Engineering Ethics Cases for Electrical and Computer Engineering Students

Charles B. Fleddermann, *Senior Member, IEEE*

***Abstract*—Rarely is electrical technology at the focus of the classic case studies used in engineering ethics courses and textbooks. This makes it sometimes difficult to excite and to motivate electrical and computer engineering students to study and discuss these cases. In teaching engineering ethics to these students, it can be valuable to employ case studies that involve technical issues that electrical and computer engineers have already studied in other courses. In this paper, four engineering ethics case studies covering topics that have been shown to interest electrical and computer engineering students are presented.**

***Index Terms*—Case studies, engineering ethics.**

I. Introduction

ENGINEERING ethics courses and texts frequently utilize "classic" case studies to illustrate important ethical concepts and to spark class discussion. Unfortunately, these classic cases rarely involve electrical technology. Although electrical engineering (EE) and computer engineering (CompE) students are capable of understanding the ethical issues brought up by cases such as the space shuttle *Challenger* accident or the failure of the walkways at the Hyatt Regency Hotel in Kansas City, these cases often do not sufficiently engage their interest. For class sections with substantial enrollment of these students, it is valuable to have case studies that draw on the students' previous classroom experience and involve technical as well as ethical issues that will engage them.

Four case studies that have been shown to interest EE and CompE students are presented in this paper. (Two of these cases are sometimes included in engineering ethics texts, but generally without thorough discussion of the technical issues.) These case studies have been successfully used in a one-semester-hour seminar course on engineering ethics taught in the electrical and computer engineering department at the University of New Mexico. These cases can be developed in enough technical depth to interest students, so that meaningful discussions of the ethical issues can take place. A brief description of each case is presented, along with a few of the ethical concepts that are illustrated by it. Primary sources of information for each case are listed.

II. The Flaw in the Intel Pentium Chip

A. Background

In late 1994, the media began to report that there was a flaw in the new Pentium microprocessor produced by Intel. A flaw in the Pentium was especially significant since at that time it was the microprocessor used in 80% of the personal computers produced worldwide [1]. Apparently, flaws in a complicated integrated circuit such as the Pentium are not uncommon. Most of these flaws cannot be detected by the user and do not affect the operation of the computer. The flaw that was discovered in 1994 was different. It caused incorrect answers when performing double-precision arithmetic, a very common computer operation. The flaw was easily detected by computer users. In fact, it first came to light when a university researcher noticed that the results of some calculations he was performing using his PC were incorrect. Many daily newspapers across the country carried stories about this problem.

Intel's initial response was that although there was indeed a defect in the chip, the defect was insignificant and the vast majority of users would never even notice it. The chip would be replaced for free only for users who could demonstrate that they needed an unflawed version [1]. Of course, this approach did not satisfy most Pentium owners since no one can predict whether the flaw might be significant in a future application. IBM, a major Pentium user, canceled the sales of all IBM computers containing the flawed chip. Finally, after much negative publicity in the popular personal computer literature and the daily press, and an outcry from Pentium users, Intel agreed to replace the flawed microprocessor with an unflawed version for any customer who asked to have it replaced.

It should be noted that long before news of the flaw surfaced in the press, Intel was aware of the problem and had already corrected it on subsequent versions [1]. They did, however, continue to sell the flawed chip, and based on their early insistence that the flaw did not present a significant problem to most computer users, apparently planned to continue this practice until the new version was available and the stocks of the flawed chip were exhausted.

In the aftermath of this, Intel's approach to chip flaws has changed. They now seem to feel that flawed chips should be replaced upon request, regardless of how insignificant the flaw seems to be.

B. Ethical Issues

This incident can perhaps be viewed as simply a public relations problem not involving any ethical issues; certainly this was a public relations disaster for Intel. However, there are also some interesting ethical issues that can be discussed. These include the following.

- Should defects be revealed to consumers? Are there times when it is ethical not to reveal defects? Is it an ethics problem only if safety is involved?

Manuscript received November 2, 1999; revised April 25, 2000.

The author is with the Department of Electrical and Computer Engineering, University of New Mexico, Albuquerque, NM 87131 USA.

Publisher Item Identifier S 0018-9359(00)07362-3.

- Suppose a manufacturer places a warning in the literature that comes with a product such as "This product may contain unexpected flaws and might not operate correctly under all conditions." Does this solve the ethical problems for the company?
- How can an engineer be sure that there are no defects in a product? If it is impossible to eliminate all defects in a product, what level of defects is acceptable? Does this depend on what the product is?
- What do codes of ethics of professional engineering organizations such as the IEEE say about selling products that are known to be defective?
- What were the responsibilities of the engineers working on the Pentium chip once they became aware of the flaw?

C. Sources of Information

This case received widespread coverage in the media. For example, see [1]–[4]. There were also numerous accounts about this in daily newspapers from late 1994 to early 1995; articles can be found in *The Wall Street Journal*, *The New York Times*, and most local newspapers.

III. The Bay Area Rapid Transit (BART) System

This case is often mentioned in engineering ethics texts. However, the issues presented and the technical depth are not generally sufficient to engage EE and CompE students.

A. Background

In the late 1940's the foundation for a regional mass transit system for the San Francisco Bay area was laid, leading eventually to construction of the Bay Area Rapid Transit (BART) system. As envisioned, BART was to be a high-tech rail system serving many of the communities along San Francisco Bay and would incorporate new technology, including fully automated control systems for all trains. The automatic train-control (ATC) system designed for BART was an innovative method for controlling train speed and access to stations. In most mass transit systems, this function is performed by human drivers who read trackside signals and/or receive instructions via radio from dispatchers. Instead, BART relied on a series of onboard sensors to determine a train's position, and data from a control center to indicate the location of other trains and information on allowed speeds. None of the control technologies that were being designed had been previously tested in a commuter rail system. The contract to design and build the ATC was awarded to Westinghouse in 1967 [5].

The key players in this case were three BART engineers working on various aspects of the ATC. These engineers became concerned about the lack of testing of some of the components of the ATC, the lack of oversight of Westinghouse by BART, and the quality of the documentation that Westinghouse was providing. Unable to get their concerns acted upon by BART management, the three engineers contacted a member of the BART board of directors indicating that their concerns were not being taken seriously by management. This action was in direct conflict with the general manager of BART, whose policy was to only allow himself and a few others to deal directly with the board [5]. The engineers were confronted by management about whether they were the sources of the leaks about the problems at BART, and all denied their involvement.

After it became clear that they were the source of the information given to the board, all three of the engineers were offered the choice of resignation or dismissal. All refused to resign, and were subsequently dismissed on the grounds of insubordination, lying to management, and failing to follow organizational procedures. None were able to find work for a number of months, and all suffered financial and emotional problems as a result.

In the course of the legal proceedings, the IEEE attempted to assist the three engineers by filing an *amicus curiae* brief in their support. The IEEE asserted that each of the engineers had a professional duty to keep the safety of the public paramount, and that their actions were therefore justified. Based on the IEEE code of ethics, the brief stated that engineers must "notify the proper authority of any observed conditions which endanger public safety and health." The brief interpreted this to mean that in the case of public employment, the proper authority is the public itself [5].

B. Ethical Issues

This case illustrates many of the issues associated with whistleblowing and can be effectively used in a discussion of when whistleblowing is appropriate and when it is necessary. Issues can include the following.

- Was it necessary for the engineers to blow the whistle?
- At what point should an engineer give up expressing his or her concerns? In this case, when several levels of management appeared to not share the engineers' concerns, how much more effort did professional ethics dictate?
- What actions short of going to the board and whistleblowing might the engineers have taken?
- Should the IEEE have intervened in the court case?
- What level of supervision should an organization have over its contractors? Is it sufficient to assume that contractors are professional and will do a good job?
- One of the perceived problems with BART was a lack of adequate documentation from Westinghouse. What are the ethical considerations regarding documentation of work? What responsibility does an engineering organization have after the design is complete?

C. Sources of Information

A book was written soon after this incident which detailed in great depth the issues involved [5]. Additional information on this case can be found in a series of articles in IEEE Spectrum [6]–[10]. These articles also contain technical details that will inform the ethical discussions.

IV. Low-Frequency Electromagnetic Fields

A. Background

By 1994, several studies had been performed that suggested a link between weak low-frequency magnetic fields and cancer or other health problems. The effects of these low-level fields, especially from electrical power distribution systems, first received widespread attention as the result of studies of childhood leukemia occurrences in residential areas of Denver, CO. These studies indicated that the incidence of leukemia was correlated to proximity of the child's home to transformers for residential electrical distribution. Although the correlation found in this study was small, it was "statistically significant."

Subsequently, there were many other studies both in the U.S. and Europe trying to verify these findings including studies of workers exposed to radiation from cathode ray tubes (such as computer monitors) and workers for electric utilities. The results of these studies were controversial, and not all research led to the same conclusion. In fact, as more refined and controlled studies were performed, the harmful effects of the fields seemed to diminish [11]. Laboratory studies were also initiated to determine the biological effects of low-frequency magnetic fields. These were typically performed on cell cultures or laboratory rodents. The results of these studies were conflicting and inconclusive, and since no studies had been performed on humans, the relationship of any results to human health was debatable.

These studies presented engineers with a problem: how to design safe products without fully understanding the nature of the dangers. A wide variety of common household items had been found to emit significant magnetic fields, including toasters, electric blankets, and even the clock radio sitting at many bedsides. Some products could be redesigned to reduce or eliminate this problem, but of course any design which will lead to reduced emission will probably cost more.

More recently, the evidence for health effects of these fields has been reviewed by panels of several professional societies. Both the IEEE and the American Physical Society have concluded that there is no evidence indicating that there are any harmful effects, although critics suggest that both of these organizations have vested interests in obtaining this finding. It seems that for now the concern over low-frequency electromagnetic radiation was unfounded [12].

B. Ethical Issues

This case illustrates the experimental nature of engineering and sparks good discussions on issues regarding safety and risk.

- What was an engineer in the early 1990's to do when designing a product that emitted magnetic fields? What is the prudent and ethical thing to do when performing a design in an atmosphere where some doubt about safety exists?
- If there are potential, but not well understood, hazards in building a product, what are the future consequences of doing nothing, i.e., of making no changes in design? Will warnings to the consumer suffice to get the designer off the hook? Must the product be engineered to be totally safe at all costs?
- How can an engineer best balance safety with cost in this case?
- In light of the findings of several professional organizations that indicate that there is no hazard associated with low-frequency magnetic fields, what should an engineer do today when designing products that will emit this type of radiation?

C. Sources of Information

A comprehensive review of this case can be found in [11].

V. Paradyne Computers

Although this case involves computer technology that is very outdated by modern standards, the issues raised are still pertinent.

A. Background

On June 10, 1980 the Social Security Administration (SSA) published a request for proposals (RFP) for computer systems to replace the older equipment in its field offices. Their requirement was for computers that would provide access to a central database that was used by field offices in the processing of benefit claims and in issuing new social security numbers. SSA wanted to purchase an off-the-shelf system already in the vendor's product line rather than a custom system. This requirement was intended to minimize the field testing and bugs associated with customized systems. In March 1981, SSA let a contract for $115 million for 1800 computer systems to Paradyne Corporation [13].

Problems occurred immediately upon award of the contract when the Paradyne computers failed the acceptance testing. The SSA subsequently relaxed the requirements so that the Paradyne computers would pass. After delivery, many SSA field offices reported frequent malfunctions, sometimes multiple times per day, requiring manual rebooting of the system.

Subsequent investigation by SSA indicated that the product supplied by Paradyne was not an off-the-shelf system. In Paradyne's response to the RFP, they had proposed selling SSA their P8400 model with the PIOS operating system. The bid was written as if this system already existed. However, at the time that the bid was prepared, the 8400 system did not exist, and had not been developed, prototyped, or manufactured.

The RFP stated that there was to be a pre-award demonstration of the product, and specifically prohibited the demonstration of a prototype. Paradyne demonstrated to SSA a different computer, a modified PDP 11/23 computer manufactured by Digital Equipment Corporation (DEC) placed in a cabinet that was labeled P8400. Many of the DEC labels on the equipment that was demonstrated to SSA had Paradyne labels pasted over them. Paradyne claimed that since the DEC equipment was based on a 16 bit processor as was the P8400 they proposed, it was irrelevant if the machine demonstrated was the DEC or the actual P8400. There were also questions about the operating system. Apparently at the time of Paradyne's bid, the PIOS operating system was under development as well, and had not been tested on a prototype of the proposed system [13].

This situation was resolved after nearly two years when the Paradyne computers were finally brought to the point of functioning as required. The final chapter in this story was not written until after numerous investigations by government organizations, including the Health and Human Services

Department (SSA's parent organization) and the Justice Department.

B. Ethical Issues

This case can be used to illustrate the pitfalls of competitive bidding, both from the point of view of the organization soliciting the bids and the company responding to the request for bids. Among the issues are the following.

- In preparing their bid, Paradyne wrote in the present tense as if the computer they proposed currently existed, rather than in the future tense which would have indicated that the product was still under development. Paradyne claimed that the use of the present tense in their bid (which led SSA to believe that the P8400 actually existed) was acceptable since it is common business practice to advertise products under development this way. Is there a distinction between a response to a bid and company advertising?
- Paradyne claimed that they were acting as a system integrator, which was allowed by the RFP, using components from other manufacturers to form the Paradyne system. These other components were mostly off-the-shelf, but had never been integrated into a system before. Does this meet the SSA requirement for an existing system?
- Once the Paradyne machine failed the initial test, should the requirements have been relaxed to help the machine qualify?
- If the requirements were going to be modified, should the bidding process have been reopened to the other bidders, and others who might now be able to bid? Should bidding be reopened even if it causes a delay in delivery and increased work for SSA?

C. Sources of Information

Information on this case can be found in [13] and [14].

VI. Conclusion

Case studies used in an engineering ethics class are an effective tool for bringing alive the theoretical ethical concepts. Students are more likely to be engaged when the case studies are related to the subject matter that they are studying in their other engineering classes. Four case studies appropriate for electrical and computer engineering students have been presented here. Although the ethical concepts presented in these cases can easily be understood by any engineering student, these cases have proved themselves to be especially interesting to electrical and computer engineers and to spark more interesting and informed discussion among them than the traditional engineering ethics cases.

References

[1] B. Crothers, "Pentium woes continue," *Infoworld*, vol. 16, no. 48, pp. 1–18, Nov. 18, 1994.
[2] ——, "Flawed chips still shipping," *Infoworld*, vol. 16, no. 49, pp. 1–18, Dec. 5, 1994.
[3] J. Castro, "When the chips are down," *Time Mag.*, p. 126, Dec. 26, 1995.
[4] D. Kirkpatrick, "The fallout from Intel's Pentium bug," *Fortune Mag.*, p. 15, Jan. 16, 1995.
[5] R. M. Anderson, *Divided Loyalties*. West Lafayette, IN: Purdue Univ. Press, 1980.
[6] G. D. Friedlander, "The grand scheme," *IEEE Spectrum*, vol. 9, pp. 35–43, Sept. 1972.
[7] ——, "BART's hardware—From bolts to computers," *IEEE Spectrum*, vol. 9, pp. 60–72, Oct. 1972.
[8] ——, "More BART hardware," *IEEE Spectrum*, vol. 9, pp. 41–45, Nov. 1972.
[9] ——, "Bigger bugs in BART?," *IEEE Spectrum*, vol. 10, pp. 32–37, Mar. 1973.
[10] ——, "A prescription for BART," *IEEE Spectrum*, vol. 10, pp. 40–44, Apr. 1973.
[11] T. S. Perry, "Today's view of magnetic fields," *IEEE Spectrum*, vol. 31, pp. 14–23, Dec. 1994.
[12] I. Goodwin, "Washington report," *Phys. Today*, pt. 1, vol. 50, no. 8, p. 47, Aug. 1997.
[13] J. S. Davis, "Ethical problems in competitive bidding: The paradyne case," *Bus. Prof. Ethics J.*, vol. 7, pp. 3–25, 1988.
[14] R. V. Head, "Paradyne dispute: A matter of using a proper tense," *Gov. Comput. News*, p. 23, Feb. 14, 1986.

Charles B. Fleddermann (M'90–SM'96) received the B.S. degree in electrical engineering from the University of Notre Dame, Notre Dame, IN, in 1977, and the M.S. and Ph.D. degrees in electrical engineering in 1980 and 1985, respectively, from the University of Illinois, Urbana-Champaign.

He has been on the electrical and computer engineering faculty at the University of New Mexico, Albuquerque, since 1985. His interest in engineering ethics began five years ago when he developed a seminar course on the subject. He has also written a textbook on engineering ethics.