity of engineering. It is true that strictly serving a manager's or client's interests will not always align naturally with serving the interests of society as a whole, but this does not entail that engineering does not have a proper purpose at all.

Invention in general, as well as engineering innovation in particular, is driven primarily by dissatisfaction with the current state of affairs (Petroski 1992). Would engineers be out of a job if humans ever attain perfect satisfaction? Presumably, but is satisfaction really an ideal on par with health and justice? Contentment might seem like a more suitable concept from that standpoint—except that contentment is supposed to be independent of outward circumstances, and engineering deals exclusively with outward circumstances.

A better candidate might be quality of life. Would engineers be out of a job if humans ever attain a perfect quality of life? Probably, but practitioners other than engineers—including physicians and attorneys—can and do contribute to quality of life, as well. Furthermore, even within engineering, improving the quality of life for some people may diminish that of others; in fact, such tradeoffs are routine in the real world.

The ancient Greeks would insist that the proper purpose of any worthwhile activity is to facilitate some aspect of *eudaimonia*, a word that is usually equated with happiness but is best translated as well-being or human flourishing. Favorable physical, social, and material conditions can be important factors for living a genuinely good life, and various practices are engaged in providing and maintaining such conditions. With this in mind, Bowen (2010) described the end of engineering as "the promotion of human flourishing through contribution to material well-being."

Ashvin Shah (personal communication, January 2, 2012) has echoed this, suggesting that the proper purposes of medicine, law, and engineering are physical, social, and material well-being, respectively. It is important to stipulate that the scope of well-being that these practices should foster is universal; i.e., engineers ought to work toward the material well-being of *all* people, not just a privileged group (Miller 1984):

> If a "practice" account of the virtues is going to be successful, the practices concerned must be those I have called purposive, and moreover those whose aims are fairly central to human existence. By implication it is a mistake to try to explain the virtues by reference to goods *internal* to practices. Although MacIntyre is quite right to draw our attention to the existence of such goods—for even in the case of purposive practices standards of excellence will develop whose achievement will be regarded as an internal good by the participants—the virtues themselves must be understood in relation to those wider social purposes which practices serve.

This requires a significant adjustment of MacIntyre's approach to virtue ethics. The proper purpose of a purposive practice constrains what will count as its internal goods, since the latter must tend to advance the former in some way. Likewise, the personal traits that enable someone to achieve the internal goods of a purposive practice only qualify as virtues if they also facilitate the accomplishment of its proper purpose. Consequently, the internal goods and virtues that are specific to the practice of engineering must be ends and attributes, respectively, that uniquely contribute to the material well-being of all people.

THE SOCIETAL ROLE OF ENGINEERING

What exactly is "material well-being" in this context? How do engineers bring it about? For one thing, "Engineering projects provide us with the technological means of overcoming some of the physical limitations that are a consequence of being human." Engineering is thus "a profession that seeks to harness technological advancements to provide solutions to a wide range of social problems" (Ross and Athanassoulis 2010). Note that material well-being, here characterized as technological advancement, is not strictly separate from physical and social well-being; instead, it facilitates both in a particular way.

Because of this, there is a specific aspect of engineering that is crucial to understanding the peculiar ethical burden that engineers bear (Ross and Athanassoulis 2010):

> Engineering projects are often innovative, long-term and involve the co-ordination of so many different variables that it is impossible to predict absolutely accurately what their consequences will be. In addition, because of the scale, and infra-structural nature of these projects there is often significant potential to do harm should something go wrong.

The engineer thus assumes a responsibility to determine which dangers are pertinent to each undertaking, decide how best to deal with them in spite of the "three enemies of knowledge"—ignorance, uncertainty, and complexity—that are associated with them (Elms 1999), and inform everyone who needs to become aware of them. In other words, the basic societal role of engineering is the assessment, management, and communication of *risk*—the very real possibility that engineered projects and products could *detract* from the material well-being of *some* people, rather than *enhancing* the material well-being of *all*.

The concepts of risk and responsibility, as well as the relationship between them, can be somewhat ambiguous. For example, there are at least five relevant senses of the word "risk" in common usage today (Hansson 2009):

- A harm that may or may not occur.
- The cause of a harm that may or may not occur.
- The probability of a harm that may or may not occur.
- The statistical expectation value of a harm that may or may not occur.
- The fact that a decision is made when the outcome probabilities are known.

The use of "harm" in place of more generic language, such as "unwanted event," better reflects the connotation that "risk" usually carries (Möller 2012). The first three definitions are often assigned to different terms—such as consequence, hazard, and threat or vulnerability, respectively—and treated as contributors to the fourth, which is the standard technical meaning of "risk" among engineers and risk analysts. The fifth is only invoked in formal decision theory, where "decision under risk" is an alternative to "decision under certainty," when each option is associated with exactly one outcome, and "decision under uncertainty," when outcome probabilities are unknown. All five acknowledge the indeterminate nature of risk; even when quantified, it reflects a degree of belief, rather than a legitimate fact (Elms 1999).

The idea of "risk" is even more nuanced in fields such as psychology and social science. In particular, contextual elements come into play, which may include "by whom the risk is run, whether the risk is imposed or voluntary, whether it is a natural or man-made risk, and so on" (van de Poel and Nihlén Fahlquist 2012). It is precisely these kinds of factors that imply at least some degree of responsibility on the part of those who confront it on behalf of others—such as engineers.

As for what is meant when referring to such responsibility, there are at least nine distinct notions (van de Poel 2011):

- Cause – The earthquake was responsible for killing 100 people.
- Role – The driver is responsible for controlling the vehicle.
- Authority – The superintendent is responsible for the construction project.
- Capacity – The person has the ability to act in a responsible way.
- Virtue – The person has the disposition to act in a responsible way.
- Obligation – The person is responsible for the safety of the passengers.
- Accountability – The person is responsible for explaining what he/she did.
- Blameworthiness – The person is responsible for what happened.
- Liability – The person is responsible for the cost of the damages.

The first four are strictly descriptive, while the other five are normative; and of those, virtue and obligation are forward-looking (prospective), while the last three are backward-looking (retrospective). Philosophers throughout history have mostly addressed *retrospective* responsibility, especially blameworthiness; in particular, the necessary and sufficient conditions for someone to be properly held responsible for something that has already occurred.

However, engineering ethics is—or at least should be—more concerned with the *prospective* responsibility of engineers who assess, manage, and communicate risk in an effort to *avoid* harms; in other words, a combination of authority, capacity, virtue, and obligation. The idea is to "prevent risks from materializing instead of distributing responsibility when it has already materialized," requiring those involved to be "virtuous-responsible people who use their judgment to form a balanced response to conflicting demands" (Van de Poel and Nihlén Fahlquist 2012). In other words, virtuous engineers are responsible engineers.

THE INTERNAL GOODS OF ENGINEERING

Admittedly, "it would be convenient if there was a formula for making good and right decisions about whether, when, and what to risk." This is essentially what the dominant modern ethical theories purport to offer: definitive guidance derived from universal principles, such as assumed duties and obligations in the case of deontology, or assessment of potential outcomes in the case of consequentialism. By contrast, virtue ethics recognizes that any truly substantive ethical inquiry will lead to "a complex, varied, and imprecise answer that cannot be captured in an overriding rule" (Ross and Athanassoulis 2012).

Consequentialism is especially deficient in this regard. Evaluations based only on what ultimately happens ignore the contributions of luck; for example, "avoiding the consequences of one's recklessness does not make one any less responsible for it." The alternative of assigning prior probabilities can easily become arbitrary, and even when there is agreement on the numbers, the subsequent utilitarian calculation often "clashes with our sense of fairness with respect to the equitable distributions of the burdens of risk taking." Furthermore, it "does not allow room for differentiating between the bearers of risks and benefits," who may not be one and the same. (Ross and Athanassoulis 2012)

In fact, people participate in any instance of risk-taking in three ways: as the decision-maker, as the potential harm-bearer, or as the intended beneficiary (Athanassoulis and Ross 2010). It is not morally problematic when a single person occupies all three positions, but for engineering risks, multiple parties are always implicated—the engineer makes the decision, the public is often in harm's way, and the engineer's employer or client presumably stands to gain something. Under such circumstances, what factors influence whether the risks associated with a given engineering decision—presumably encompassing the potential outcomes, their corresponding likelihoods, and relevant contextual features (Elms 1999)—are reasonable, and therefore justifiable?

The widespread assumption that this is purely a matter of "objective" probabilistic calculation should be rejected. Instead, a number of "subjective" considerations must also come into play, including the desires and priorities of the engineer, different perspectives on how to describe various outcomes should they come about, and the range of available options (Ross and Athanassoulis 2010). Virtue ethics shifts the focus from *individual* actions to *patterns* of behavior—"choices that people make, those choices that are reaffirmed over time, and those choices that express their deeply held values and beliefs" (Ross and Athanassoulis 2012).

The primary concern is thus with someone's long-term *attitude* toward risk, especially with respect to the potential impacts on the well-being—material and otherwise—of others. The central concept here is *character*, defined as "the set of stable, permanent, and well-entrenched dispositions to act in particular ways" (Athanassoulis 2005). These dispositions qualify as *virtues* when they enable and incline someone "to respond well to whatever situation is encountered" (Ross and Athanassoulis 2012), which usually entails having "a clear and accurate view of the situation" and producing "a proportionate, rational response" (Athanassoulis and Ross 2010).

What subsequently transpires may not be entirely within the person's control, so what matters from an ethical standpoint is the quality of the decision at the time when it is made, rather than the effects that emerge from it afterward. Therefore, "the assignment of moral responsibility for risk-taking and for the results of risk-taking needs to be done on a case by case basis" (Ross and Athanassoulis 2010).

This is not to say that engineering ethics is consigned to a form of relativism. On the contrary, "engineers, like other professionals, have distinctive reasons to take or refuse to take risks that they acquire by being members of their particular profession." They share a common consensus—although they rarely articulate it—about what they do and how it fits into the bigger picture (Ross and Athanassoulis 2010)`:

> It is our contention that the chief good internal to the practice of engineering is safe efficient innovation in the service of human wellbeing and that this good can only be achieved where highly accurate, rational decisions are made about how to balance the values of safety, efficiency

> and ambition in particular cases ... engineers don't just strive to find technological solutions to human problems, they strive to do so in a manner fitting for the conduct of an engineer which involves consciously foregrounding the values of safety and sustainability.

This passage invokes the notion of an internal good and connects it directly with engineering's proper purpose. However, the references to "values" seem out of place, and the attempt to pinpoint a single internal good is needlessly restrictive. Instead, upon rearranging the terminology, three such goods emerge:

- safety – protecting people and preserving property;
- sustainability – improving environments and conserving resources; and
- efficiency – performing functions while minimizing costs.

These three distinct aspects of material well-being and risk mitigation are goals inherent to some degree in nearly every engineering endeavor today. Engineers can—and regularly do, even if only subconsciously—treat them as ends in themselves, rather than as means to some other end. They qualify as goods that are internal to the practice of engineering because they are specific to it, can only be *fully* understood as defined here by those who participate in it, and generally benefit the entire practicing community.

Even so, it is important to acknowledge that safety, sustainability, and efficiency may be—and in fact, frequently are—in tension with each other to some extent. Most notably, "decisions about risk made by engineers require them to weigh their concerns about risk against economic considerations ... the demands of efficiency and safety/minimisation of risk tend to conflict" (Ross and Athanassoulis 2010). Similarly, "it is difficult to apply sustainability principles in a competitive commercial environment ... If sustainability can give a market edge or can be shown to produce a cheaper alternative, then it is acceptable, otherwise its application is difficult to achieve" (Elms 1999).

THE MORAL VIRTUES OF ENGINEERING

The question then arises: What personal attributes would enable someone to make the necessary trade-offs among these internal goods without inappropriately compromising any of them? Finding the answer requires once again taking into account the fact that the practice of engineering serves a wider social purpose. If the proper purpose of engineering is the material well-being of all people, and if its basic societal role is the assessment, management, and communication of risk, then its moral virtues must be grounded accordingly. After all, the risk-taking aspect of engineering is precisely what makes it such a morally significant endeavor, especially since the perspective of the potential harm-bearer carries greater ethical weight than that of the decision-maker.

As a result, it is not simply up to engineers to define the limits of their own responsibility; instead, the public understandably *assigns* particular responsibilities to them. Acknowledging these "ascribed obligations" would be beneficial for engineers, "not because they provide pre-formed rules that engineers can blindly follow, but because they can be used to help engineers develop a capacity for moral imagination" (Busby and Coeckelburgh 2003).

The first step is to admit that "the picture of engineering as morally neutral is misleading" (Busby and Coeckelburgh 2003). It is true, as discussed above, that engineers are not completely autonomous and rarely have the authority to establish on their own the degree of risk that is acceptable for a given assignment. The consensus process by which most technical codes and standards are developed today provides opportunities for all stakeholders—engineers and non-engineers alike—to have a say in establishing the overall baseline level.

However, this does not absolve engineers from also taking risk into account on a case-by-case basis—especially its moral dimensions (Coeckelburgh 2006). In fact, the current trend toward more complex and prescriptive design criteria carries its own risks, which may be easily overlooked (Bulleit 2012). For example, "if codes deal with failure in ordinary and foreseen circumstances, then the real task of the designer is to deal with the extraordinary" (Elms 1999). Instead of only asking, "How can I justify the design that I want to develop?" engineers should also wonder, "How can I find the design that reasonably minimizes risk?" (Busby and Coeckelburgh 2003)

There are at least three motives for engineers to embrace this kind of "ascribed ethics." First, people generally behave in accordance with their expectations, so understanding common presuppositions about engineers and (especially) engineered systems may help better inform the design process. Second, non-engineers perceive risks that engineers, precisely because of their specialized expertise, are not in the habit of noticing. Third, and most important, "The ability to imagine the implications of one's actions, such as taking risks with others' welfare in one's product design ... [is] as important to morality as any general principle" (Busby and Coeckelburgh 2003).

How can following an approach along these lines facilitate deriving the moral virtues that are specific to engineering? In the *Nicomachean Ethics*, Aristotle (1984) advocated locating most virtues at the mean between corresponding extremes of excess and deficiency that are deemed to be vices. With this in mind, adopting the standpoint of those put at risk by engineering endeavors in order to identify the types of behavior that engineers ought to avoid may lead to insights about those to which they should aspire.

It seems logical to begin with three specific virtues that are widely viewed as prerequisites for *all* practices: justice, courage, and honesty. Without them, internal goods of any kind are ultimately unattainable, because these characteristics are integral to the types of relationships that must be maintained among the participants in a practice (MacIntyre 1981, p. 191):

> It belongs to the concept of a practice as I have outlined it ... that its goods can only be achieved by subordinating ourselves within the practice in our relationship to other practitioners. We have to learn to recognize what is due to whom; we have to be prepared to take whatever self-endangering risks are demanded along the way; and we have to listen carefully to what we are told about our own inadequacies and to reply with the same carefulness for the facts.

Justice is necessary because the authority of the standards of excellence that define a practice must be accepted by all who enter into it, along with the inadequacy of their initial performances when measured by those standards. Courage is necessary because the willingness to sacrifice is a component of genuine care and concern for others, and pursuing internal goods may sometimes require foregoing external goods. Honesty is necessary because trust is indispensable, not only among practitioners, but also between them and the general public—especially in a practice like engineering that involves significant uncertainties.

The picture becomes a bit clearer when we recognize how these three virtues apply within the specific practice of engineering. Justice precludes both favoritism and indifference; every single person who will potentially be affected by what an engineer does deserves due consideration. Courage calls for being neither overconservative nor overconfident; engineers must "balance degrees of caution and (social) ambition that are appropriate to the circumstances and nature of [their] decisions" (Ross and Athanassoulis 2010). Honesty means eschewing both deception and indiscretion; respect for confidentiality must be balanced with the public interest.

Moriarty (2009) proposed a similar trio of virtues even more closely tailored to engineers. Objectivity is a stance of impartiality or fairness that diligently examines all relevant factors, and ultimately resolves each matter on the merits. Care entails assuming personal concern for another, and then instinctively doing whatever the situation demands accordingly. Honesty encompasses cooperation and transparency, as well as truthfulness.

In light of the usual connotations of "objectivity" and "care," it may appear at first glance that these two dispositions are incompatible. Moriarty (2009, p. 243) was aware of this and explicitly downplayed the association of objectivity with "coldness, lack of emotional involvement, bureaucracy ... To be objective is not to be aloof, uninvolved, or uncommitted. It is to be disinterested rather than uninterested." This notion of objectivity is perfectly consistent with the kind of empathy that care demands, and that engineers ought to cultivate (Busby and Coeckelburgh 2003).

Other emotions also come into play: "Decisions about risk that proceed from a good character involve emotional responses, which are integral to firm and stable dispositions to virtue … The person of practical wisdom is someone who has the appropriate emotions, to the right degree at the right time" (Ross and Athanassoulis 2012). Such sentiments may seem out of place when talking about engineering; after all, engineers generally view themselves—and are widely viewed by others—as paragons of unbiased analysis and dispassionate design. But is this an accurate picture? And if so, should it be?

The answer is obvious if, in fact, the moral virtues of engineering include not only objectivity and honesty, but also care. Is it possible for engineers to demonstrate real care for the people who will be affected by their work while not experiencing any feelings toward them whatsoever? Can they be completely indifferent and still truly "hold paramount the safety, health, and welfare of the public" as stipulated by the most fundamental canon in their codes of ethics (ASCE 2006)? On the contrary, it seems that emotions ought to play a more explicit and conscious role in engineers' decision-making about risk (Roeser 2012).

Of course, the attributes of objectivity, care, and honesty are hardly exclusive to engineering; perhaps there is nothing more to being a virtuous engineer than being a virtuous person in general who happens to be an engineer. While this is accurate to an extent, Miller's insight about purposive practices leads to the realization that Moriarty's three moral virtues of engineering naturally align with the three components of its societal role. Virtuous engineers *objectively* assess risk, *carefully* manage risk, and *honestly* communicate risk in order to achieve safety, sustainability, and efficiency for the sake of the material well-being of all people.

THE INTELLECTUAL VIRTUE OF ENGINEERING

But how does this happen in spite of the potential for conflicts among the individual goods or virtues in each list? For one thing, recall that engineering involves the exercise of skill. Rules and maxims can help novices and advanced beginners learn to incorporate safety, sustainability, and efficiency into their designs; but it takes someone who has enough experience to be at least competent, if not proficient, to do so consistently. Successfully integrating all three could be seen as the mark of a true expert.

Many philosophers, going all the way back to the ancient Greeks, have drawn a strong analogy between virtues and skills (Stichter 2007); so the same terminology can be applied to engineers who characteristically exhibit objectivity, care, and honesty in the proper proportions. Ethical competence should be seen as an essential component of technical competence, such that it is impossible for an engineer to be both competent and unethical at the same time.

Engineers internalize their practice-specific goods and virtues to the point that they are able to balance them rightly in particular cases, having developed "a reliable capacity to respond to risk with the appropriate attitude." Evidently, "professionals acquire, through training and thought, settled dispositions to judge in accordance with their distinctive professional values and thus can be said to exemplify a kind of professional practical wisdom" (Ross and Athanassoluis 2010)—in other words, *phronesis*. This produces "a state in which the faculties of perception, motivation, thought, and reason seamlessly interact" to discern the relevant contextual features and properly take them into account (Ross and Athanassoulis 2012).

Such practical judgment is manifested as "the cultivated capacity to make [particular judgment 'calls'] resourcefully and reliably in all the complex situations that they address," as well as "an ability to recognise situations, cases or problems ... and to deal with them adequately and appropriately" (Dunne 2005). This notion appears to be closely related to a faculty that engineers constantly take for granted but rarely try to explain: engineering judgment. It is widely understood to be so critical that "[o]ne who otherwise knows what engineers know but lacks 'engineering judgment' may be ... a handy resource much like a reference book or database, but cannot be a competent engineer" (Davis 2012).

Judgment in this sense is "the *disposition* (including the ability) to *act* as competent members of the discipline act." It involves more than just theoretical knowledge-that or even technical knowledge-how; it is "the embodiment of a high likelihood of making certain decisions in the appropriate way at the appropriate time" (Davis 2012). Such judgment is neither arbitrary nor algorithmic, and the reference to peers as the benchmark is consistent with the legal notion of the standard of care: "that level or quality of service ordinarily provided by other normally competent practitioners of good standing in that field, contemporaneously providing similar services in the same locality and under the same circumstances" (Kardon 1999).

Judgment could also be seen as the key to integrating ethics into any discipline that requires it. "Once we see judgment as central to the discipline, we can also see how central ethics is to its competent practice. There is no good engineering, no good science, and so on without good judgment and no good judgment in these disciplines without ethics" (Davis 2012).

However, there is still the matter of which approach to ethics is being applied. Davis (2012) revealed a deontological orientation: "I mean those (morally permissible) standards of conduct (rules, principles, or ideals) that apply to members of a group simply because they are members of that group. Engineers need to understand (and practice) engineering ethics to be good engineers, not moral theory, medical ethics, or the like." This actually makes ethics a matter of technical rationality or *techne*, rather than practical judgment or *phronesis*.

Despite recognizing that engineering judgment, like *phronesis*, is "a disposition to act in an appropriate way," Davis (2012) defined the latter much more broadly as "the ability reliably to respond to any situation with a course of action that makes life better ... *Phronesis* is (more or less) a global term; judgment is not global ... We should speak of the art, craft, or skill of [an engineer] rather than his *phronesis* when he shows good [engineering] judgment."

Nevertheless, Davis (2012) explicitly wondered whether engineering judgment is a virtue, since it admittedly "is a disposition that contributes to living well (both to the engineer's living well and to others living well)." Ultimately, though, he was worried about the limited scope of judgment in this sense: "The traditional virtues (courage, hospitality, truthfulness, and so on) concern the whole of life. No traditional virtue concerns only a single discipline as, for example, engineering judgment does."

This really is not a problem if virtues are situated within distinct practices (MacIntyre 1981). Engineering judgment is, in fact, a discipline-specific form of practical judgment, which the ancient Greeks classified as an *intellectual* virtue—importantly, the one that guides and ultimately unifies the corresponding *moral* virtues. In summary (Moriarty 2009, p. 266):

> *Phronesis* is at work in discerning and choosing appropriate goals of ethical virtue. Thus, ethical virtue without *phronesis* remains directionless. But, discernment of the good and perfection of deliberation are dependent on having good character. Hence, without ethical virtue, one might have cleverness in figuring out the means to any end, but one would not have *phronesis*, the virtue of choosing the appropriate means to the right end.

VIRTUOUS ENGINEERING

This paper has defined the concept of a paradigm, identified the dominant ones in modern philosophy and ethics, questioned their suitability for application to engineering, and offered an alternative framework for understanding and practicing the profession. What remains at this point is to consolidate that description under three headings that correspond to the central concepts in the classical approach to virtue ethics.

***Praxis*: The "What" of Engineering**

First, the social aspect of engineering is such that engineers engage in a combined human performance in which they play a particular societal role: the assessment, management, and communication of risk.

Engineers must convince others to hire or retain them, and then ascertain and attempt to satisfy their expectations for each assignment. Furthermore, research has repeatedly indicated that engineers across all disciplines, career stages, and types of employers spend the majority of their time at work interacting with others. Engineering is thus always a collaborative endeavor, assembling expertise that is distributed among multiple participants; someone whose technical activities are self-motivated and solitary is more accurately labeled as an inventor.

Engineers are the decision-makers in situations where members of the general public are usually the potential harm-bearers, even when they are also supposed to benefit in some way. The latter take it for granted that engineering design adequately accounts for all of the applicable hazards, and thus ascribe to engineers the obligation to mitigate them. Embracing this responsibility entails not only recognizing these uncertainties and dealing with them appropriately, but also calling attention—preferably beforehand—to any residual risk that is associated with an engineered product or project, including anticipated social and environmental impacts.

***Phronesis*: The "How" of Engineering**

Second, engineers exercise the intellectual virtue of engineering, which is practical judgment—specifically, engineering judgment—while exhibiting the moral virtues of engineering, which are objectivity, care, and honesty.

Engineers routinely confront difficulties and predicaments, rather than well-structured problems that have deterministic solutions. Learning theories, rules, and maxims—also known as heuristics and design procedures—provides a necessary and solid foundation. However, it is only through experience that someone can develop the skill to discern quickly what is important in a specific set of circumstances and then select a suitable way forward.

Risk assessment requires *objectively* evaluating the likelihood and severity of possible threats and identifying alternatives for reducing one or both of these parameters. Risk management requires *carefully* deliberating over multiple viable options and choosing one that rightly balances caution and ambition on behalf of all those who may be affected. Risk communication requires *honestly* acknowledging the dangers that cannot reasonably be eliminated and informing everyone who needs to be aware of them.

***Eudaimonia*: The "Why" of Engineering**

Third, engineers strive to fulfill the proper purpose of engineering, which is to enhance the material well-being of all people, by achieving the internal goods of engineering, which are safety, sustainability, and efficiency.

It takes a deliberate decision and ongoing resolve to do this faithfully. Engineers must prioritize it over not only their own immediate interests, but also the external goods that are valued by those who typically make the major decisions and ultimately pay the bills. The prospective reward is the opportunity to escape, at least partially, the "social captivity" that renders engineering largely instrumental, subject to exploitation by managers and clients.

As a step in this direction, engineers can pursue their most fundamental aims—protecting people and preserving property, improving environments and conserving resources, and performing functions while minimizing costs—for their own sake, rather than merely as means to another end. When merged, they constitute an overall notion of quality that engineers seek to incorporate into everything that results from their efforts. Nelson (2012) hinted at this when he wrote that "design is inherently goalless" because the precise outcome is unknown during the process of creating it.

CONCLUSION

Uniting all of these ideas in an arrangement that states what engineers do, how they do it, and why it matters in broad terms, and then presents the details in the reverse order, produces the following concise yet comprehensive statement of their unique and vital contribution to human flourishing:

Virtuous Engineers assert their responsibility
for engaging in a combined human performance
that involves the exercise of practical judgment
to enhance the material well-being of all people
by achieving safety, sustainability and efficiency
while exhibiting objectivity, care and honesty
in assessing, managing and communicating risk.

This formulation is not intended to replace the codes of ethics that engineering organizations have developed over the years. Instead, it complements them by offering an aspirational vision of what it looks like for an engineer to practice with genuine integrity. Virtue ethics is less concerned with what someone has done and will do than with what kind of person—what kind of engineer—someone is now and will become in the future. The goal is not so much better engineering decisions, but rather better engineering decision-makers; that is, better engineers.

Fortunately, adopting virtue ethics is unlikely to require engineers to change radically what they are already doing on a day-to-day basis. Deontology and consequentialism effectively treat ethics as something that engineers pursue separately from engineering itself. By contrast, a virtue perspective affirms that ethics is fully integral to the profession. This is captured by the following assertion directed at any engineers reading this paper: Your practice *is* your ethics!

If being an engineer is inherently virtuous in this sense, then the assignment going forward is simply to be a little more intentional about it. For example, perhaps engineers could start spending the first five minutes of every work day contemplating who will potentially be affected by their efforts; the risks to which they are subjecting them; and how they anticipate assessing, managing, and communicating those risks on their behalf. This exercise could be especially effective if engineers allow their moral imaginations to engage their emotions along the way.

Finally, the framework outlined here addresses two common and related complaints within the engineering profession: that people do not really understand or appreciate engineers, and that engineers' social and political influence is not what it could be or should be. Conscientiously living as virtuous engineers will likely improve the collective status of the profession and enable its members to assume a more prominent position of leadership in today's technologically advanced culture.

The approach to engineering ethics set forth in this paper is still a work in progress. I invite reflective engineers, philosophers, and other interested parties to collaborate with me in refining and implementing it at www.VirtuousEngineers.org. Issues that need to be addressed include the following:

- Confirming that the proper purpose of engineering is the material well-being of all people and defining what all this encompasses, or exploring possible alternatives.
- Clarifying which specific definitions of risk represent what society relies on engineers to assess, manage, and communicate; and which specific definitions of responsibility pertain to them accordingly.
- Establishing more precisely what it means for an engineer to achieve (or fail to achieve) safety, sustainability, and efficiency; to exhibit (or fail to exhibit) objectivity, care, and honesty; and to exercise (or fail to exercise) practical judgment.
- Identifying any additional internal goods or virtues that are specific to the practice of engineering, and elaborating on the appropriate role of emotions.
- Devising strategies for reform of engineering education to incorporate these concepts into the typical curriculum.
- Developing concrete applications within the various disciplines of engineering, as well as in the diversity of industries that employ or retain engineers.
- Determining whether and how virtuous engineers can and should lead and otherwise contribute to initiatives that seek to deal with major ethical and technological challenges, such as poverty and climate change.

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