Monitoring Air Bag Performance: Exploring the Social Facets of Engineering with STS

Jameson M. Wetmore

Department of Science, Technology & Society
University of Virginia

Introduction

Over the past several decades a new social science discipline has been emerging that seeks to better understand the relationship between technology and society. This discipline is sometimes called "Science & Technology Studies" or "Science, Technology, and Society," but is often simply given the umbrella title of "STS."[1] The discipline has attracted scholars from the fields of sociology, history, anthropology, philosophy, political science, law, and others, and has even begun to produce scholars with PhDs in STS.

This paper will offer an example of how STS can be used to educate engineers. Specifically I will focus on how STS has explored the complex ways in which technology and society co-create one another. The basic insight of STS is that science, technology, and society, are not separable entities. Rather, all three are intimately interwoven; they grow and change with each together. As such, one cannot understand one of the three without also understanding the other two. For instance, STS scholars have examined the ways in which risk is constructed, perceived, and dealt with; how political decisions are often disguised as technically necessary decisions; and how the success or failure of simple negotiations with co-workers can have profound effect on a final product. These insights can be used in the classroom to enable engineering students to better see the social aspects of their day-to-day practice and better understand the broader social effects that their practice helps to create. By exploring STS texts and arguments, students can be better prepared to grasp the social, political, and cultural facets of engineering and introduced to complex social issues that are an inextricable part of engineering.

In this paper I want to examine a particular social and political history of engineers in practice to demonstrate how STS can provide a window into aspects of engineering that are not always addressed, but are important for the profession nevertheless. The particular cases involves the efforts that engineers took to anticipate, determine the cause of, and then deal with the fatalities associated with air bags in the 1990s.

[1] There are some who claim that there are distinct differences between S&TS and S, T, and S. The argument is usually that the former is more theoretical and academic and is often associated with constructivist ideas. The later, on the other hand, is framed as being more focused on practical change and sometimes has activist tendencies. For the sake of brevity, I will gloss over these differences in this paper and refer to the field more generally.

A Bag full of Uncertainties

In the late 1980s, millions of air bags were being installed in American automobiles as a result of marketing techniques, popular demand, and government regulation. Although this was the first widespread production of the technology, it had a long history. The basic concept had been first patented in the 1950s. Throughout the '60s and '70s it had been developed and tested by countless engineers at automobile manufacturers and automotive suppliers around the world.

Despite this extensive experience, in the late 1980s, engineers at not only the automobile manufacturers, but also the insurance companies, safety organizations like the National Safety Council, and the government agency that established air bag regulations – the National Highway Traffic Safety Administration (NHTSA) – were concerned about the technology they were promoting. Their experience with air bags as well as technologies in general had convinced them that there were a number of disturbing uncertainties about the technology. Although the basic idea of an air bag – to inflate a bag in front of an occupant during a collision to distribute the load of the crash widely over the occupants body – was simple enough, getting it to work routinely and successfully was an immense engineering challenge.

There were two main sources of their uncertainty. The first of these was technical uncertainty. Engineers did not know exactly how the air bags would deploy (or whether they would indeed deploy) in a crash. Air bags are not simply a "plug in" component. They are a complicated system that must mesh with and be designed to be compatible with other systems – many of which cannot be controlled. For instance, it is incredibly difficult to design a sensor that reliably triggers an air bag when it is needed. Every crash impulse is different. There are different angles, speeds, rates of deceleration, and size and masses of objects being hit. Some of these may produce very similar effects in the first millisecond, but very different effects when the crash forces transfer to the occupant. Inflation rates are also incredibly important to configure correctly for the particular type of crash. If the bag comes out too slow, it may offer no protection. If it comes out too fast or too late, it could be very dangerous and perhaps even deadly. Each of these facets will differ car to car and from situation to situation.

The second source of uncertainty was social uncertainty. Engineers did not know exactly how people would interact with their air bags. Would the occupants be buckled or unbuckled when a collision began? Would they be sitting two inches away from the bag or 3 feet from the bag? Would there be one person in the passenger seat or four? Would the passenger be wearing the combination lap/shoulder belt, or simply the lap belt? Again, to optimize the safety of the occupants in each of these scenarios would require very different air bags. The combination of these two uncertainties, including the fact that they could easily compound one another, made predicting the effect of putting air bags in automobiles very difficult.

In many ways, the engineers that dealt with air bags realized that they were engaged in what Mike Martin and Roland Schinzinger have called "engineering as social experimentation" (1). They had an informed and educated idea of what would happen, but they recognized that there were potential problems that they may have not predicted.

The engineers took a number of steps to limit this uncertainty. First they continued to support the effort that had been going on for several years already – to convince the American public to put on their seat belts. Although much of this was done at the political level, engineers were actively engaged in a number of ways. They gathered statistics that demonstrated the benefits of wearing belts and even testified before state legislatures in an effort to promote laws which mandated the use of seat belts. Engineers believed that not only would such belt use make occupants safer because of the belts, but it would also make air bag safer because people would be in a safe and predictable position should the bag deploy.

Second, engineers continued to experiment with air bags in the laboratory. They continued to try to replicate a variety of crash scenarios. They ran tests to see the effects of hitting trees, hitting cars at different angles, and side collisions. They also continued to broaden the array of testing dummies that they used. They conducted a number of tests on dummies designed to replicate women of different weights and stature, children, and babies in child safety seats.

And finally, the auto safety community also carefully tracked the performance of air bags on the road. NHTSA, the automakers, and the insurance companies all created special teams to pinpoint and correct any problems that might arise. Their goal was to catch small problems before they became major problems. Insurance companies examined the claims of their policyholders closely and analyzed them for trends. Automakers followed up media reports about crashes involving their products and continued to conduct evaluative crash tests. The different offices and groups within NHTSA were especially busy. Its Office of Defects Investigations gathered information on possible air bag side effects from the public complaints it received; its National Center for Statistics and Analysis careful tracked and analyzed every U.S. traffic fatality in which an air bag was present; its Special Crash Investigation Program kept an eye out for any air bag problems when it visited crash scenes; and its Vehicle Research and Test Center ran special crash tests to better understand air bags. In addition, NHTSA formed a special "Air Bag Technology Review Group" devoted solely to discerning air bag difficulties before they could become serious problems.

Monitoring Air Bag Performance

By 1990, the insurance companies, automobile manufacturers, and NHTSA had independently uncovered a handful of air bag problems. At the end of 1992, NHTSA estimated that 25,000 people had been injured by air bags between 1988 and 1991. Ninety-six percent of these were rated "minor," nearly four percent moderate, and two-tenths of a percent serious (2). As problems were discovered, engineers took quick action to remedy them.

For instance, reviews of crash victim injuries, customer complaints, and continuing crash tests revealed that some drivers were getting forearm burns and arm and face abrasions from their air bags (3). Engineers quickly determined that some of the burns were caused by the hot nitrogen gas generated to inflate the bag as it escaped through vents designed to release excess gas and ensure that it had a reasonable amount of "give" when the occupant made contact with it. Vehicles with the vents placed at the "three o'clock" and "nine o'clock" positions on the bag tended to force out the hot gas close to where many drivers held the steering wheel. Other burns, they argued, were the result of the fact that when air bags deploy, they do not just move directly

forward toward the occupant. The bags are folded inside the steering wheel or dashboard and move both toward and perpendicular in every direction to the occupant as they inflate. Engineers at the automakers maintained that the abrasions were often caused by the way this perpendicular movement, as well as the bulging that can occur when the bag first fully inflates, could drag the fabric of the bag across the surface of the skin.

Once they determined the causes, automotive engineers quickly addressed these concerns. By 1991, most companies had moved the exhaust vents away from the occupant's arms to the 12 o'clock position and used a tether inside the bag to keep the bag from bulging toward the occupant thereby reducing the risk of abrasions (4). These were not perfect fixes, as current air bags can still cause burns and abrasions, but they did significantly alleviate the problems.

The continuing analysis of air bag performance did, however, reveal some potential problems that were more disconcerting to the auto safety community than minor burns and abrasions. In the fall of 1991, engineers at NHTSA's Vehicle Research and Test Center in East Liberty, Ohio, ran several barrier tests with a rear-facing infant safety seat in front of a passenger-side air bag. In one test an air bag impacted with an infant seat and the seat was "blown into the back[seat]" (5). NHTSA engineers argued that because most rear-facing child safety seats extended into the area displaced by a fully deployed air bag, jolts like this one could be a common dangerous occurrence. In addition to these disturbing tests, auto manufacturers and NHTSA had become aware of at least five fatalities that they believed would not have occurred had air bags not been present (4).

Further Educating the Public

The auto safety community responded to these concerns in two ways in the early 1990s. First, testing at laboratories was increased even more. NHTSA, for instance, sought to better understand the problem through its own lab testing and through a joint research project with the Society of Automotive Engineers (SAE). Second, the community began an extensive program to convince parents to place rear-facing child safety seats in the back seat of their automobiles. They publicized the importance of putting rear-facing child safety seats in the back through its normal channels—press releases, doctors, public information pamphlets, and the media.

But the auto industry claimed that this was not enough. They believed it was necessary to post a warning of the dangers of air bags in every automobile. But none of the companies wanted to do this voluntarily because they feared that a competitor could gain a sales advantage by not warning their buyers. Thus in February of 1992, the Motor Vehicle Manufacturers Association (MVMA) petitioned NHTSA to require a "consumer information label" that would remind occupants of the dangers of air bags, the need to wear their seat belts, and the need to put rear-facing child safety seats in the back seat (6).

This request led to a series of debates over how to best convey the appropriate information to the public. NHTSA officials were afraid that they might frighten the public unnecessarily, so they proposed the following label:

For maximum safety protection in all types of crashes, you must always wear your safety belt.
Do not install rearward-facing child restraints in any front passenger seat position.
Do not sit or lean unnecessarily close to the air bag.
Do not place any object over the air bag or between the air bag and yourself.
See the owner's manual for further information and explanations. (7)

The Big Three U.S. automakers were concerned that this label was not powerful enough. They wanted to emphasize not just how to be safe, but also why these instructions were so important. They countered with the following option:

! CAUTION :

Air bags are not designed to reduce the risk of injury in rollovers or in rear, side, or low-speed-frontal crashes.

Air bags inflate with great force, faster than you can blink your eyes. An occupant who is too close to the inflating air bag can be seriously injured.

An inflating passenger air bag can seriously injure a child in a rear-facing child restraint. Follow all instructions in the vehicle owner's manual regarding child restraints.

Do not place packages or other objects between the air bag and the occupant. Such objects could injure you if the air bag inflates in a crash. (8)

NHTSA officials settled for a compromise of sorts. They required the text of the label as it had originally proposed, but added the heading, "CAUTION, TO AVOID SERIOUS INJURY:" in an attempt to satisfy the demands of the automakers.

Dealing with Increasing Concern

The addition of the label in new cars calmed the concerns in the auto safety community for a couple of years. But engineers did not stop collecting and monitoring ever increasing amounts of data about air bags on the road. By 1995, some of the uncertainties were being resolved in disturbing ways. In March of that year, the Insurance Institute for Highway Safety blamed air bags for the death of eleven people (9). Concerns at the automakers were similarly raised.

NHTSA engineers researched the handful of documented fatalities and developed a theory for how the deaths were occurring. They described it in the following way:

In a frontal crash, the occupant moves forward toward the windshield and instrument panel prior to air bag deployment. The air bag inflator must produce enough energy to inflate the air bag fully in about 25 milliseconds to "cushion" the occupant before the occupant strikes the vehicle interior. The energy necessary to inflate the air bag in such a short time interval can cause injury or even fatality to an occupant who is not properly restrained, especially to children, given their small stature and light weight. (10)

They also noted that some specific groups were more likely to experience negative effects from air bags than others. In particular they singled out unrestrained small-statured and/or older people, infants in rear-facing child restraints, children unrestrained in front seat, out-of-position occupants, and persons with disabilities, as having the potential to be more at risk.

Things got worse before they got better. In November of 1996, NHTSA's statistics cited air bags as the cause of death for twenty adults as well as thirty children (11). The agency argued that it appeared that shorter female drivers were especially at risk because they often sat close to the steering wheel. At the same time, NHTSA called for parents to put all children age twelve and under in the back seat, rather than just those infants in rear-facing safety seats. By the spring of 1997, auto safety researchers had found that air bags took the lives of 3.5 children for every one that they saved (12). The media jumped on the story and there was widespread outrage. There were calls for air bags to be ripped out of automobiles.

Most engineers were frightened by this plan, however. They were certainly concerned about the fatalities, but they believed that air bags were saving many lives and that to abandon the technology would be a mistake. But there was no simple fix for the problem. Redesigning the technology would take a great deal of time and would not be able to address the millions of air bags already on the road. A recall would be expensive, difficult, and might not even solve the problem since air bag design entailed not only the bag, but the shape of the cockpit, windows, etc.

First Aid for Air Bags: Educating the User

Thus the first response recognized that the automobile is not simply a hunk of metal – it is a human-machine system. If engineers could not quickly fix the hardware, they argued that individual motorists could immediately take steps that would eliminate or significantly lessen air bag injuries and fatalities. After analyzing the fatalities and conducting experimental crash tests, the engineering researchers came up with a revised set of responsibilities for automobile occupants. The new motorist responsibilities were:

1. Properly restrain all passengers;
2. Put all children up to age twelve in the back seat; and
3. Maintain at least ten inches between yourself and the air bag.

Once these three basic safety measures were developed, the automobile companies, safety organizations like the National Safety Council, NHTSA, and the insurance companies began a concerted program to re-educate the public. On May 21, 1996, the National Safety Council announced the formation of the Air Bag Safety Campaign, a joint project between NHTSA and nearly every major automobile company, air bag supplier, and insurance company (13).

This campaign was different from previous efforts to educate the public about air bags in three significant ways. First, the nation's driving public was given many more responsibilities than it had been in previous warnings. Sitting back from the air bag and putting children in the back seat required a significant change in habit for many people and had never been strongly recommended prior to air bags. Second, the education effort in the late 1990s was a much bigger

project than any of the previous attempts to tell people how to best use air bags. And finally, the educational materials stressed the potential penalties of not following these steps much more forcefully. Pamphlets no longer offered suggestions on how to act. Instead they were titled with phrases like: "The Air Bag that Saves Your Life Could KILL Your Child." One particular television commercial, for instance, first showed an air bag slamming into a rear-facing child safety seat at full speed to show the violence of the crash and then again in slow motion to show how the infant dummy is jolted and thrown about. The newly required air bag warning label included a picture of an air bag shattering a child safety seat and was worded much more strongly:

> **WARNING**
> DEATH or SERIOUS INJURY can occur
> Children 12 and under can be killed by the air bag
> The BACK SEAT is the SAFEST place for children
> NEVER put a rear-facing child seat in the front unless air bag is off
> Sit as far back as possible from the air bag
> ALWAYS use SEAT BELTS and CHILD RESTRAINTS (14)

Resolving the problem

As this public campaign waged on, automotive engineers looked for ways to redesign air bags to limit the risk to automobile occupants. They found that one of the reasons the bags had been so dangerous is that they were designed primarily with one test in mind – NHTSA's New Car Assessment Program (NCAP) – the test that awarded vehicles with the coveted government safety rating stars. Engineers found that the tests, which were run at high speeds using adult male dummies, favored very fast and powerful air bags. Such air bags, however, were not as safe for out of position occupants and occupants of smaller stature. As a result, NHTSA relaxed some of its regulations and automakers "depowered" some of their air bags. The result was that the new design might not provide quite as much protection in some violent crashes, but would be "more forgiving" to smaller occupants.

Despite these significant changes, it is unclear whether this "technical fix" was as significant as the public education. The allocation of new responsibilities to motorists and the efforts to educate the public yielded a significant change in the practices of American automobile occupants. NHTSA's statistics on observed seat belt use rose from 60 percent at the beginning of 1996 to 70 percent by the end of 1998. The use of child restraints also increased measurably. Restraint use for infants (1–12 months) rose from 85 percent to 93 percent, from 60 percent to 87 percent for toddlers (1–4 years), and from 65 percent to 69 percent for children (5–15 years).[2] Parents were also putting their children in the back seat much more often than they had been previously.

By the year 2000, to the relief of all in the auto safety community, the number of deaths being attributed to air bags each year had dropped significantly. The number of fatalities per year dropped from a high of forty-three in 1997 to eleven in 2000, even though the number of air bags

[2] Air Bag & Seat Belt Safety Campaign, *A Powerful Partnership: Saving Lives and Protecting Futures*, Brochure, Washington, D.C., April 2000, pp. 4–5.

being sold increased dramatically. Most experts believe that because the recent changes to air bag design had affected only a small number of the total air bags in the nation's fleet, the only explanation for the decrease in fatalities is that the public's acceptance of their new responsibilities was widespread and effective in mitigating the problem.

Conclusion

Many argue that the air bag experiment should not have left the laboratory or that air bags should have been immediately recalled once any problem was realized. This is a valid complaint. The loss of these lives was tragic and perhaps preventable. But those who lodge these complaints must remember two important things.

First, engineering is inherently risky and there will be instances of tragedy that result. Engineering is risky precisely because it is a practice that can never proceed with a complete understanding of all the variables involved. Not only are socio-technical systems too complicated to fully grasp, it can be argued that purely technical systems (if there are such things) are never completely understood. To avoid introducing any new technological risk would require that society not only immediately stop introducing new technologies, but also ban people from using technologies in new ways.

Second, as with nearly all engineering practice, the engineers were engaging in a complicated form of cost-benefit analysis. Not only did they have to weigh the risk of what they were doing, they also had to weigh the risks that were present if they chose to do nothing. An average of 45,000 Americans a year are killed in motor vehicle collisions. As a society we have chosen to accept the automobile and its drawbacks, but engineers work hard every day to minimize these drawbacks as much as possible.

What is important about this case is that the engineers involved recognized the dangers and actively took steps to reduce them. When we think about what engineers do, we usually envision them building or designing. But there are aspects of the job that often go unnoticed that are incredibly important to society. For the last decade, engineers involved with air bags could not simply sit in a lab and research and design. They have had to stand before congressional hearings, be interviewed by the media, find social solutions to technical problems, and some of them even had to face the rage of parents who's children had been killed by air bags. They did not always have a completely accurate picture of the risks, but they recognized their own uncertainties and took numerous actions that are rarely mentioned in undergraduate classrooms to solve problems.

The case given above is quite complex. It is not simply a story about professionalism, policy making, or education. It involves all of those things and more. It is an example of the messy way in which society and technology are intertwined in the modern world. The field of STS specializes in bringing to light this complicated nature. Not all of the work in the field is easily accessible to undergraduate engineers, but much of it is. By introducing engineers to this messiness before they face the reality after graduation can help prepare them in important and meaningful ways.

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Biography

Jameson Wetmore is currently a postdoctoral fellow at the University of Virginia's Department of Science, Technology, & Society. His work focuses primarily on the history of automobile safety in the United States and he is currently working on an engineering ethics reader that draws on STS texts and ideas with Deborah Johnson. He received his PhD in Science & Technology Studies from Cornell University in 2003.