Professional Ethics and Values in Engineering HS(317)

UNIT – V:

Engineering Ethics-Case Studies: Examine each case and discuss in groups the reasons and possible solutions in each case for the ethical and technical issues through oral presentations

Case 1: Killer Robot; Case 2: DC-10 Jumbo Jet Crash; Case 3: Whistle Blowing, Case 4: Citicorp Building; Case 5: The Challenger Disaster; Case 6: Bhopal Gas Tragedy; Case 7: Chernobyl; Case 8: Three Miles Island, Case 9: Columbia disaster, Case 10: Ford Pinto safety problems

Case 1: Killer Robot

(Taken from: Richard G. Epstein, The Case of the Killer Robot, Wiley & Sons, presented by Ronald J. Kizior, Loyola University, Chicago)

Summary of the case: Bart Matthews, a robot operator at Cybernetics, Inc., has been killed by an out-of-control robot named Robbie. The creator of the robot, Silicon Technologies, is also in a tight financial position and had hoped that the robot would put the company back on its feet.

It has been determined that several situations contributed to the death of Matthews:

1. Improper methodology was used in developing the software.
2. Testing of the software was faked.
3. The company pressured Robbie's creators to by-pass testing.
4. Part of the software used in the robot was stolen from another vendor's application.
5. The programmer did not understand or know the code which he used.
6. Security measures used were illegal, and therefore all information gathered in regard to the case might not be permissible in court.
7. The project leader did not understand or use proper design methodologies.
8. The end-user interface was designed improperly.

Questions for students:

- Who is at fault?
- Which situations are unethical?
- Which situation is the major contributor to the death of Bart Matthews?

This case could be the basis of a class discussion and debate

Case: Engineers and Safety

A company is the design subcontractor for an airframe manufacturer about to start building and delivering a new, wide-bodied plane. Despite the fact that the plane is about to be certified by the Federal Aviation Administration (FAA), Ron Swartz, an engineer, is convinced that a design defect, if not corrected, will sooner or later result in serious accidents.

Ron has made known his concerns to his supervisors from the earliest stages. As a result, the company's management urged the manufacturer to correct the problem. This urging was rebuffed, but later an accident happened while a prototype of the plane was being tested on the ground. This event led to some modifications, but Swartz considers them inadequate, possibly even worsening the problem.

2. DC-10 Jumbo Crash

In 1974, Turkish Airlines Flight 981 experienced a mid-flight cargo door failure which led to the first total loss of a wide-bodied aircraft in history. The aircraft was a McDonnell Douglas DC-10, and this tragedy was compounded by the fact that sufficient corrective action had not been taken by the manufacturer after precursory failures had occurred over the four previous years. The purpose of this report is to evaluate the ethical nature of McDonnell Douglas's decisions throughout this crisis, discerning their priorities with regard to safety and financial gain, and to assess if these qualities have changed in response. The origin of this catastrophe lay in a poor handling of design and manufacturing. The cargo door's design employed faulty philosophies, and decisions regarding its manufacture were driven by savings at the expense of safety. However, though the door's faults were later exposed, a more serious problem involving the tail control lines in the passenger floor was continually overlooked until the crash. This was due primarily to a policy of using old design strategies which met minimum federal requirements. The company oversimplified the control lines' failure mode when confronted with it in ground testing and, being committed to their own design, were unable to recognize the root problem. In 1972, after the commercial release of the DC10, a mid-flight incident occurred which exhibited the exact same failure mode. Federal government agencies investigated the incident and concluded that the aircraft required modifications before it would be safe for flight. Due to the damage that the federal mandates could inflict upon McDonnell Douglas's global sales effort, the company struck up a 'Gentlemen's Agreement' with the Federal Aviation Administration in which they promised to handle the problem themselves. However, the modifications were then handled clumsily, resulting in the crash of Flight 981. In all likelihood, what allowed the company management to accept this risk in safety was the miscommunication of the gravity of the flaws, and so they acted to preserve the reputation of their new aircraft. There can be no doubt that their engineers had sufficient technical indication of such a crash, but they were unable to recognize the implications. Unfortunately, the opinions of the fuselage contractor's engineers, those who knew the problem best, were essentially squelched due to closed lines of communication between Douglas and their contractor. Thus, due to the intense competition within the industry, the managers were willing to employ ethically questionable tactics of undermining the FAA's procedures and playing down the seriousness of the design flaws in order to save themselves financially. Following the crash of Flight981, McDonnell Douglas quickly implemented the originally-promised modifications in order to adhere with new regulations. However, in the subsequent investigation, the company did not recognize their primary liability and attempted to pin it on virtually every other involved party. Unfortunately, this issue of liability was never legally resolved because the same insurance group would incur the costs no matter who was at fault. Thus the accident occurred and passed without absolute resolution, a deficiency which may have paved the way for the future accidents which continued to plague the career of the DC-10.

As a case study, the story of Turkish Airlines Flight 981 stands as a classic example of the complex nature of most applications of ethics in engineering, for though McDonnell

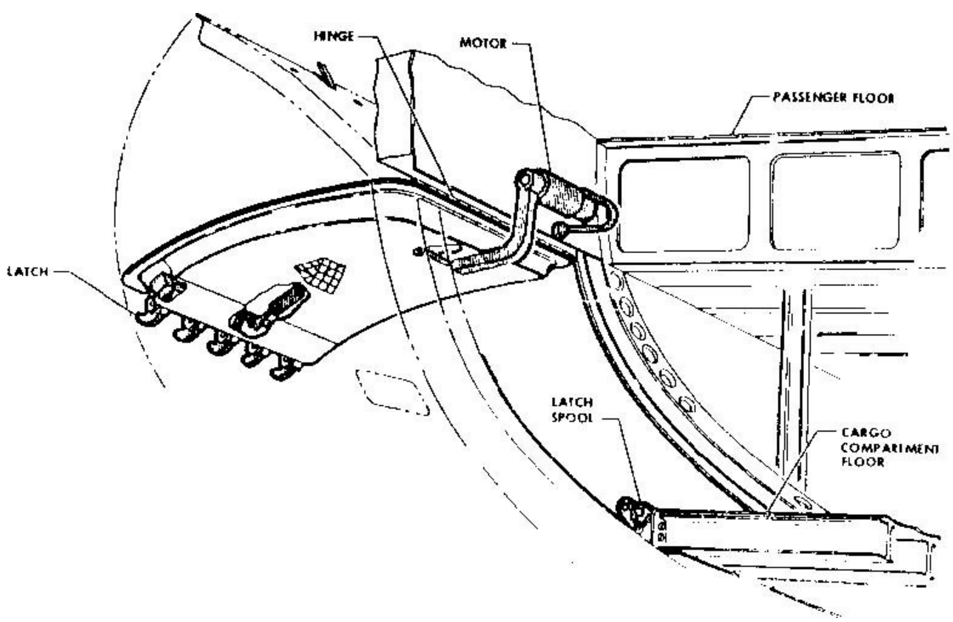
Douglas handled a challenge in what it perceived to be a fair manner, the company's lack of total focus on safety and ethics resulted in the death of hundreds. Thus this study finds that although the crisis involved many private and public factors, McDonnell Douglas bears primary responsibility for the disaster. Through its poor production stages, McDonnell Douglas may be considered entirely responsible for allowing their defective product to reach the market. However, the company's most crucial fault lay in that they were not ethically conscientious at every decision-making level throughout the life of their product.

On March 3, 1974, Turkish Airlines Flight 981, a DC-10 out of Paris (see Fig.1), experienced explosive decompression ten minutes after take-off when the rear cargo door burst open. The cargo area evacuated, and the floor of the passenger area, which separated the cabin from the lower cargo hold, buckled under the enormous pressure differential. As a result, the hydraulic control lines that ran under this floor to the tail of the craft were severed, and witnesses watched as the non- responsive plane plummeted at nearly 500 mph into the Ermenonville forest outside Paris, killing all 346 people onboard (Schlager, 1994). Figure 2shows the horrifying scene left behind. Prior to this crash, the DC-10 design had experienced similar failure when cargo doors blew off both in 1970 during a ground test and later in 1972on an American Airlines flight over Windsor, Ontario. Following both incidents, investigators largely concluded that the door had been improperly locked so no major modifications were made to the doors, only small "Band-Aid fixes" .

The 1974 crash is significant because it occurred at a critical time in history for both the airline industry and McDonnell Douglas. That decade saw the birth of modern air travel as jumbo jets' increased capacity and range allowed airlines to provide international travel at lower costs to both consumers and themselves. A few large companies, including McDonnell Douglas, were therefore trying to establish reputations for reliability and gain a piece of this emerging market. The crash was increasingly devastating because it was the first total loss of a wide-bodied airliner, an event that was feared since their inception (Schlager, 1994, p. 52).The crash of Flight 981 is worth further examination because it is an excellent case study of how safety and ethics can be compromised. McDonnell Douglas overlooked incidents that indicated a potentially fatal safety problem, and the penalty was the loss of hundreds of lives and the beginnings of a marred reputation for the company's newest, yet largest, investment. The lessons that McDonnell Douglas learned from this disaster are readily applicable today. Due to present struggles to pull a profit, the airline industry is as competitive as ever, requiring constant improvement of old designs and adaptation to new designs (Sharkey, 2001). This constant flux spells a higher urgency than ever for companies that develop and manufacture aircraft to remain focused on safety and ethical practices.

The purpose of this report is to evaluate the ethical nature of McDonnell Douglas's decisions, discerning their priorities with regardto safety and financial gain, and to assess how these qualities have changed in response. This will be accomplished by investigating into McDonnell Douglas's industrial processes, reactions to the crisis, and overall policies in place at the time of the accident.The study begins with a look at the company's design and manufacturing processes as they pertained to developing the cargo door, including a technical look at the features andflaws in the door, delegation of the work, and ground testing practices. Next, we will examine

McDonnell Douglas's response to the mid-fligh tincident of 1972 and to the opinions of the involved engineers. In addition, we will discuss the circumstances and ethics of McDonnellDouglas's recourse to gradually install modifications. Finally, the focus will shift to an analysis of the responsibility assumed by the company, looking specifically at their cleanup actions and public statements. McDonnell Douglas's Design, Manufacturing, and Testing Policies, Design Philosophy and Failure of the Cargo Door The cargo door was the component of the DC-10 aircraft whose failure ultimately led to loss of control of the plane. A failure sequence observed both in the prior incidents and the crash was triggered by an inadequate closure of this door each time. In order to gain a perspective on McDonnell Douglas's policies of safety in design, we begin with an analysis of the door and an examination of the design philosophies employed and their implications as they pertained to the crash of Flight 981. On any aircraft, the integrity of each door is vital to maintaining cabin pressure so that passengers may breathe at the high cruising altitudes of long-range airliners. On the DC-10, however, the criticality of a sound design for the cargo door is increased due to the design of the plane's control system. Three independent systems of hydraulic and electrical lines, which allow the cockpit to control the tail, run through the passenger floor that separates the cabin from the cargo hold. A door failure at high altitudes would cause depressurization of the cargoarea and a large pressure differential across the cabin floor. The floor, an open truss arrangement not intended to hold this pressure, would then collapse, severing the hydraulic lines which control the tail. This would result in a complete loss of the plane's pitch control, and the front-heavy mass distribution of the aircraft would cause it to pitch forward naturally into a nose-dive. This fatal sequence is in addition to any damage to the fuselage as the door is ripped away as well as subsequent damage to the tail from the door or any ejected cargo (Fielder, 1992, pp. 71-72). Passenger doors on every airplane are 'plug type' (inward-opening), and so while in-flight, the cabin pressure aids in keeping the door sealed shut. However, a cargo door is large and cannot be made this way due to interio rspace issues. Thus it is common practice for the doors to be designed to hinge outward with a series of latches, or hooks, which rotate around a latch spool and use the interior pressure to hold the door tightly in place (see Fig. 3). This rotation is driven by an actuator which moves the latches into place through a linkage. The rotation is completed when the linkage passes 'over center', thereby causing the pressure forces conducted through the latches to keep the door shut. As an additional measure, locking pins then move into place which prevent backward movement of the linkage (see Fig. 4-a).Finally, a small vent door is installed as a visual indicator of proper closure such that it only closes once the lock pins are in place, allowing the cargo hold to pressurize (see Fig. 5-a).This door is closed by turning the external handle (Fielder, 1992, pp. 72-73).



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Overall, in most cases airplane malfunctions are not discovered until after a major incident occurs; however, in this instance McDonnell Douglas was presented with a problem in their design well before any person ever stepped on board a DC-10. The fact that the problem with the cargo door and the hydraulic lines was not given the proper amount of concern indicates that McDonnell Douglas lost sight of the first responsibility of an engineer, which Unger describes as "taking responsibility for the consequences of their work and playing an active role in directing it toward human ends" . On July 29, 1971, actual FAA personnel certificated the DC-10 for commercial flight .

3. Whistle Blowing

The term *whistle-blower* comes from the whistle a referee uses to indicate an illegal or foul play. US civic activist Ralph Nader coined the phrase in the early 1970s to avoid the negative connotations found in other words such as "informers" and "snitches".

A **whistleblower** (**whistle-blower** or **whistle blower**) is a person who tells the public or someone in authority about alleged dishonest or illegal activities (misconduct) occurring in a government department or private company or organization. The alleged misconduct may be classified in many ways; for example, a violation of a law, rule, regulation and/or a direct threat to public interest, such as fraud, health/safety violations, and corruption. Whistleblowers may make their allegations internally (for example, to other people within the accused organization) or externally (to regulators, law enforcement agencies, to the media or to groups concerned with the issues).

Most whistleblowers are *internal whistleblowers*, who report misconduct on a fellow employee or superior within their company. One of the most interesting questions with respect to internal whistleblowers is why and under what circumstances people will either act on the spot to stop illegal and otherwise unacceptable behavior or report it. There is some reason to believe that people are more likely to take action with respect to unacceptable behavior, within an organization, if there are complaint systems that offer not just options dictated by the planning and control organization, but a *choice* of options for absolute confidentiality.

External whistleblowers, however, report misconduct to outside persons or entities. In these cases, depending on the information's severity and nature, whistleblowers may report the misconduct to lawyers, the media, law enforcement or watchdog agencies, or other local, state, or federal agencies. In some cases, external whistle blowing is encouraged by offering monetary reward.

Under most US federal whistleblower statutes, in order to be considered a whistleblower, the federal employee must have reason to believe his or her employer has violated some law, rule or regulation; testify or commence a legal proceeding on the legally protected matter; or refuse to violate the law.

In cases where whistle blowing on a specified topic is protected by statute, US courts have generally held that such whistleblowers are protected from retaliation. However, a closely divided US Supreme Court decision, Garcetti v. Ceballos held that the First Amendment free speech guarantees for government employees do not protect disclosures made within the scope of the employees' duties.

If workers bring information about a wrongdoing to the attention of their employers or a relevant organisation, they are protected in certain circumstances under the Public Interest Disclosure Act 1998. This is commonly referred to as 'blowing the whistle'. The law that protects whistle-blowers is for the public interest – so people are encouraged to speak out if they find malpractice in an organisation. Blowing the whistle is more formally known as 'making a disclosure in the public interest'.

Qualifying disclosures are disclosures of information where the worker reasonably believes one or more of the following matters is either happening, has taken place, or is likely to happen in the future:

- A criminal offence

- The breach of a legal obligation
- A miscarriage of justice
- A danger to the health and safety of any individual
- Damage to the environment
- Deliberate attempt to conceal any of the above.

If a worker is going to make a disclosure it should be made to the employer or a prescribed person, so that employment rights are protected.

Workers who 'blow the whistle' on wrongdoing in the workplace can complain to an employment tribunal if they are dismissed or victimised for doing so. An employee's dismissal (or selection for redundancy) is automatically considered 'unfair' if it is wholly or mainly for making a protected disclosure.

Whistleblowing is a valuable tool in any organisation's corporate governance strategy as it empowers employees to act on incidences of misconduct and help maintain a safe workplace, while protecting profits and reputation.

But is whistleblowing ethical? Such conversations provide great scope for dizzying philosophies – but let's keep it simple for the moment – surely at base level, altruistically reporting wrongdoing *must* be ethical? The act of whistleblowing can cause a conflict of interest between the personal, organisational and societal spheres. Much of this conflict stems from the context that one views a whistleblower – as someone sharing knowledge of misconduct for the benefit of others or someone who is a 'grass' and acting 'disloyal' to their organisation.

The 'Broken Windows' theory championed by former Mayor of New York, Rudolph Giuliani, promotes an ideology where communities will report or fix a broken window, rectifying even the smallest incidents of wrongdoing, thereby instilling similar responsibilities in others and creating a better environment for all. Advocating whistleblowing within organisations follows a similar premise. By fostering a culture of self-regulation and accountability, management can help ensure their staff and business operations are protected.

Public perception of ethics and whistleblowing

Whistleblowing can be a divisive topic and, while most would agree with the value of reporting wrongdoing and condone good organisational governance, external contexts can colour acceptance and perception. There are elements of chicken and egg as attitudes that are encouraged in the work place extend to the street – if businesses promote good corporate governance for all, whistleblowing needn't be viewed negatively or as solely the preserve of business or community leaders.

In 2007, a survey commissioned by the US Democracy Corps of 1014 "likely voters" revealed that 70% supported whistleblower protections and 40% stated that they would be much more likely to vote for a congress that enacts such legislation. When we vote, use services or entrust our money with banks we want to know that they are secure and working in our best interests (although the latter example might stick in your throat somewhat!). If an engineer at a water sanitation plant in your area uncovered safety issues we would hope they had ample opportunity to report this without fear of reprisal; avoiding danger and incident and allowing for the company in question to assess and improve their practices.

Personal perception of ethics and whistle-blowing

The whistleblower is ultimately torn between loyalty to their employer (or the subject of their revelation) and their moral commitment to the law and society at large. Many feel they have the most to lose, at least in the first instance. It could be argued that it is incongruous with human nature to display loyalty to a bureaucratic organisation because it is composed of so many different people. This dehumanising environment could distort the whistleblower's perception of their relevance within a company or their ability to influence change, thus degrading their sense of responsibility and motivation to report.

As long as the whistleblower is sure that their motivations are sound and that they are confident in the system they should not hesitate to relay such information and be pleased that they are helping to create a safer working environment for their colleagues.

Whistleblowers and the media have enjoyed a somewhat symbiotic relationship. 'Though agendas and motivations may vary, they share the ambition of exposing wrongdoing and encouraging changes in systems that aren't working in the interests of those they are supposed to protect. Recent high profile cases, such as the care homes scandal, are excellent examples of individuals reporting for altruistic reasons – but if a whistleblower appears to be seeking a soapbox for public attention or engineering an act of retaliation, it is of paramount importance that the investigative body in question ensures that the case is conducted in the correct way and that a message of intolerance is clear. If an individual feels disenfranchised by their position in the process, to transfer it to the public sphere might seem their best or only option. It's up to business and community leaders to ensure this does not happen.

Corporate perception of ethics and whistleblowing

Even if an organisation has a whistleblowing hotline in place they should not be complacent when it comes to its usage and communication. If a company doesn't receive many whistleblowing reports they shouldn't assume that no news is good news (read more about communicating your whistleblowing hotline service). In addition, if companies don't use the data collected from their reports in a progressive manner (analysing trends, investigation and resolution etc) it negates the benefits of the service considerably. Businesses have a responsibility to the public to act on whistleblowing intelligence or risk adverse consequences. They are additionally accountable to the governing bodies of their sector such as the FSA, HSE and of course the Ministry of Justice. Where there are environmental concerns arising from a whistleblowing report, these too must be addressed with the correct authorities.

There are isolated instances where whistleblowing could be considered the wrong course of action in an ethical context; the Republicans branded Bradley Manning, the Wikileaks informant, a terrorist and whipped the media and public into a frenzy regarding breaches of national security. This of course is an extreme case and it is unlikely that whistleblowing cases made in a corporate context will ever mirror this level of drama. But, no matter what size or sector, businesses cannot afford to allow a culture of misconduct and corruption to infiltrate operations.

It might seem obvious as an employee of a market-leading hotline provider to believe in the ethics of whistleblowing – but personal politics aside, it is true to say that individual ethics are born of a culture of ethics and no matter what your personal take on whistleblowing in this realm, that assertion, at least, is undeniable.

What does whistle blowing have to do with ethics?

A whistle blower once testified in a California court about how his boss had regularly ordered him to discard some of the company's toxic waste into a local storm drain rather than dispose of it properly. Why, the judge wanted to know, had the man finally decided to step forward after having participated in this illegal dumping for years. "Well," the man explained, "I was fishing with my grandson, and it suddenly occurred to me that the waste I was dumping was going to pollute the water so that he might never be able to go fishing with his grandson."

Whistle blowing has to do with ethics because it represents a person's understanding, at a deep level, that an action his or her organization is taking is harmful—that it interferes with people's rights or is unfair or detracts from the common good. Whistle blowing also calls upon the virtues, especially courage, as standing up for principles can be a punishing experience. Even though laws are supposed to protect whistle blowers from retaliation, people who feel threatened by the revelations can ostracize the whistle blower, marginalizing or even forcing him or her out of public office. On the other hand, there have been occasions when the role of whistle blower has actually catapulted people into higher office and has earned the respect of constituents. (eg?)

How can government encourage whistle blowing?

In an article about whistle blowing in a business context , Lilanthi Ravishankar makes a useful distinction between external and internal whistle blowing. She argues that companies should encourage internal whistle blowing so that problems are solved within the organization before employees feel they must go outside to get action. The same is true for government bodies, which need to know about problems early—before illegal contracts must be renegotiated or aquifers have been polluted or the public's money has been squandered or unethical behavior has become front-page news.

She makes several suggestions about how to encourage internal whistle blowing in companies. We repeat some of them here, with slight modifications for a government context:

- Create a policy about reporting illegal or unethical practices, which should include:
  - Formal mechanisms for reporting violations, such as hotlines and mailboxesÿ
  - Clear communications about the process of voicing concerns, such as a specific chain of command, or the identification of a specific person to handle complaints
  - Clear communications about bans on retaliation
- Get endorsement of the policy from top officials—mayor, manager, councilmembers, boards—and publicize the organization's commitment to the process. Elected and administrative leadership must encourage ethical behavior and hold everyone within the organization to the highest standards, including the disclosure of activities that would have a negative impact on the public's business.
- Investigate and follow up promptly on all allegations of misconduct. Report on these investigations to the council or board.

What ethical dilemmas does whistle blowing present?

When a person encounters wrongdoing in the public sphere, his or her first step should probably be to use the organization's internal whistle blowing mechanisms. William Black, professor of law and economics at University of Missouri-Kansas City, was himself a whistle blower when he worked as a Savings and Loan regulator in the 1980s. During a term as visiting scholar at the Ethics Center, he wrote about his experience:

Whistle blowers in the public sector often face the unique problem that their disclosure may constitute a crime. This can create an ethical dilemma when the ongoing misconduct is severe and there is no reasonable prospect that the abuse will end absent blowing the whistle….I would still recommend trying to get the responsible organs (e.g., your agency's/department's congressional oversight committees and/or inspector general) to take action first unless the threat to public safety was imminent.

All government bodies should have fairly straightforward lines of authority. For example, if a councilperson has a problem with city staff, he or she would go to the city manager. If an employee of the water district sees wrongdoing, he or she would start with a supervisor and move up the chain of command, and so forth. It's always best to start with the mechanisms the organization has set up to deal with problems because these represent the best chance at an amicable solution.

If this process does not produce results, however, it's not enough to say, "Well, I did my best." If wrongdoing is not being addressed within the organization, it may be time to move outside—to the district attorney, the grand jury, or to the press.

Kirk Hanson, Ethics Center executive director, and Jerry Ceppos, former vice president/news, Knight-Ridder, have written on the ethics of leaking information to the press and suggest these considerations:

The first thing a potential leaker should ask is the status of the information itself. Is the information "classified," "proprietary," or otherwise "protected?" Is there a system in place which clearly considers this information restricted? If the information is clearly intended to be protected, then the leaker must meet a stiff test if he or she wants to leak it.

The second consideration is whether the potential leaker has a specific obligation, legal or ethical, to protect the information, or has the information only because another person violated his or her obligation to keep it secret. If so, then it is a much more serious matter to reveal it.

The third consideration is whether the information is about public or private matters. Information about another's sexual orientation, about his or her private finances, or about personal phone calls has more of a claim to privacy than information about a person's actions as a corporate executive or a government official. The difficult cases, of course, are those where the private life of individuals arguably influences their public actions.

Hanson and Ceppos also argue that potential leakers must assess the good and harm their leak may do. When lives are at stake or millions of public dollars are being misappropriated, those concerns for the public good trump the harm to personal privacy or government secrecy.

On the other hand, a leaker must determine if the conduct he or she is exposing represents actual wrongdoing or if it is simply represents a policy disagreement. Of course, much of the public's business should be debated in public, and speaking up about disagreements on most issues is not only acceptable but also desirable. Closed-door sessions, however, are secret for a reason. Revelations about a city's interest in a particular piece of property may boost the price of that parcel. Exposure of sensitive information about a hiring or firing decision may needlessly cause harm to an individual. As much as council or board members' views may differ on these issues, they should remain secret if the problem does not rise to the level of misconduct.

4. Citicorp Building

The Citicorp Tower is a famous case in engineering ethics that is often celebrated as a *positive* example, rather than the more notorious case studies of ethical failures. In this video, Dr. Michael Loui summarizes the highlights of the case, including the fact that:

- The design flaw was revealed by a Princeton University engineering student who was analyzing the structure for a class project.
- The structural engineer came to realize that the risk of building collapse exceeded all reasonable expectations. He notified the building owner, admitted the error, and worked out an expensive retrofit paid for by his liability insurance and the building owner.
- The discovery and remedy happened to coincide with a newspaper strike in New York City, which effectively suppressed publicity or investigation of the project.

As Dr. Loui explains it, the structural engineer took personal responsibility to protect the public safety. However, given the interesting epilogue regarding the structural engineer's liability insurance premiums, it's not clear what aspect of self-interest the engineer placed at risk.

A more dramatic account of the case produced by PBS includes testimony from William LeMessurier, the engineer responsible. It's available on YouTube in three parts, and reveals some aspects of the case that are *not* in Michael Loui's account, and question whether the case is really the paragon on professional virtue it is celebrated to be, including the secrecy that surrounded the retrofit

The "engineer at the table" referenced in the above clip is Leslie Robertson, as this more concise account of the case recounts. Robertson, a celebrated structural engineer in his own right who designed the World Trade Center, was directly involved in the Citicorp retrofit, but barely credited by LeMessurier's accounts in these videos. I met Robertson when I was a PhD student at Clarkson University, prior to the 9/11 attacks on the World Trade Centers, but following the 1993 World Trade Center bombing. Robertson is in a unique position to comment on the eventual collapse of the World Trade Center and the controversy and speculation surrounding the subsequent investigation.

In the third video, one interview subject speculates as to whether LeMessurier actually had any choice. It seems he is referring to the question of whether or not to retrofit the building, but there were clearly *more* choices to make that went beyond the question of the structural integrity of the building.

Lastly, there are several aspects of the story that are *not* revealed in the videos.

One of these is that the PBS special credits an unnamed male engineering student "in New Jersey", when in fact it was a *female* student from Princeton University (which is in New Jersey) but remains uncredited by popular accounts, largely because LeMessurier himself pays little attention to who she was

LeMessurier had no choice, the retrofit was necessary. This was a design flaw with potentially catastrophic consequences. He obeyed the 1st canon in which an engineer shall hold paramount the safety, health, and welfare of the public. Doing nothing to save face would have put thousands of lives in jeopardy which is unethical and immoral. I don't blame him for conducting the retrofit in secrecy, he did not want to raise a panic. I am confident that had a storm arrived with a wind strength that could bring down the tower prior to completion, LeMessurier would have evacuated the area. Therefore, he also obeyed the 5th & 6th canons that state an engineer shall avoid deceptive acts and conduct themselves honorably.

This is by far the most interesting case Iv'e heard about. To think that this massive building could have fallen over at anytime is extremely scary. I don't believe he did anything wrong from what the video tells us. My main question is how does the structural engineer not hear that the subcontractor is going to use bolts and not welds?????? Is that even possible in today's engineering with all of the codes and standards that need to be met through communication??? This part seems a little fishy to me but if he really didn't know then you can't really fault him for it.

http://www.youtube.com/watch?feature=player_embedded&v=AOYVaYZvg2Q
http://www.youtube.com/watch?feature=player_embedded&v=TZhgTewKhTQ
http://www.youtube.com/watch?feature=player_embedded&v=4fUwgH0gOWo
http://www.youtube.com/watch?feature=player_embedded&v=IBjyB8EY2m4

5. Space Shuttle *Challenger* disaster

The **Space Shuttle *Challenger* disaster** occurred on January 28, 1986, when Space Shuttle *Challenger* (mission STS-51-L) broke apart 73 seconds into its flight, leading to the deaths of its seven crew members. The spacecraft disintegrated over the Atlantic Ocean, off the coast of central Florida at 11:38 EST (16:38 UTC). Disintegration of the entire vehicle began after an O-ring seal in its right solid rocket booster (SRB) failed at liftoff. The O-ring failure caused a breach in the SRB joint it sealed, allowing pressurized hot gas from within the solid rocket motor to reach the outside and impinge upon the adjacent SRB attachment hardware and external fuel tank. This led to the separation of the right-hand SRBs aft attachment and the structural failure of the external tank. Aerodynamic forces promptly broke up the orbiter.

The crew compartment and many other vehicle fragments were eventually recovered from the ocean floor after a lengthy search and recovery operation. Although the exact timing of the death of the crew is unknown, several crew members are known to have survived the initial breakup of the spacecraft. However, the shuttle had no escape system and the impact of the crew compartment with the ocean surface was too violent to be survivable.

The disaster resulted in a 32-month hiatus in the shuttle program and the formation of the Rogers Commission, a special commission appointed by United States President Ronald Reagan to investigate the accident. The Rogers Commission found NASA's organizational culture and decision-making processes had been key contributing factors to the accident.[1] NASA managers had known contractor Morton Thiokol's design of the SRBs contained a potentially catastrophic flaw in the O-rings since 1977, but failed to address it properly. They also disregarded warnings from engineers about the dangers of launching posed by the low temperatures of that morning and had failed in adequately reporting these technical concerns to their superiors.

What Rogers did not highlight was that the vehicle was never certified to operate in temperatures that low. The O-rings, as well as many other critical components, had no test data to support any expectation of a successful launch in such conditions. Bob Ebeling from Thiokol delivered a biting analysis: "[W]e're only qualified to 40 degrees ...'what business does anyone even have thinking about 18 degrees, we're in no man's land.'"[2]

As a result of the disaster, the Air Force decided to cancel its plans to use the Shuttle for classified military satellite launches from Vandenberg Air Force Base in California, deciding to use the Titan IV instead.

Many viewed the launch live because of the presence of crew member Christa McAuliffe, the first member of the Teacher in Space Project and the (planned) first female teacher in space. Media coverage of the accident was extensive: one study reported that 85 percent of Americans surveyed had heard the news within an hour of the accident. The *Challenger* disaster has been used as a case study in many discussions of engineering safety and workplace ethics.

O-ring concerns

Each of the two Space Shuttle Solid Rocket Boosters (SRBs) that comprised part of the Space Transportation System was constructed of six sections joined in three factory joints and three "field joints".[3] The factory joints had asbestos-silica insulation applied over the joint, while the field joints—assembled in the Vehicle Assembly Building at Kennedy Space Center (KSC)—depended on two rubber O-rings, a primary and a secondary (backup), to seal them. (After the destruction of *Challenger*, SRB field joints started using three O-rings.) The seals of all of the SRB joints were required to contain the hot high-pressure gases produced by the burning solid propellant inside, forcing it out the nozzle at the aft end of each rocket.

During the Space Shuttle design process, a McDonnell Douglas report in September 1971 discussed the safety record of solid rockets. While a safe abort was possible after most types of failures, one was especially dangerous, a burnthrough by hot gases of the rocket's casing. The report stated that "if burnthrough occurs adjacent to [liquid hydrogen/oxygen] tank or orbiter, timely sensing may not be feasible and abort not possible", accurately foreshadowing the *Challenger* accident.[4] Morton Thiokol was the contractor responsible for the construction and maintenance of the shuttle's SRBs. As originally designed by Thiokol, the O-ring joints in the SRBs were supposed to close more tightly due to forces generated at ignition. However, a 1977 test showed that when pressurized water was used to simulate the effects of booster combustion, the metal parts bent *away* from each other, opening a gap through which gases could leak. This phenomenon, known as "joint rotation," caused a momentary drop in air pressure. This made it possible for combustion gases to erode the O-rings. In the event of widespread erosion, an actual flame path could develop, causing the joint to burst—which would have destroyed the booster and the shuttle.[5]

Engineers at the Marshall Space Flight Center wrote to the manager of the Solid Rocket Booster project, George Hardy, on several occasions suggesting that Thiokol's field joint design was unacceptable. For example, one engineer suggested that joint rotation would render the secondary O-ring useless. However, Hardy did not forward these memos to Thiokol, and the field joints were accepted for flight in 1980.[6]

Evidence of serious O-ring erosion was present as early as the second space shuttle mission, STS-2, which was flown by *Columbia*. However, contrary to NASA regulations, the Marshall Center did not report this problem to senior management at NASA, but opted to keep the problem within their reporting channels with Thiokol. Even after the O-rings were redesignated as "Criticality 1"—meaning that their failure would result in the destruction of the Orbiter—no one at Marshall suggested that the shuttles be grounded until the flaw could be fixed.[6]

By 1985, Marshall and Thiokol realized that they had a potentially catastrophic problem on their hands. They began the process of redesigning the joint with three inches (76 mm) of additional steel around the tang. This tang would grip the inner face of the joint and prevent it from rotating. However, they did not call for a halt to shuttle flights until the joints could be redesigned. Rather, they treated the problem as an acceptable flight risk. For example, Lawrence Mulloy, Marshall's manager for the SRB project since 1982, issued and waived launch constraints for six consecutive flights. Thiokol even went as far as to persuade NASA to declare the O-ring problem "closed".[6] Donald Kutyna, a member of the Rogers Commission, later likened this situation to an airline permitting one of its planes to continue to fly despite evidence that one of its wings was about to fall off.

6. Bhopal Gas Tragedy

The pre-event phase

The UCIL factory was built in 1969 to produce the pesticide Sevin (UCC's brand name for carbaryl) using methyl isocyanate (MIC) as an intermediate.[5] A MIC production plant was added in 1979.[9][10][11] After the Bhopal plant was built, other manufacturers including Bayer produced carbaryl without MIC, though at a greater manufacturing cost. However, Bayer also uses the UCC process at the chemical plant once owned by UCC at Institute, West Virginia, USA.[12]

The chemical process employed in the Bhopal plant had methylamine reacting with phosgene to form MIC, which was then reacted with 1-naphthol to form the final product, carbaryl. This "route" differed from the MIC-free routes used elsewhere, in which the same raw materials were combined in a different manufacturing order, with phosgene first reacting with naphthol to form a chloroformate ester, which was then reacted with methylamine. In the early 1980s, the demand for pesticides had fallen, but production continued, leading to buildup of stores of unused MIC.[5][12]

Earlier leaks

In 1976, two trade unions complained of pollution within the plant.[5][13] In 1981, a worker was splashed with phosgene. In a panic, he removed his mask, inhaling a large amount of phosgene gas which resulted in his death 72 hours later.[5][13] UCC was warned by American experts who visited the plant after 1981 of the potential of a "runaway reaction" in the MIC storage tank. Local Indian authorities had warned the company of the problem as early as 1979, but constructive actions were not undertaken by UCIC at that time.[5][12] In January 1982, a phosgene leak exposed 24 workers, all of whom were admitted to a hospital. None of the workers had been ordered to wear protective masks. One month later, in February 1982, a MIC leak affected 18 workers.[5][13] In August 1982, a chemical engineer came into contact with liquid MIC, resulting in burns over 30 percent of his body.[5][13] Later that same year, in October 1982, there was another MIC leak. In attempting to stop the leak, the MIC supervisor suffered intensive chemical burns and two other workers were severely exposed to the gases.[5][13] During 1983 and 1984, there were leaks of MIC, chlorine, monomethylamine, phosgene, and carbon tetrachloride, sometimes in combination.[5][13]

Contributing factors

Factors leading to the magnitude of the gas leak mainly included problems such as; storing MIC in large tanks and filling beyond recommended levels, poor maintenance after the plant ceased MIC production at the end of 1984, failure of several safety systems due to poor maintenance, and safety systems being switched off to save money—including the MIC tank refrigeration system which could have mitigated the disaster severity. The situation was worsened by the mushrooming of slums in the vicinity of the plant, non-existent catastrophe plans, and shortcomings in health care and socio-economic rehabilitation.[4][5]

Other factors identified by the inquiry included: use of a more dangerous pesticide manufacturing method, large-scale MIC storage, plant location close to a densely populated area, undersized safety devices, and the dependence on manual operations.[5] Plant management deficiencies were also identified – lack of skilled operators, reduction of safety management, insufficient maintenance, and inadequate emergency action plans.[5][13]

Work conditions

Attempts to reduce expenses affected the factory's employees and their conditions. Kurzman argues that "cuts...meant less stringent quality control and thus looser safety rules. A pipe leaked? Don't replace it, employees said they were told ... MIC workers needed more training? They could do with less. Promotions were halted, seriously affecting employee morale and driving some of the most skilled ... elsewhere".[14] Workers were forced to use English manuals, even though only a few had a grasp of the language.[15][16]

By 1984, only six of the original twelve operators were still working with MIC and the number of supervisory personnel was also halved. No maintenance supervisor was placed on the night shift and instrument readings were taken every two hours, rather than the previous and required one-hour readings.[15][14] Workers made complaints about the cuts through their union but were ignored. One employee was fired after going on a 15-day hunger strike. 70% of the plant's employees were fined before the disaster for refusing to deviate from the proper safety regulations under pressure from the management.[15][14]

In addition, some observers, such as those writing in the Trade Environmental Database (TED) Case Studies as part of the Mandala Project from American University, have pointed to "serious communication problems and management gaps between Union Carbide and its Indian operation", characterised by "the parent companies [*sic*] hands-off approach to its overseas operation" and "cross-cultural barriers".[17]

Equipment and safety regulations

The MIC tank alarms had not been working for four years and there was only one manual back-up system, compared to a four-stage system used in the United States.[4][5][15][18] The flare tower and several vent gas scrubbers had been out of service for five months before the disaster. Only one gas scrubber was operating: it could not treat such a large amount of MIC with sodium hydroxide (caustic soda), which would have brought the concentration down to a safe level.[18] The flare tower could only handle a quarter of the gas that leaked in 1984, and moreover it was out of order at the time of the incident.[4][5][15][19] To reduce energy costs, the refrigeration system was idle. The MIC was kept at 20 degrees Celsius, not the 4.5 degrees advised by the manual.[4][5][15][18] Even the steam boiler, intended to clean the pipes, was inoperational for unknown reasons.[4][5][15][18] Slip-blind plates that would have prevented water from pipes being cleaned from leaking into the MIC tanks, had the valves been faulty, were not installed and their installation had been omitted from the cleaning checklist.[4][5][15] The water pressure was too weak to spray the escaping gases from the stack. They could not spray high enough to reduce the concentration of escaping gas.[4][5][15][18] In addition to it, carbon steel valves were used at the factory, even though they were known to corrode when exposed to acid.[12]

According to the operators, the MIC tank pressure gauge had been malfunctioning for roughly a week. Other tanks were used, rather than repairing the gauge. The build-up in temperature and pressure is believed to have affected the magnitude of the gas release.[4][5][15][18] UCC admitted in their own investigation report that most of the safety systems were not functioning on the night of 3 December 1984.[20] The design of the MIC plant, following government guidelines, was "Indianized" by UCIL engineers to maximise the use of indigenous materials and products. Mumbai-based Humphreys and Glasgow Consultants Pvt. Ltd., were the main consultants, Larsen & Toubro fabricated the MIC storage tanks, and Taylor of India Ltd. provided the instrumentation.[21] In 1998, during civil action suits in India, it emerged that the plant was not prepared for problems. No action plans had been established to cope with incidents of this magnitude. This included not informing local authorities of the quantities or dangers of chemicals used and manufactured at Bhopal.

7. Chernobyl Accident

Under normal operating regime, nuclear power stations practically do not release
aerosol products to the atmosphere leading to essential radioactive fallout. According to studies conducted by scientists from different countries, under the normal operating
regime nuclear reactors can release to the atmosphere inert gases (some cases with insignificant admixture of tritium.

Under normal operating regime, nuclear power stations can release (2-4) ·105
Ci/year in the form of gaseous products (mainly, due torelatively short-lived inert gas isotopes), up to 10 Ci/year of aerosol products, 0.5 Ci/year
of radioactive iodine; only very small quantity of aerosol products can fall on the su
rface, including the Iodine isotopes. When this takes place, only a small quantity of the aerosol products can be felt onto the ground surface. However, accidents at nuclear reactors are an important exception, as well accidents of different type at atomic enterprises. Among notable accidents occurred at nuclear reactors, it should be noted here (in a chronological order) the following: the Windscale accident (the Great Britain, 1957), LSthe Three-Mile-Island nuclear power station accident (the USA, 1983), and the greatest all over the world Chernobyl nuclear power station accident (the former USSR, 1986). For comparison, total release ofradioactivity under tests of nuclear weapon and largest accidents (PBq per D+3) is as follows:
This had happened on April 26, 1986. Accidentat the Chernobyl Nuclear Power Plant
(CNPP) had occurred during technical tests in a regime of small power which were carried out at a reactor of the Unit IV. The safety systems of the reactor were switched off that resulted in its abnormal and unstable working regime that led to sharp and
\uncontrolled rise of the power. The enormous power caused a series of vapor explosions which had destroyed the reactor itself and damaged the building. Fragments of the reactor active zone, being thrown out, caused 30 more centers of burning on the roof that was covered by the easily ignitable material tar. A crater had been formed after destruction of the building and the reactor (Figure 1). Already in five minutes the first group of 14 firemen had arrived at the accident place, and in two hours 250 people were working at the site, and 69 among them were directly involved in the fire suppression. These works were carried out at the 70-meter altitude and under condition of high levels of radiation and strong smoking that had caused heavy defeat of almost half of the participants with further deaths. Thus, this accident was a result of both, faults of the reactor construction (high positive coefficients ofreactivity under certain conditions) and inadmissible erroneous actions of operators who had switched off emergency protective systems. At the first step of the struggle against the fire and the radionuclide release, huge quantity of special compositions absorbing the neutrons as well material used to put out (extinguish) fires was dropped from helicopters into the crater on the roof. Totally, about 5 000 tons of different materials had been thrown down, and those were as follows: lead, compounds of boron (Br), dolomite, sand, and clay aswell as sodium phosphate and liquid polymer materials. During the first of the total 1 800 flights, the

helicopters were hovering above the reactor, but, later on, the doses those were taken by pilots were considered too high, so, the decision had been made to throw the materials down during the moment of their flight over the reactor. This led to inaccurate hits and this caused new destructions and further spread of radioactive contamination.

On the 7-8thday dumping (discharge) of the materials had been decreased, and then stopped totally because offears that the building structureswould not be able to stand.

Melted materials of the active zone (corium or lava) flew down to the bottom of the reactor shaft. Here, under graphite that played the role of a peculiar filter for volatile compounds, and a layer of metallized fuel had been formed.

The resulting quick spreading of the coriumand its contacting with water had caused the water vapor formation that promoted a sharp increase of intensity of the radioactive releases occurring at the final step of the accident active period. Approximately in 9 days, the corium had quickly solidified and lost capability of reacting with surrounding materials that significantly decreased the heatrelease, and, as a consequence, reduced the intensity of the radionuclide rele ase by two-three orders of magnitude. Since is accident was really very large and had rather serious consequences, many people wanted to know the reason why this could happen. There were many different versions of conjectures on the possible cause. Some scientists proposed that this could be caused in response to a distant earthquake, some – that this was a deep fault in the Earth's crust. We do not think that it is reasonable to present here this discussion. According to the conclusion of the Governmental commission, the official version on the Chernobyl NPP accident is the following: the thermal (nonnuclear) explosion had occurred in a course of tests aimed at examination of a possibilityto apply a voltage from the turbo-generator in a regime of de-energizing of the CNPP. As a matter of fact, this only cause had ledtodestruction of the unit IV, the fire in the reactor, and the release of significant quantity of radioactivity, accumulated in the reactor by the moment of the explosion, into the ambient environment. However, the great dimensionsof the accident and its consequences make us to ponder

over the causes of this accident, and, first of all, over reliability of the reactor type (MK) that burst in Chernobyl as well as over a right way of organization of functioning of these reactors and over general state of national nuclear power engineering. Reactor RBMK had been developed in the USSR and had undergone all necessary tests. A decision to build atomic stations (NPPs) and to equip them with this type of reactor had been made only on the basis of all the tests done. The special Interagency Scientific-Technical Council on the nuclear power stations existed in the Ministry of Middle Machine Building headed by academician A.P. Aleksandrov existed in former USSR for solution of technical problems in the field of nuclear power engineering. All leading scientists and specialists in this field took

part in the work of this Council: scientific leaders and main designers of reac

tors, general designers of nuclear stations and chief specialists. And, no decision made by this Council contained any information allowing any doubts on the safety of these type reactors. All basic scientific and technical decisions in relation to nuc

lear stations for different purposes were made in the Ministry of Middle MachineBuilding of USSR that was responsible for nuclear protective potential of the country, and it had all scientific, research, and designing organizations needed for the works for the nuclear power engineering. But, in middle of the 1960s exploitation of nuclear plants was entrusted to the USSR Ministry of Power Engineering and Electric Power Supply that possessed a great scientific-technical potential in the field of traditional power engineering, but had no means to control and sustain works for the nuclearstation exploitation. In June of 1986, i.e. already after the Chernobyl accident, theproblem of improvement of the nuclear power engineering was considered at special meetings of Politbureau of Central Committee of the Communist Party. Different opinions wereexpressed but only one was prevailing that was necessary to entrust exploitation of NPPs to that ministry where all necessary means and relevant experience were available. One should take into account that in all countries where nuclear power engineering exists it was a new type of industrial activity that was developed on the basis of specific works for creation of nuclear weapons. Different reorganizations and "perestroikas" in this field took place earlier or later everywhere all over the world. It seems reasonable to consider the reorganization mentioned above as the main mistake that resulted in tragic consequences. New, and still not sfficiently examined (studied) and mastered, this power production was potentially dangerous and at the same time was introduced too early into ordinary framework of civil industry. By the time of the Chernobyl accident, the USSR nuclear power engineering was only 22 years old. Together with development of the nuclear power engineering the basis for norms and standards for this new type of industry wasdeveloped too. The norms and standards were developed and improved together withaccumulation of experience of the NPP functioning. This process was ratherquick, and, for several years, the operation of nuclear power units did not comply with the improved norms accepted on the basis of their work. But, no recons

truction or modernization of them was carried out. It seems that functioning of NPP in the system of civil industry was not carefully thought out. It was supposed

that regulations and instructions on the nuclear power stations maintenance would be strictly beperformed by the personnel. It became clear after the Chernobyl accident how much this isimportant to take into account the so-called "human factor". Analysis of many aspects of this event had demonstrated that itwas not possible to foresee all circumstances that led to the accident. But, this allows making conclusions and learning lessons for further development and progress of the nuclear power engineering that is the extremely important field of human activity. Unit IV of the Chernobyl NPP (CNPP) was destroyed, and a short-time outburst
(release) to the environment of accumulated radionuclides took place as a result of thermal (non-nuclear) explosion on April 26, 1986. Then, during two weeks (including 6 May) a plume of gaseous and aerosol radioactive products continued to be released into the atmosphere due to high temperature of graphite burning and inner heating. The data on radionuclide release from the reactor and the problem of possibility to reconstruct the radioactivity source as a whole during the CNPPaccident are in more detail discussed in Section 5. Naturally, the mechanism of aerosol particle formation, and, consequently, the structure, composition and other characteristics of aerosol particles, resulting from "nuclear" accidents, considerably differ from those resulting from nuclear explosions. This distinction is determined by quite different physical and chemical conditions of particle generation, difference in the material of which the particles are formed, etc. The conditions of radioactive particle formation during the Chernobyl accident are discussed below. The following scheme of emergency release has been proposed by Sivintsev and Khrulev (1995). Itincludes four main stages:

8.Three Miles Island Accident

On March 28, 1979 the most serious United States commercial nuclear power plant accident happened outside of Middletown , Pennsylvania . Although no deaths occurred, the accident at Three Mile Island Unit 2 was the worst in operating history. It highlighted the need for changes in emergency response planning, reactor operator training, human factors engineering, and radiation protection. The accident was a result of equipment malfunctions, worker errors, and design related problems that ultimately led to a partial core meltdown and a small release of radioactivity.

The Accident

Early morning on March 28, 1979 the Three Mile Island plant, which used pressurized water reactors, "experienced a failure in the secondary, non-nuclear section of the plant" (NRC). Due to a mechanical or electrical failure, the central feedwater pumps terminated and "prevented the steam generators from removing heat" (NRC). As a consequence the turbine and reactor shut down, this caused an increase in pressure within the system. When pressure increases in the primary system a monitored pilot-operated relief valve opens until pressure reaches an acceptable level then shuts. In the case of the Three Mile Island accident the pilot-operated relief valve never closed and no signal was given to the operator. Consequently, the open valve poured out cooling water to assist in the lowering of pressure "and caused the core of the reactor to overheat" (NRC). The indicators which were designed to let the operator know when malfunctions were occurring provided conflicting information. There was no indicator displaying the level of coolant in the core nor was there a signal that the relief valve was open; therefore, the operators assumed the core was properly covered. Alarms went off in the plant due to the loss of coolant but the operators were confused on what was wrong thereby making the situation worse. The overheating caused a rupture in the zirconium cladding and melting of the fuel pellets. Thankfully, the worst case consequences of a dangerous meltdown such as a breach of the walls f the containment building or releases of large amounts of radiation did not happen.

Impact of the Accident

The Three Mile Island accident prompted several upgrades in the maintenance and building of nuclear power plants. As described by the United States Nuclear Regulatory Commission Three Mile Island Fact Sheet, some of the changes which occurred post accident are the following: upgrading and strengthening of plant design and equipment requirements, identifying human performance as a critical part of plant safety, revamping operator training and staffing requirements, improved instruction to avoid the confusing signals that plagued operations during the accident, enhancement of emergency preparedness, regular analysis of plant performance, and expansion of performance-oriented as well as safety-oriented inspections.

In addition, the accident permanently changed the nuclear industry and the Nuclear Regulatory Commission's approach to regulation. The Nuclear Regulatory Commission (NRC) developed broader and more vigorous regulations and inspections in order to circumvent the public's worry and distrust. Since the Three Mile Island accident, the NRC has expanded its method of regulation. As shown in Figure 2.5, the NRC's "primary mission to protect the public health and safety, and the environment from the effects of radiation from nuclear reactors, materials, and waste facilities" is carried out in five different manners: regulations and guidance, licensing and certification, oversight, operational experience, and support for decisions (NRC website). By promoting each facet of its regulation method, the NRC strives to protect plant workers, the environment, and society as a whole.

Although no injuries occurred due to the accident, the idea of an extremely dangerous nuclear meltdown happening near one's household is disturbing. Yes, nuclear power provides 15% of the United States ' electricity but the risks of disposal and possible radiation exposure outweighs the desperateness of electrical power. What if X number of people were injured or killed due to the accident? Would taking that risk and sacrificing those people be worth nuclear power?

In the end, making one key ethical choice can solve the ethical dilemma regarding the use of nuclear power plants. Even though it has been shown that nuclear power outperforms other power sources in the creation of electrical power, there are inherent public risks involved. The first code of the *IEEE Codes of Ethics* states, " to accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment." This aspect of the code of ethics answers the question. Even if the risk to public health is small, eliminating that risk takes precedence over the cheaper electricity output of nuclear power.

In conclusion, it can be said that the use of nuclear power is unethical. Even though the risk is low, the slightest possibility of a disaster is too much to risk. The safety of the public and of the environment must be held paramount over any utilitarian aspects of nuclear power.

9. Columbia disaster

The **Space Shuttle *Columbia* disaster** occurred on February 1, 2003, when, shortly before it was scheduled to conclude its 28th mission, STS-107, the Space Shuttle *Columbia* disintegrated over Texas and Louisiana during re-entry into the Earth's atmosphere, resulting in the death of all seven crew members. Debris from *Columbia* fell to Earth in Texas. A debris field has been mapped[1] along a path stretching from south of Fort Worth to Hemphill, Texas, as well as into parts of Louisiana.[2]

The loss of *Columbia* was a result of damage sustained during launch when a piece of foam insulation the size of a small briefcase broke off from the Space Shuttle external tank (the 'ET' main propellant tank) under the aerodynamic forces of launch. The debris struck the leading edge of the left wing, damaging the Shuttle's thermal protection system (TPS), which shields the vehicle from the intense heat generated from atmospheric compression during re-entry. While *Columbia* was still in orbit, some engineers suspected damage, but NASA managers limited the investigation, under the rationale that the *Columbia* crew could not have fixed the problem.[3] The Columbia Accident Investigation Board (CAIB) later concluded that a rescue mission using *Atlantis* may have been possible.[4]

NASA's original shuttle design specifications stated that the external tank was not to shed foam or other debris; therefore, strikes upon the vehicle were safety issues that needed to be resolved before a launch was cleared. Launches were often given the go-ahead as engineers came to see the foam shedding and debris strikes as inevitable and unresolvable, with the rationale that they were either not a threat to safety, or an acceptable risk. The majority of shuttle launches recorded such foam strikes and thermal tile scarring.[5] On STS-112, two launches before, a chunk of foam broke away from the ET bipod ramp and hit the SRB-ET Attach Ring near the bottom of the left solid rocket booster (SRB) causing a dent four inches wide and three inches deep in it.[6] After that mission, the situation was analyzed and NASA decided to press ahead under the justification that "The ET is safe to fly with no new concerns (and no added risk)"[7] of further foam strikes, justification that was revisited while Columbia was still in orbit and Chair of the Mission Management Team (MMT) Linda Ham re-assessed, stating that the "Rationale was lousy then and still is". Ham as well as Shuttle Program Manager Ron Dittemore had both been present at the October 31, 2002, meeting where this decision to continue with launches was made.[8]

During re-entry of STS-107, the damaged area allowed hot gases to penetrate and destroy the internal wing structure,[9] rapidly causing the in-flight breakup of the vehicle. An extensive ground search in parts of Texas, Louisiana, and Arkansas recovered crew remains and many vehicle fragments.

Mission STS-107 was the 113th Space Shuttle launch. The mission was delayed 18 times[10] over the two years from the planned launch date of January 11, 2001, to the actual launch date of January 16, 2003. (It was preceded by STS-113.) A launch delay due to cracks in the shuttle's propellant distribution system occurred one month before a July 19, 2002, launch date. The Columbia Accident Investigation Board determined that this delay had nothing to do with the catastrophic failure six months later.[10]

The Columbia Accident Investigation Board's recommendations addressed both technical and organizational issues. Space Shuttle flight operations were delayed for over two years, similar to the delay following the *Challenger* accident. Construction of the International Space Station was put on hold, and for 29 months the station relied entirely on the Russian Federal Space Agency for resupply until Shuttle flights resumed with STS-114 and 41 months for crew rotation until STS-121. Major changes to shuttle operations, after missions resumed, included a thorough on-orbit inspection to determine how well the shuttle's thermal protection system had endured the ascent, and keeping a designated rescue mission at the ready in case irreparable damage was found. Also it had been decided that all missions would be flown only to the ISS so that the crew could use that spacecraft as a "safe haven" if need be. Later NASA decided it would be an acceptable risk to make one exception to that policy for one final mission to repair the Hubble Space Telescope in its high-altitude low-inclination orbit.

Hot gases seeped into the wing as Columbia attempted re-entry, triggering an explosion that killed all seven astronauts. Photograph: Nasa/Getty Images

Nasa managers discussed their obligation to inform the Columbia space shuttle crew of damage to the craft and the risks of returning it to Earth just days before it blew apart over Texas in 2003, a former project leader has revealed.

Speaking candidly to mark the 10th anniversary of the disaster that almost ended the agency's manned spaceflight programme, former shuttle project manager Wayne Hale revealed the depths of the moral debate that took place in Houston after the orbiter was struck by falling insulation foam on its launch from Florida 16 days earlier.

Hale wrote on his blog that he was told by Jon Harpold, then Nasa's director of mission operations: "You know, there is nothing we can do about damage to the thermal protection system. If it has been damaged it's probably better not to know. I think the crew would rather not know.

"Don't you think it would be better for them to have a happy successful flight and die unexpectedly during entry than to stay on orbit, knowing that there was nothing to be done, until the air ran out?"

At the time, Hale stressed, Harpold's words were purely hypothetical because the space agency's engineers were working on what he called "the wrong problem". They were looking at whether the briefcase-sized piece of foam, which knocked a hole in the leading edge of the orbiter's left wing, had instead damaged the softer thermal protection tiles on the wing's underside.

After showing the astronauts in orbit a video of the foam strike and discussing with them what they thought they knew, mission managers concluded that it was a non-issue and posed no threat to the crew's safe return.

They were proved wrong when hot gases seeped into the wing as Columbia attempted re-entry to Earth's atmosphere and caused the 17,5000mph explosion that sent chunks of the spacecraft raining down over eastern Texas.

Although the circumstances of the tragedy have been well documented, and Hale insists there was "never any debate about what to tell the crew", his revelation brings new insight to the mindset of some Nasa employees at the time.

The agency was heavily criticised by the report of the Columbia accident investigation board, published six months after the explosion, for "a culture of complacency" that led to the cutting of corners and the legitimate concerns of low-level employees being ignored. It was established that junior engineers had asked eight times for military satellite images to be studied to determine damage to the shuttle but were rebuffed by superiors.

Hale, now retired from Nasa after serving as flight director for 40 of the shuttle programme's 135 missions, said he did not agree with his manager's assessment that nothing could have been done for the astronauts.

"We would have pulled out all the stops. There would have been no stone left unturned. We would have had the entire nation working on it," he said, even though he realised such efforts would probably have been futile.

On his personal blog, he writes: "If there were some magical way to find out Columbia's status, a week after launch it was too late. The best case scenario, which had virtually no chance of succeeding, would only have worked if action had been taken on the second or third day of the flight; by the sixth day it was too late."

The three surviving shuttles, Endeavour, Discovery and Atlantis, were grounded for two and a half years after the disaster. For every mission after their 2005 return to flight until the fleet's eventual retirement in 2011, Nasa always kept another orbiter in an advanced state of readiness for a launch-on-need rescue mission.

The seven astronauts who died aboard Columbia were honoured Friday morning at a ceremony at Florida's Kennedy Space Center, attended by mission commander Rick Husband's widow Evelyn and family members of the other victims.

Nasa officials also paid tribute to the seven shuttle astronauts who perished in the 1986 Challenger disaster and the three killed in the 1967 Apollo 1 launchpad fire, and acknowledged the agency's failings a decade ago.

"The accident wasn't caused by a single event or a single person but by a series of technical and cultural missteps stemming all the way back to the first shuttle launch in 1981," said Bill Gerstenmaier, associate administrator for human exploration and operations.

"We continued to lose foam on many missions and this reinforced the idea that all was well. We did not stay hungry and we didn't deeply analyse the implications of foam being released at precisely the wrong moment.

"We need to stay vigilant and recognise that even the smallest potential flaw can become a big problem. Even small problems can serve as major failures."

The central ethical issue

* What should NASA have done and said about the known possibility that Columbia might not survive re-entry?

Facts about the case.

* Foam struck Columbia's wing at launch.
* Videos of the launch showed this, so NASA knew about it.
* Past foam strikes had caused minor scratching of wing heat tiles. If the heat tiles had major damage this time (broken or missing), then Columbia would crash.
* NASA had the means to examine the wing, but chose not to.
* NASA also chose to not tell the crew anything.

Available options.

* Don't find out, and don't tell (the one taken).
* Find out, but don't tell.
* Don't find out, but tell (in the form of a warning).
* Find out, and tell.

Ethical analysis.

*** Don't find out, don't tell.**
o Utilitarian perspective - what could be the benefits to anybody from running the space program this way?

o Kantian Perspective - puts people carelessly at risk for the glory of NASA.

*** Find out, but don't tell.**
o Utilitarian Perspective - depends on benefits that might follow from running the mission to conclusion.
o Kantian Perspective - denies respect to crew.

*** Don't find out, but tell.**
o Utilitarian Perspective - depends on amount of resources needed to find out and on the benefit that would follow from telling.
o Kantian Perspective - even though it respects the crew by telling, it writes them off without proper evidence as being unworthy of a rescue effort.

*** Find out, and tell.**
o Utilitarian Perspective - especially when costs to NASA of simply not finding out are taken into account.
o Kantian Perspective - respects crew in all ways.

RESISTANCE TO CHANGE
During the last thirty years, the agency has experienced one crucial shift in its culture. The Von Braun culture established beginning in 1958 was rigorous in engineering precision and detail oriented. It put safety first. Overtime, however, those emphases receded as the agency became more managerially and production oriented. Efficiency subsequently became the agency's core value. NASA's emergent culture of production proved to be very hardy and resistive. As a result, the space shuttle program, despite the wake-up calls of Apollo and Challenger and other mishaps, successfully fought to maintain its new culture of production. Moreover, following its reorganization after the failings of 1986, NASA's culture fought even harder to return to its efficiency-based value system. Partial evidence of this is found in the Board's report that cited eight ‘‘ missed opportunities'' when NASA engineers could have possibly averted the Columbia tragedy. The report concludes that NASA's flawed culture kept its employees from reading these signals and responding adequately to them. The NASA culture of the 1960s and early 70s would have responded to these signals; its culture of production of the1980s and 90s did not.
A CULTURE EXPRESSES ITS UNDERLYING ETHICS
A culture stems from fundamental ethical values and subsequently structures its members' patterns of thought and perception. The distinctions people make about the reality they face, the values they place on them, and the language they use to describe them are all first created by a culture as it evolves. Subsequently, the new language and work norms are learned by others as‘‘ the way things are done around here.'' As a consequence, an organization's culture influences the range of choices that managers will view as rational or appropriate in any given situation. It provides them with a worldview that confines and directs their thinking and behavior. When norms of safety, respect, honesty, fairness and the like are integral parts of a culture, its people make ethical decisions. A climate of trust evolves. Cultures that lack these ethical norms (e.g., Enron Corp., World-Com Inc., Tyco International) can make terribly harmful choices; and, often its members do not realize it. For most members the assumptions of a culture are taken for granted. Consequently, leaders must make clear to all involved that their organization's culture and its ethics are inextricably linked. It appears that by stressing cost cutting and meeting delivery dates so stringently NASA's leaders, perhaps inadvertently, encouraged less than forthright behavior on the part of some members of the organization.

10. Ford Pinto Safety problems

Abstract
The cases involving the explosion of Ford Pinto's due to a defective fuel system design led to the debate of many issues, most centering around the use by Ford of a cost-benefit analysis and the ethics surrounding its decision not to upgrade the fuel system based on this analysis.
ISSUE
Should a risk/benefit analysis be used in situations where a defect in design or manufacturing could lead to death or seriously bodily harm, such as in the Ford Pinto situation?
RULE
There are arguments both for and against such an analysis. It is an economically efficient method which has been accepted by courts for numerous years, however, juries may not always agree, so companies should take this into account.
ANALYSIS

Although Ford had access to a new design which would decrease the possibility of the Ford Pinto from exploding, the company chose not to implement the design, which would have cost $11 per car, even though it had done an analysis showing that the new design would result in 180 less deaths. The company defended itself on the grounds that it used the accepted risk/benefit analysis to determine if the monetary costs of making the change were greater than the societal benefit. Based on the numbers Ford used, the cost would have been $137 million versus the $49.5 million price tag put on the deaths, injuries, and car damages, and thus Ford felt justified not implementing the design change. This risk/benefit analysis was created out of the development of product liability, culminating at Judge Learned Hand's BPL formula, where if the expected harm exceeded the cost to take the precaution, then the company must take the precaution, whereas if the cost was liable, then it did not have to. However, the BPL formula focuses on a specific accident, while the risk/benefit analysis requires an examination of the costs, risks, and benefits through use of the product as a whole. Based on this analysis, Ford legally chose not to make the design changes which would have made the Pinto safer. However, just because it was legal doesn't necessarily mean that it was ethical. It is difficult to understand how a price can be put on saving a human life.

There are several reasons why such a strictly economic theory should not be used. First, it seems unethical to determine that people should be allowed to die or be seriously injured because it would cost too much to prevent it. Second, the analysis does not take into all the consequences, such as the negative publicity that Ford received and the judgments and settlements resulting from the lawsuits. Also, some things just can't be measured in terms of dollars, and that includes human life. However, there are arguments in favor of the risk/benefit analysis. First, it is well developed through existing case law. Second, it encourages companies to take precautions against creating risks that result in large accident costs. Next, it can be argued that all things must have some common measure. Finally, it provides a bright line which companies can follow.

I. Introduction

In May of 1968, the Ford Motor Company, based upon a recommendation by then vice-president Lee Iacocca, decided to introduce a subcompact car and produce it domestically. In an effort to gain a large market share, the automobile was designed and developed on an accelerated schedule. During the first few years sales of the Pinto were excellent, but there was trouble on the horizon.

A. Grimshaw v. Ford Motor Company[1]

In May 1972, Lily Gray was traveling with thirteen year old Richard Grimshaw in a 1972 Pinto when their car was struck by another car traveling approximately thirty miles per hour. The impact ignited a fire in the Pinto which killed Lily Gray and left Richard Grimshaw with devastating injuries. A judgment was rendered against Ford and the jury awarded the Gray family $560,000 and Matthew Grimshaw $2.5 million in compensatory damages. The surprise came when the jury awarded $125 million in punitive damages as well. This was subsequently reduced to $3.5 million.[2]

B. The Criminal Case[3]

Six month following the controversial Grirnshaw verdict, Ford was involved in yet another controversial case involving the Pinto. The automobile's fuel system design contributed (whether or not it was the sole cause is arguable) to the death of three women on August 10, 1918 when their car was hit by another vehicle traveling at a relatively low speed by a man driving with open beer bottles, marijuana, caffeine pills and capsules of "speed."[4]

The fact that Ford had chosen earlier not to upgrade the fuel system design became an issue of public debate as a result of this case. The debate was heightened because the prosecutor of Elkart County, Indiana chose to prosecute Ford for reckless homicide and criminal recklessness.

Some felt the issues raised in the Ford Pinto cases were an example of the "deep pocket" company disregarding consumer safety in pursuit of the almighty dollar. Others feel they are an example of runaway media coverage blowing a story out of proportion.[5] Regardless of opinion, the Ford Pinto case is a tangled web of many complex legal and ethical issues.

To determine if the proper result was achieved in this case, one has to evaluate and weigh these many issues. The central issue in deciding whether Ford should be liable for electing not to redesign a defective product in order to maximize its bottom line, one must analyze the so-called "cost/benefit" analysis Ford used to defend this decision. Within the scope of this paper, this cost/benefit issue (and associated sub-issues) will be the focus of discussion. Other issues, such as the ethics involved in Ford's decision, the choice of prosecuting Ford criminally, whistle-blowing, the assignment of punitive damages and the Court of Appeals decision reducing the damages are all important issues of this case that will not be the focus herein.

II. Facts

A. Incident Facts

On August 10, 1978, three teenage girls stopped to refuel the 1973 Ford Pinto sedan they were driving. After filling up, the driver loosely reapplied the gas cap which subsequently fell off as they headed down U. S.

Highway 33. Trying to retrieve the cap, the girls stopped in the right lane of the highway shoulder since there was no space on the highway for cars to safely pull off the roadway. Shortly thereafter, a van weighing over 400 pounds and modified with a rigid plank for a front bumper was traveling at fifty five miles an hour and stuck the stopped Pinto. The two passengers died at the scene when the car burst into flames. The driver was ejected and died shortly thereafter in the hospital. Inspecting the van shortly after the accident, the police found open beer bottles, marijuana and caffeine pills inside.[6]

The subsequent proceedings were rather surprising. Based on the facts of the case, it seemed that any one of a number of parties could be liable in a civil action or prosecuted criminally. The obvious target seemed to be the driver of the van. It seems he could have been prosecuted for criminal homicide or the families of the victims could have pursued a civil action, in light of the fact the driver possessed several controlled substances at the time of the accident.

A second potential party open to a civil suit was the Indiana Highway department. It was their design which left no safe stopping place along Highway 33 where cars could pull over for emergencies. In fact, the road was so dangerous that the Elkart County Citizens' Safety Committee had previously written a letter to the department asking that the road design be modified to provide safe stopping place for emergencies.[7] It is also conceivable, the driver of the Pinto could have been found negligent for stopping a car in the middle of the highway. The first surprise of the resulting litigation carne when Indiana state prosecutor filed suit against Ford Motor Company for criminal recklessness and reckless homicide. The famous and highly publicized legal battle was underway. Some have argued the prosecution acted unethically from day one, gathering and hiding evidence from the defendant and concealing information about the condition of the van driver. Whether true or not, the following litigation caused damage that would take Ford years to recover from.

B. Questionable Design

The controversy surrounding the Ford Pinto concerned the placement of the automobile's fuel tank. It was located behind the rear axle, instead of above it. This was initially done in an effort to create more trunk space. The problem with this design, which later became evident, was that it made the Pinto more vulnerable to a rear-end collision. This vulnerability was enhanced by other features of the car. The gas tank and the rear axle were separated by only nine inches. There were also bolts that were positioned in a manner that threatened the gas tank. Finally, the fuel filler pipe design resulted in a higher probability that it would to disconnect from the tank in the event of an accident than usual, causing gas spillage that could lead to dangerous fires. Because of these numerous design flaws, the Pinto became the center of public debate.

These design problems were first brought to the public's attention in an August 1977 article in Mother Jones magazine. This article condemned the Ford Motor Company and the author was later given a Pulitzer Prize.[10] This article originated the public debate over the risk/benefit analysis used by the Ford Motor Company in their determination as to whether or, not the design of the Pinto fuel tank be altered to reduce the risk of fire as the result of a collision.

The crux of the public debate about The Ford Motor Company was the decision not to make improvements to the gas tank of the Pinto after completion of the risk/benefit analysis. Internal Ford documents revealed Ford had developed the technology to make improvements to the design of the Pinto that would dramatically decrease the chance of a Pinto "igniting" after a rear-end collision.This technology would have greatly reduced the chances of burn injuries and deaths after a collision. Ford estimated the cost to make this production adjustment to the Pinto would have been $11 per vehicle. Most people found it reprehensible that Ford determined that the $11 cost per automobile was too high and opted not to make the production change to the Pinto model.

C. Risk/Benefit Analysis

In determining whether or not to make the production change, the Ford Motor Company defended itself by contending that it used a risk/benefit analysis. Ford stated that its reason for using a risk/benefit analysis was that the National Highway Traffic Safety Administration (NHTSA) required them to do so. The risk/benefit approach excuses a defendant if the monetary costs of making a production change are greater than the "societal benefit" of that change. This analysis follows the same line of reasoning as the negligence standard developed by Judge Learned Hand in United States vs. Carroll Towing in 1947 (to be discussed later). The philosophy behind risk/benefit analysis promotes the goal of allocative efficiency. The problem that arose in the Ford Pinto and many other similar cases highlights the human and emotional circumstances behind the numbers which are not factored in the risk/benefit analysis.

The Ford Motor Company contended that by strictly following the typical approach to risk,/benefit analysis, they were justified in not making the production change to the Pinto model. Assuming the numbers employed in their analysis were correct, Ford seemed to be justified. The estimated cost for the production change was $11 per vehicle. This $11 per unit cost applied to 11 million cars and 1.5 million trucks results in an overall cost of $137 million.

The controversial numbers were those Ford used for the "benefit" half of the equation. It was estimated that making the change would result in a total of 180 less burn deaths, 180 less serious burn injuries, and 2,100 less burned vehicles. These estimates were multiplied by the unit cost figured by the National Highway Traffic Safety Administration. These figures were $200,000 per death, $67,000 per injury, and $700 per vehicle equating to the total "societal benefit" is $49.5 million. Since the benefit of $49.5 million was much less than the cost of $137 million, Ford felt justified in its decision not to alter the product design. The risk,/benefit results indicate that it is acceptable for 180 people to die and 180 people to burn if it costs $11 per vehicle to prevent such casualty rates. On a case by case basis, the argument seems unjustifiable, but looking at the bigger picture complicates the issue and strengthens the risk/benefit analysis logic.

In the early 1970's when competition from Japan's auto makers was heating up, gas prics were easing, the demands for energy conservation were just around the corner (awaiting the Arab oil boycotts that arrived first in 1973-74), Ford Motor Company with Lee Iacocca as its president, introduced a new line of cars, the Ford Pinto. The Pinto was to cost less than $2,000 and weigh less that 2,000 pounds.

During crash tests which preceded the introduction of the Pinto to the public, it became apparent that the vehicle had a dangerous design flaw. The gas tank was so designed and located that when it was involved in a rear end collision at an impact speed of 20mph or higher, the tank was apt to rupture, causing a fire or explosion. The tank was only five inches forward of the rear sheet metal of the body and only three inches back of the rear axle housing. In not just one, but most of the rear-end crash tests, the axle housing deformed the tank and sharp, protruding bolts punctured the tank. In only 20 mph moving barrier crashes, the rear end crush distance was large--more than eight inches.

Ford's conclusion, following the crash tests, was that the rear end structure of the car was not satisfactory because of several types of damage deformation of the gas tank, leakage and damage to the filler pipe. Suggested changes to repair the defects were not expensive, something in the range of $11 per car. A confidential company policy memo issued in late 1971, directed that no additional safety features be adopted for the 1973 and later cars until required by law.

A cost-benefit analysis prepared by Ford concluded that it was not cost-efficient to add an $11 per car cost in order to correct the flaws. Benefits derived from spending this amount of money were estimated to be $49.5 million. This estimate assumed that each death which could be avoided would be worth $200,000, that each major burn injury that could be avoided would be worth $67,000 and that an average repair cost of $700 per car involved in a rear end accident would be avoided. It further assumed that there would be 2,100 burned vehicles, 180 serious burn injuries, and 180 burn deaths in making this calculation. When the unit cost was spread out over the number of cars and light trucks which would be affected by the design change, at a cost of $11 per vehicle, the cost was calculated to be $137 million, much greater then the $49.5 million benefit.