Curbing Air Bags' Dangerous Excesses

New smarts, new sensors, and variable inflation could reduce injury and death

By PETER WEISS

Air bags punch out of their dashboard cocoons at more than 140 miles per hour. Because of their speed, they both save lives and occasionally squander them.

The rapidly inflating nylon sacks have prevented nearly 3,500 auto collision deaths since the late 1980s, according to the National Highway Traffic Safety Administration (NHTSA). From 1991, when the first air bag–induced death was reported until Sept. 1, 1998, the agency has tallied 113 people, mostly children and small adults, killed by the bags during minor accidents when their lives weren't otherwise at risk.

"Anyone who gets too close to [an inflating] bag, whether a young child or a 300-pound football player, is in big trouble," says Barry Felrice, director of regulatory affairs for the American Automobile Manufacturers Association. Air bags, which are inflated by gas from a rapidly burning propellant and sometimes also from a pressurized cartridge, have caused nonfatal injuries including broken bones, burns, and eye damage, although the damage may have been worse in many cases had the air bag not deployed.

Today's automobiles carry only one-size-fits-all air bags. Nonetheless, these bags, by federal decree, pack a wallop intended to immobilize an average-size man. So, by design, they unleash too much energy for people at the smaller end of the scale.

As this dark side of air bags gained wide attention over the past few years, automobile manufacturers and the companies that build safety restraints for them stepped up efforts to develop a safer technology.

"It's a difficult problem, in my opinion, but that doesn't mean it's not achievable," says Robert L. Phen, program manager for energy and surface transportation at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif. Phen led a year-long JPL study of advanced air bag technology for the National Aeronautics and Space Administration and NHTSA. The study, released in April, concluded that in model year 2003 "systems should be able to remove most of the risk of injury from deploying air bags."

To achieve this goal, the auto industry must boost the ability of air bag–control computers to predict within an instant of onset a crash's severity. Too often today, restraint engineers say, the computers that control air bag firing misjudge the severity of a crash.

Safety improvement also relies on developing sensor arrays that can feed the air bag controller up-to-the-millisecond details about vehicle occupants, such as their weight, position, and whether or not they are wearing seat belts.

At the same time, the air bags themselves must also become more talented—for instance, by being able to inflate at several different rates and pressures. Engineers must coordinate all new air bag technology with the advanced seat belt features that are also under development, such as automatic tightening at the start of a crash.

Air bag technology is a highly controversial issue. James Walker is the air bag specialist for the National Motorists Association, a motorists' advocacy group based in Waunakee, Wis., and a vocal critic of mandatory air bags. He says it is folly to make air bag systems more complex. "There are just too many points of failure, and we can't make the simple systems work now," he argues.

Walker notes that millions of air bag–equipped cars have been recalled, many of them because bags have fired at random, when no accident was taking place, sometimes causing injuries.

The high-tech approach is "backwards," says Morris Kindig, president of TIER ONE, an automotive electronics market research firm in Mountain View, Calif. The firm has just completed a study of sensors that would provide information about the occupants of a car to the air bag controller. Rather than installing complex and costly equipment, he argues, people should be better taught to use seat belts and to put children and small adults in the back seat. "The solution is education. It's not technology," he says.

Automakers have already introduced some changes to air bag equipment to reduce air bag–induced injuries, but these alterations are considered only stopgaps until more sophisticated solutions are ready. Foremost among the changes is so-called air bag depowering, which means installing air bags that inflate more slowly and to a lesser volume than the original designs. Most 1998 American vehicle models contain air bags depowered by 20 to 35 percent compared to 1997, says Felrice.

Engineers have also incorporated an air bag disabling switch for the passenger side of new vehicles with only a single row of seats, such as pickup trucks. Under limited circumstances, the federal government is also allowing vehicle owners to install on-off switches or disconnect air bags in older models.

Companies keep tight wraps on many details. "It's a competitive issue for manufacturers," explains Felrice. "They all want to be first with safety improvements. Whether it's night vision or antilock brakes, safety sells these days."

Earlier this month, the U.S. government reconfirmed its commitment to technology as a necessary part of preventing crash fatalities and injuries. In a Sept. 14 preliminary ruling, NHTSA unveiled plans to order vehicle makers to install smarter restraints in 25 percent of new passenger cars and light trucks by Sept. 1, 2002, and in all new models by Sept. 1, 2005. Instead of mandating specific technologies, the agency will require vehicles to pass a battery of tests.

These plans demonstrate that NHTSA officials, as well as industry designers, regard better crash prediction as a high priority.

"The challenge is to predict this event with very little up-front information," Phen says.

In a typical crash, the air bag–control microprocessor must decide within 20 milliseconds whether or not to fire the air bag. Otherwise, the bag won't be fully deployed before the occupant strikes it. During that time, the controller examines voltage readings from a tiny accelerometer mounted at the front of the passenger compartment, typically just behind the firewall.

To interpret the often wildly fluctuating deceleration and acceleration of a car during an accident, the computer employs problem-solving pathways, or algorithms. They either compare the accelerometer's signal to a library of known crashes or extrapolate forces and other crash parameters from accelerometer readings.

Accelerometer readings vary greatly

from one crash to the next, making the forecasting of the impact's severity daunting, experts say. Head-on wrecks into poles particularly dumbfound current software.

The impact of these collisions is so concentrated that, at first, its energy goes more into folding the car's grille around the pole than into decelerating the vehicle, tricking air bag controllers into predicting a minor collision. When the pole finally meets the engine block, the sudden enormous deceleration flings the car occupants forward. By then, it may be too late because air bags have not fired or are in the process of filling, possibly adding to injuries from the crash.

Algorithms can be made to do much better, engineers say. Some air bag suppliers are building more complete libraries of possible crash profiles into controllers and speeding up the comparison between those profiles and accelerometer data. Others have learned to distill more accurate predictors of crash behavior from accelerometer signals and are writing software to make those calculations more nimble.

Beyond getting smarter about a crash in progress, some air bag researchers have proposed giving vehicles the ability to prejudge a crash before it begins. Such precrash sensors could include radar systems now being developed for collision avoidance. The warnings that such sensors could provide might boost safety by making it possible to inflate air bags sooner in a severe crash.

While better crash profiles will help, gathering information about the people inside the vehicle is also vital to boosting air bag safety, engineers say. Most often, it's small people who end up dangerously close to air bags.

Small, adult drivers may sit forward to reach controls, putting them up against the steering-wheel air bag. Children's faces may hover at the same height as the passenger-side air-bag compartment positioned at an adult's chest level. Child seats, especially rear-facing infant seats, often protrude into the space into which an air bag inflates—called the keep-out zone.

When an air bag occasionally does smack someone, small people, with their more delicate frames, also tend to suffer worse injury than bigger folk.

Advanced air bag controllers need answers to many questions about a car's occupants in order to recognize who is most vulnerable to air bag–induced injuries and to solve physics equations for the forces and motion that vehicle restraints are meant to control.

Is there a front-seat passenger? A child seat? How much do the driver and passenger each weigh? Are they wearing seat belts? Where are parts of their bodies relative to the keep-out zone for each bag?

Restraint makers have yet to settle on the best ways to get those answers.

A group of engineers from TEMIC Telefunken Microelectronic GmbH, a German firm, have developed a sensing method using infrared light. They described it in February 1997 at the Society of Automotive Engineers' International Congress and Exposition in Detroit.

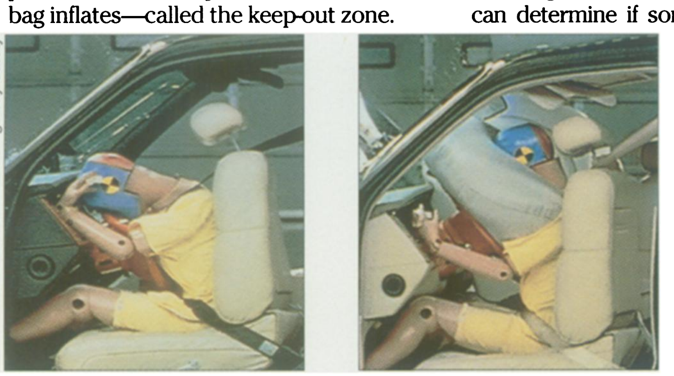
Mounted in front of a seat and above it, the device shines beams of infrared light onto the seat from top to bottom. By comparing transmitted and reflected beams, it constructs a profile of the seat or whoever is sitting in it.

Another company, unidentified in the JPL report, would electrify the seats to detect the presence and size of an occupant. Four electrodes would generate an oscillating electric field whose properties change when someone sits down. The system would sense the human body's ability to store electric charge, or its capacitance, which increases with body volume.

Other engineering teams have built instruments that bounce sound waves inside the vehicle compartment at frequencies above the human hearing range. Detectors pick up ultrasound echoes, which the circuitry can use to determine shapes and positions of people and objects in the vehicle.

According to the JPL report, restraint equipment suppliers are also investigating optical camera–based sensors, radar, and other approaches.

Weight sensors already developed can determine if someone is present and how heavy they are by measuring the pressure in a gas-filled bag in the seat or by detecting the change in current through force-sensitive resistors. Although tests have shown that these sensors lack the accuracy needed, for instance, to reliably distinguish between a child and a slightly heavier small woman, the weight-sensing technology, which is inexpensive and sturdy, has proved useful.



Insurance Institute for Highway Safety

In most accidents, an air bag adds protection for the driver. In these crash tests at 35 miles per hour, a 5-foot-tall female dummy seated all the way forward suffers possible head, face, and neck injuries despite wearing a seat belt (left) but only possible neck harm in the air bag–equipped car (right).

Mercedes-Benz customers can opt for a front passenger seat weight detector that shuts off the air bag if it senses less than 30 kilograms of force, indicating that the seat is unoccupied or that a child is present.

The strategies of advanced air bag controllers will rely so heavily on information indicating whether an occupant is belted or not that engineers have felt compelled to introduce a more reliable seat belt sensor.

Currently, a simple electric contact switch typically monitors whether the seat-belt tongue is in the buckle, but its contacts can become dirty. Newly developed sensors register an altered magnetic field when the tongue is in place.

Along with more information, restraint designers also plan to give air bag controllers more ways to respond to a crash. Manufacturers have developed air bags with two gas sources rather than the typical single source. The change gives controllers four levels of response: no inflation, a relatively slow inflation, a faster rate, and finally, a simultaneous firing of both inflators for the quickest bag filling.

As an example of how the options might provide an advantage, suppose that a small woman is driving when she has an accident at low speed but still severe enough to cause injuries. The current options are for the air bag to do nothing, risking broken cheek bones or worse, or for it to fire, possibly causing neck injury or other damage.

With the two-inflator bag, the controller could choose its gentlest inflation, possibly avoiding injury either from crash or bag. This technology will be available in at least one 1999 model of European car this year, according to TRW Vehicle Safety Systems of Washington, Mich. Air bag makers also are exploring adding even more inflation levels and developing fully adjustable inflators that could give a continuous range of rates.

The sophistication of seat belts is growing too, giving controllers more factors to consider and more options for responses.

Belt manufacturers have developed ways to draw belt webbing back into the reel as a crash begins, cinching the occupant more tightly against the seat—a safer way to ride out a crash. Engineers are also designing load limiters into seat belts to reduce tension when it reaches potentially harmful levels. Inflatable seat belts may be in the offing too. Their shoulder straps would puff up to hold and cushion occupants during a crash.

In the next few years, as these new technologies come into play, many people will be watching to see whether air bag–induced death and injury rates drop and crash survival improves.

Whatever the outcome, the dark side of air bags won't disappear entirely. As the JPL report notes, sometimes air bags will fire when they shouldn't and not fire when they should, no matter how reliably they are made. The nature of technology is that it sometimes fails. □