Volume 108
Issue 1 *Dickinson Law Review - Volume 108, 2003-2004*

6-1-2003

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Recommended Citation

Vinton Cerf, *Ethics and Engineering*, 108 DICK. L. REV. 113 (2003).
Available at: https://ideas.dickinsonlaw.psu.edu/dlra/vol108/iss1/8

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Vinton Cerf*

I. Introduction

In this short essay, I am going to try to give the reader a sense for some of the practices and procedures of ethics in the practice of engineering. I am most familiar with electrical engineering, but believe many of these observations are applicable to almost any aspect of other fields of engineering including civil, chemical, mechanical, and industrial engineering.

I approach this subject from two different contexts. One is as Chairman of the Board of the Internet Corporation for Assigned Names and Numbers ("ICANN"). ICANN is responsible for the oversight of and the policy for the assignment of domain names, the creation of new Internet domains, and the assignment of Internet addresses. I am also Senior Vice President for Architecture and Technology at MCI. Both of my roles have involved their share of disputes to be resolved within the organization and surrounding the organization's work, but my approach here is primarily that of an engineer.

II. Ethics in the Engineering Profession

A. An Engineering Code of Ethics

The National Institute for Engineering Ethics ("NIEE") publishes its own model code of ethics, as well as a comprehensive list of the ethics codes of other professional engineering organizations.[1] The NIEE's

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1. NAT'L INST. FOR ENG'G ETHICS, STATEMENT OF ETHICS PRINCIPLES (2000), *available at* http://www.niee.org/fpg.cfm?pt=Murdough&doc=codes.cfm. For other model codes of engineering ethics, see ACCREDITATION BD. FOR ENG'G & TECH., CODE OF

model code turns out to be like almost every other code of ethics that you may have encountered; however, some of the code's provisions are worth special mention. The first provision essentially says, "Don't do any harm," a concept derived from the ancient medical code of ethics.[2] The second provision requires engineers to work only in their area of competence.[3] Thirdly, engineers are supposed to pay attention to the side effects of their work, environmental and otherwise; fourth, if engineers are going to issue public statements, they should be objective.[4] The fifth provision requires engineers to sign and take responsibility for the work they directly supervise.[5] The sixth provision requires engineers to faithfully maintain confidentiality, to avoid conflicts of interest, and to report conflicts of interest if they develop.[6]

The seventh provision requires engineers to ensure that the client is aware of the engineer's professional concerns and of the consequences of ignoring the engineer's judgment.[7] Business decisions need to be informed by engineering judgments, but business decisions are going to be made. I consider it my job to lay out on the table, to the best of my ability, what the options are and what the potential implications are, one way or the other. If the client then chooses to place business over engineering concerns, then I must defer to the client's choice unless, of course, it violates one of the canons listed above. If there are any dangers to health, safety, or welfare, all engineers must notify the

CONDUCT (1999), *available at* http://www.abet.org/code.html; AM. INST. OF CHEM. ENG'R, ETHICS CODE (2003), *available at* http://www.aiche.org/about/ethicscode.htm; AM. SOC'Y OF CIVIL ENG'R, CODE OF ETHICS (1996), *available at* http://www.asce.org/membership/codeofethics.cfm; AM. SOC'Y OF MECH. ENG'R, CODE OF ETHICS (2002), *available at* http://asme.org/asme/policies/p15-7.html; ASS'N FOR COMPUTING MACH., SOFTWARE ENGINEERING CODE OF ETHICS AND PROFESSIONAL PRACTICE (1999), *available at* http://www.acm.org/serving/se/code.htm#full; INST. OF ELECTRICAL & ELECTRONICS ENG'R, CODE OF ETHICS (1990), http://www.ieee.org/about/whatis/code.html; NAT'L COUNCIL OF EXAMINERS FOR ENG'G & SURVEYING, MODEL RULES OF PROFESSIONAL CONDUCT (2002), *available at* http://www.ncees.org/introduction/about_ncees/ncees_professional_conduct.pdf; NAT'L SOC'Y OF PROF'L ENG'R, CODE OF ETHICS FOR ENGINEERS (2003), *available at* http://www.npse.org/ethics/eh1-code.asp.

2. The provision reads: "Engineers shall hold paramount the health, safety and welfare of the public in the practice of their profession." NAT'L INST. FOR ENG'G ETHICS, *supra* note 1.

3. *Id.*

4. *Id.*

5. *Id.*

6. *Id.* I can tell you that even at the former WorldCom, once we had gone through a period of explanations, we developed an office of ethics. Senior management signs pledges to avoid conflicts of interest of all kinds, and if a potential conflict occurs, it must be sent to the ethics office for evaluation. This same pledge incorporates an essentially zero tolerance for ethical violations of any kind.

7. *Id.*

authorities internal to the project—and if that fails, then externally.

The NIEE code of ethics also requires engineers to stay up to date in their field.[8] Engineering is a continuously changing discipline, and it does not take long to become out of date. Promoting ethics and education is, of course, also a requirement.[9]

These are the sorts of requirements we see in many different disciplines, and there are many variations on these statements in organizations with codes of ethics. Like the field of dispute resolution, the engineering profession continues to struggle in its application of the ethics principles listed above to its every day practice.

B. The Application of Engineering Ethics

I am not an architect or an architectural engineer, but that field provides some accessible examples. One of the primary concerns when you design buildings and bridges is safety. One of the techniques by which safety is assured is designing for safety purposes, or "over-engineering." In that discipline, there are many tools available for testing the design criteria. Engineers will often share the information and make use of the available software tools to make improvements.

But the desire to over-engineer often creates a tension. One of the major problems is that while you can over-engineer something so that it will survive an earthquake, a dramatic increase in traffic, or other stresses, it might cost a lot more than originally planned. This raises the problem of economic infeasibility and, therefore, the ethical question of how to establish the point at which you are willing to compromise in order to make the project profitable.

Furthermore, in spite of your best efforts and in spite of over-engineering, it is also possible that you simply do not know something that is critical about the materials, design, or architecture, and then later learn about it in unfortunate circumstances. In the collapse of the World Trade Center towers, for example, there were a whole series of things specific to those buildings that were unanticipated. The designers had, in fact, anticipated aircraft flying into buildings—but not an aircraft of today's modern commercial airliner size, filled with fuel, and capable of heating a metal structure to the degree that it did. The collapse was the result, first of the failure of the insulation surrounding the internal steel girders, and then the steel itself. There is even speculation that the intense heat altered the properties of the concrete. The collapse of the upper floors onto the ones below established a momentum that

8. *Id.*
9. *Id.*

repeatedly overcame the ability of the lower structure to withstand a sudden increase in load. This resulted in the unbelievably rapid collapse of both towers. Those were unanticipated things; an ethical engineer will *not* build a building made unsafe by cost-saving measures. All that is possible is for engineers to go back and look at what they can learn from that experience, and examine alternatives in design in order to combat failures in the future.

I chose to discuss buildings first because many non-engineers understand something about how buildings are built. Software engineering is instructive in another way; it is much, much harder to control, because the term "engineering" applies to a discipline, practices and procedures, methods of testing features, and analytical methods of determining whether the system meets functional criteria. By these standards, "software engineering" is almost as bad an oxymoron as "computer science." We do better with computer hardware than we do with software, even though hardware is also complicated, because with software, the number of permutations and combinations of circumstance is either incalculable, or at least too large to test. So the big problem with software is that we have a huge difficulty figuring out *whether* we got it right. You can test and test and test; but if you fail to find a problem, it does not mean that a problem is not there; it just means that you failed to find it. And of course, we are all familiar with stories about how the first day that any end user installs software it crashes. We have not mastered a "discipline" of software engineering at all.

The most dramatic example is the Internet. On the Internet, there are, as of this writing, approximately six hundred million users and probably a billion devices. The problem of analyzing or predicting software performance, with an often unpredictable mix of software interacting over the Internet, is extremely difficult.

A few observations seem appropriate about the order of complexity, expense, and occasional politics involved, and the distortions in judgment that result. The Challenger space shuttle, for example, had one really big problem: the O-ring did not work in cold weather. This was followed by a combination of bad engineering judgments, and what seems to me to be truly unethical management; the engineers informed management of the potential problem, but the managers nevertheless decided to proceed with the launch.[10]

Cascade failures are different; instead of one large problem, a series of small things happen. Pretty soon the system cannot absorb the failure

10. For a more detailed discussion of the Challenger disaster, see Melvin Blumberg, *Why Good Engineers Make Bad Decisions: Some Implications for ADR Professionals*, 108 PENN ST. L. REV. 137, 151-56 (2003).

rate and the whole shebang, a technical term, collapses. There have been failures of power grids, in the Northwest for example, that start with one tree falling and hitting a power line; the fallen tree then knocks out the power line, and then a series of other things trip in turn. Epidemiology is another example of a propagating, cascade failure. But again, there is some progress. *Six Degrees: The Science of a Connected Age*, by Duncan Watts, is an accessible treatment of some key issues.[11] It appeals to mathematical intuition and graph theory, but is for the most part a very accessible text. It gives a sense of the way in which complex systems can fail, and what is fascinating is that there are measurable concrete and quantitative points at which the design of the system will move from the resilient to the highly fragile.[12] If these are calculable points, they become something we can project, plan for, and perhaps prevent.

It is all too easy to overlook that maintaining professional ethics is a two-way street, in which the users and customers also play a part. It is deeply troubling that we have a whole generation of people who think it is okay to copy software off of the Internet, regardless of whether it is copyrighted material or not. Part of the reason is that software, in its digital form, is weird stuff that you can copy while the original is not damaged or removed. Whoever had the original copy still has it; many have rationalized themselves into thinking, "I didn't really steal it, because it's still there." But what has happened, of course, is not simply a private wrong, but that the copier has unilaterally removed a part of the economic base by which the next improvement in that software would logically be financed. Therefore, everyone who might use that software in the future is harmed.

Another form of ethical violation in the software world is the creation of viruses and worms. People who deliberately inject pieces of software that cause trouble probably do it for largely the same reasons that people vandalize buildings. But it is evidence of poor ethical training. If there is anything in our industry that we need to teach people starting at a young age, it is what is and is not ethical.

III. A Future for Engineering Ethics and Dispute Resolution

The computer world provides plenty of opportunities for ethical lapses of types that might have occurred elsewhere. Some of these bring us closer to the ethical issues faced by the dispute resolution world. In the ICANN world, for instance, there is a great deal of disputing going on; people register domain names that other people don't want them to use, or wish they themselves had registered, and a fight ensues. This

11. DUNCAN J. WATTS, SIX DEGREES: THE SCIENCE OF A CONNECTED AGE (2003).
12. *Id.*

kind of pressure will make ICANN, an organization of roughly twenty-four people, unable to serve the population of six hundred million users who are in dispute with each other some part of the time.

ICANN has turned to the World Intellectual Property Organization to set up a dispute resolution procedure.[13] This procedure is not binding, so if one of the disputing parties is not satisfied with the resolution, they can still litigate. Yet, these are frequently international disputes; litigation within the international framework is quite difficult, expensive, lengthy, and sometimes does not resolve the matter at all. So we look to these alternative mechanisms to try to find a rapid, lower cost, and possibly online mechanism for resolving disagreements with regard to domain name registration. Experience to date has been a mixed bag. There have been several thousand cases over the last two or three years, with most of them reaching a successful resolution. Still, some people do not like the results. It is not a perfect process; but again, we are learning.

13. To learn more about the World Intellectual Property Organization's dispute resolution procedures, see World Intellectual Property Organization, *Arbitration and Mediation Center*, *at* http://arbiter.wipo.int/center/index.html (last visited Aug. 1, 2003).