Professional Ethics (HS-219)

Week 9 (Handout)

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Safety and Risk

The engineering codes of ethics show that engineers have a responsibility to society to produce products, structures, and processes that are safe. There is an implied warranty with regard to all products that they will perform as advertised—a bridge should allow automobiles to cross from one side of a river to the other, and a computer should correctly perform calculations. Similarly, there is an implied warranty that products are safe to use. Clearly, nothing can be 100% safe, but engineers are required to make their designs as safe as reasonably possible. Thus, safety should be an integral part of any engineering design.

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Definition

Safety is at the same time a very precise and a very vague term. It is vague because, to some extent, safety is a value judgment, but precise because in many cases, we can readily distinguish a safe design from an unsafe one. It is impossible to discuss safety without also including a discussion of risk.

Risk is a key element in any engineering design; it is impossible to design anything to be completely risk free. How much risk is appropriate? How safe is safe enough? To answer these questions, we must first study the nature of safety and risk.

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The *American Heritage Dictionary* defines risk as the possibility of suffering harm or loss. Risk is sometimes used synonymously with danger. The same dictionary defines safety as freedom from damage, injury, or risk. There is some circularity to these definitions: We engage in risky behavior when we do something that is unsafe, and something is unsafe if it involves substantial risk. Although these definitions are precise, safety and risk are essentially subjective and depend on many factors:

1. Voluntary vs. Involuntary Risk
2. Short-term vs. Long-term Consequences
3. Expected Probability
4. Reversible Effects
5. Threshold Levels for Risk
6. Delayed vs. Immediate Risk

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Voluntary vs. Involuntary Risk

Many consider something safer if they knowingly take on the risk, but would find it unsafe if forced to do so. If the property values are low enough, some people will be tempted to buy a house near a plant that emits low levels of a toxic waste into the air. They are willing to assume the risk for the benefit of cheap housing. However, if a person already living near a plant finds that toxic fumes are emitted by the plant and he was not informed, the risk will appear to be larger, since it was not voluntarily assumed. This principle is true even if the level of emission is identical to that in the example of a person choosing to move near the plant.

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Short-term vs. Long-term Consequences

Something that might cause a short-lived illness or disability seems safer than something that will result in permanent disability. An activity for which there is a risk of getting a fractured leg will appear much less risky than an activity with a risk of a spinal fracture, since a broken leg will be painful and disabling for a few months, but generally full recovery is the norm. Spinal fractures, however, can lead to permanent disability.

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Expected Probability

Many might find a one-in-a-million chance of a severe injury to be an acceptable risk, whereas a 50:50 chance of a fairly minor injury might be unacceptable. Swimming at a beach where there is known to be a large concentration of jellyfish would be unacceptable to many, since there would be a high probability of a painful, though rarely fatal, sting. Yet, at the same beach, the risk of a shark attack is low enough that it doesn't deter anyone from swimming, even though such an attack would very likely lead to death or dismemberment. It is important to remember here that the expected probability is only an educated guess.

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Reversible Effects

Something will seem less risky if the bad effects are ultimately reversible. This concept is similar to the short-term vs. long-term risk question discussed previously.

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Threshold Levels for Risk

Something that is risky only at fairly high exposures will seem safer than something with a uniform exposure to risk. For example, the probability of being in an automobile accident is the same regardless of how often you drive. (Of course, you can reduce the likelihood of being in an accident by driving less often.) In contrast, studies have shown that low levels of nuclear radiation actually have beneficial effects on human health, while only at higher levels of exposure are there severe health problems or death. If there is a threshold for the effects, generally there will be a greater tolerance for risk.

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Delayed vs. Immediate Risk

An activity whose harm is delayed for many years will seem much less risky than something with an immediate effect. For example, for several years now, Americans have been warned about the adverse long term health effects of a high-fat diet. This type of diet can lead to chronic heart problems or stroke later in life. Yet, many ignore these warnings and are unconcerned about a risk that is so far in the future. These same people might find an activity such as skydiving unacceptably risky, since an accident will cause immediate injury or death.

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Engineers and Safety

Since safety is an essential aspect of our duties as engineers, how can we be sure that our designs are safe? There are four criteria that must be met to help ensure a safe design.

First, the minimum requirement is that a design must comply with the applicable laws. This requirement should be easy to meet, since legal standards for product safety are generally well known, are published, and are easily accessible.

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Second, a design must meet the standard of “accepted engineering practice.” You can’t create a design that is less safe than what everyone else in the profession understands to be acceptable. For example, federal safety laws might not require that the power supply in a home computer be made inaccessible to the consumer who opens up her computer. However, if most manufacturers have designed their supplies so that no potentially lethal voltages are accessible, then that standard should be followed by all designers, even if doing so increases the cost of the product.

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A real-life example of this will be shown later when we consider the DC-10 case, in which an airframe was adapted from another design, but was not in accordance with the practice of other aircraft manufacturers at the time. This requirement is harder to comply with than the legal standard, since “accepted engineering practice” is a somewhat vague term. To address this issue, an engineer must continually upgrade her skills by attending conferences and short courses, discussing issues with other engineers, and constantly surveying the literature and trade magazines for information on the current state of the art in the field.

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Third, alternative designs that are potentially safer must be explored. This requirement is also difficult to meet, since it requires a fair amount of creativity in seeking alternative solutions. This creativity can involve discussing design strategies with others in your field and brainstorming new alternatives with them. The best way to know if your design is the safest available is to compare it to other potential designs.

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Fourth, the engineer must attempt to foresee potential misuses of the product by the consumer and must design to avoid these problems. Again, this requires a fair amount of creativity and research. It is always tempting to think that if someone is stupid enough to misuse your product and is injured, then it’s his own fault and the misuse and its consequences shouldn’t bother you too much. However, an engineer should execute designs in such a way as to protect even someone who misuses the product. Juries aren’t always concerned with the stupidity of the user and might return a substantial judgment against you if they feel that a product was not properly designed. Placing a warning label on a product is not sufficient and is not a substitute for doing the extra engineering work required to produce a safe design.

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Finally, once the product is designed, both prototypes and finished devices must be rigorously tested. This testing is not just to determine whether the product meets the specifications. It should also involve testing to see if the product is safe. The importance of adequate testing can be illustrated by the *Kursk* submarine disaster. The *Kursk* was a Russian navy submarine that sank in August of 2000, killing everyone on board. The sinking has been attributed to an explosion in the torpedo room that ripped open a large hole in the hull. Many crew members of the *Kursk* survived the initial explosion, but died because they were unable to escape from the submarine, and no attempts at rescue by other ships were successful. The June 3, 2002, edition of *Time* reported that Russian naval engineers say that the *Kursk* was equipped with a rescue capsule designed to allow crew members to float safely to the surface in an emergency. However, in the rush to get the submarine into service, this safety system was never tested. After the accident, some of the survivors attempted to rescue themselves by using this system, but it did not function properly. It is essential that in any engineering design, all safety systems be tested to ensure that they work as intended.

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Designing for Safety

How should safety be incorporated into the engineering design process? Texts on engineering design often include some variation on a basic multistep procedure for effectively executing engineering designs. One version of this process is found in Wilcox [1990] and is summarized as follows:

1. Define the problem. This step includes determining the needs and requirements and often involves determining the constraints.
2. Generate several solutions. Multiple alternative designs are created.
3. Analyze each solution to determine the pros and cons of each. This step involves determining the consequences of each design solution and determining whether it solves the problem.
4. Test the solutions.
5. Select the best solution.
6. Implement the chosen solution.

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In step 1, it is appropriate to include issues of safety in the product definition and specification. During steps 2 through 5, engineers typically consider issues of how well the solution meets the specifications, how easy it will be to build, and how costly it will be. Safety and risk should also be criteria considered during each of these steps. Safety is especially important in step 5, where the engineer attempts to assess all of the trade-offs required to obtain a successful final design. In assessing these trade-offs, it is important to remember that safety considerations should be paramount and should have relatively higher weight than other issues.

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Minimizing risk is often easier said than done. There are many things that make this a difficult task for the engineer. For example, the design engineer often must deal in uncertainties. Many of the risks can only be expressed as probabilities and often are no more than educated guesses. Sometimes, there are synergistic effects between probabilities, especially in a new and innovative design for which the interaction of risks will be unknown. Risk is also increased by the rapid pace at which engineering designs must be carried out. The prudent approach to minimizing risk in a design is a “go slow” approach, in which care is taken to ensure that all possibilities have been adequately explored and that testing has been sufficiently thorough. However, this approach isn’t always possible in the real world.

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Are minimizing risks and designing for safety always the more expensive alternatives? Spending a long time engineering a safer product may seem like a very expensive alternative, especially early in the design cycle before the product has been built or is on the market. This, however, is a very short-term view. A more long-term view looks at the possible consequences of not minimizing the risk. There is a great deal of guesswork involved here, but it is clear that any unsafe product on the market ultimately leads to lawsuits that are expensive to defend even if you don't lose and are very costly if you do lose. The prudent and ethical thing to do is to spend as much time and expense as possible up front to engineer the design correctly so as to minimize future risk of injury and subsequent criminal or civil actions against you.

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Risk Benefit Analysis

One method that engineers sometimes use to help analyze risk and to determine whether a project should proceed is called risk–benefit analysis. This technique is similar to cost–benefit analysis. In risk–benefit analysis, the risks and benefits of a project are assigned dollar amounts, and the most favorable ratio between risks and benefits is sought. Cost–benefit analysis is tricky because it is frequently difficult to assign realistic dollar amounts to alternatives. This task is especially difficult in risk– benefit analysis because risks are much harder to quantify and more difficult to put a realistic price tag on. Still, this can be a useful technique if used as part of a broader analysis, but only if used objectively.

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In doing a risk–benefit analysis, one must consider who takes the risks and who reaps the benefits. It is important to be sure that those who are taking the risks are also those who are benefiting. This consideration is fundamental to issues of economic justice in our society and can be illustrated by the concept of "environmental racism," which is the placing of hazardous-waste sites, factories with unpleasant or noxious emissions, etc. near the least economically advantaged neighborhoods. This practice is sometimes thought of as racism because in the United States, these types of neighborhoods are generally disproportionately occupied by minority groups. The only ethical way to implement risk–benefit analysis is for the engineer to ensure to the greatest extent possible that the risks as well as the benefits of her design are shared equally in society.

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