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# Crashless Cars: Making Driving Safer

## Next-generation automotive safety technology could give us vehicles that are difficult to crash—and eventually may not need drivers at all

By Steven Ashley

The empty highway stretches straight out to the horizon, so I take a moment to peek at the electronic display down in the car's center console. I read out the numbers on the screen swiftly and glance back to the windshield, when I see ... nothing. A dense fog has swallowed the roadway, and I am driving blind. Before I can feel for the foot brake, an unmistakable warning—a brake-light red rectangle—flashes onto the windshield. Without another thought, I slam hard on the pedal, cursing loudly. My vehicle comes to a hasty halt as a disabled car emerges abruptly from the murk dead ahead.



Before I can even exhale, bright lights burn all around, and laughter rings out incongruously through the passenger cabin. I remember suddenly that I'm sitting inside the VIRTTEX (VIRtual Test Track EXperiment) driving simulator lab at Ford's Research and Innovation Center in Dearborn, Mich. The big, egg-shaped simulator dome enables specialists there to conduct driving tests under totally safe but highly convincing virtual-reality conditions. The disembodied mirth on the intercom is the control-room technicians having a chuckle over my brief discomfiture.

For the past quarter of an hour they have thrown various tasks at me—each one designed to demonstrate the dangers of driving while distracted. One of my jobs—the last one, in fact—had been to look down at the central display when asked and call out the numbers that appeared there without losing control of the vehicle. Glances away from the road that are longer than two seconds double the odds of a crash or near crash.

During the follow-up debriefing, Mike Blommer, technical leader at the VIRTTEX lab, tells me that the windshield alarm that popped up during the final task is a visual alert generated by a forward-collision warning unit on Volvos. The system acts like an electronic guardian angel, monitoring traffic up front with radars and cameras and signaling the driver when it senses danger. The warning's marked resemblance to a standard red brake light is no accident, he notes: "The engineers chose that particular signal because its meaning is intuitively clear to every experienced driver. Even though you'd never seen it before, you knew exactly what it meant and took corrective action."

This system is just one example of the latest generation of advanced safety devices designed to ward off traffic accidents. Although they are currently available on many high-end car models, these technologies are starting to migrate to lower-cost cars and trucks as well. And the next major iteration of collision avoidance technology should be even more effective, as it will be able to engage the brakes automatically without any input from the driver at all. These and related safety capabilities may herald a new era for the automobile, a time in which car owners become increasingly willing to accept automated assistance on the road, even if that means ceding to robotic systems some of their traditional feelings of mastery over their vehicles. Within a few decades, experts say, many advanced cars will be able to avoid most crashes. At some point, in fact, they will drive themselves.

### Trends toward Safety

The main motivations for these innovations are clear enough. Some six million motor vehicle traffic accidents occurred in the U.S. in 2006, according to the National Highway and Traffic Safety Administration (NHTSA). Those incidents led to nearly 39,000 fatalities and 1.7 million injuries. And almost 95 percent of the 10.6 million vehicles involved in crashes that year were passenger cars or light trucks. In the meantime, despite continuing calls for greater investment in mass transit, American roads are only growing more crowded. Similar circumstances prevail in the rest of the world, particularly in developing nations, where auto ownership is skyrocketing.

Accident statistics indicate that driver error is the main cause of safety problems on the road, states Jörg Breuer of Mercedes-Benz. "For instance, it can be difficult for the driver to assess how hard to brake when a lead vehicle suddenly slows," he says. "And you lose precious microseconds determining the severity of the danger." Hence, "many people are braking too late, too little or not at all," he explains, so Mercedes and their competitors are working to provide automated braking assistance.

Two trends are also pushing toward greater automation in cars. First, the average age of most of the world's driving populations is rising rapidly. As motorists' faculties and capabilities decline, technology can increasingly take up the slack to keep vehicle occupants—and others on the road—safe.

The second trend is a bit less obvious. Greener, more environmentally responsible cars that consume less energy are currently all the rage. Most such efforts focus on developing more energy-efficient engines, but engineers can achieve much the same effect by building cars that are lighter weight. Unfortunately, such "lightweighting" often results in vehicles with less robust structures that tend to sustain more damage in collisions. Autos that avoid accidents can somewhat compensate for that drawback.

On the other hand, some factors are limiting the speed at which advanced safety technology is coming online. It is still rather expensive. Also, car manufacturers remain wary of any costly legal ramifications that might arise from injuries or deaths caused by safety system failures. And perhaps paramount, automakers are careful not to intrude too much on customers' strong feeling of control over their road machines, so they focus on educating drivers about the benefits of the latest features as they introduce them. This effort comes down to building trust in the new capabilities.

**Staying Alive**

Some first-generation technologies that help drivers to prevent accidents or lessen the intensity of crash injuries and damage—known in the business as active safety systems—are already familiar. (So-called passive safety features, such as seat belts, air bags, and crumple or crush zones, protect you when a collision occurs.) Antilock brakes (ABS), which entered the market in 1978, improve steerability and hasten deceleration when someone slams on the brakes. "ABS constituted the first time a sensor was allowed to 'feel' a critical driving situation and then act automatically to mitigate it," Breuer says.

Traction-control systems (TCS) were the next major active safety technology to be introduced. They prevent the engine-driven wheels from losing traction and thereby improve overall vehicle control when the driver applies too much gas (engine throttle), producing torque (rotational force) that is beyond what the road-surface conditions can handle.

After TCS came enhanced stability control, or ESC. These systems constantly monitor the angle of the steering wheel and the vehicle's direction; the latter is assessed by the speed of sideways motion, the angle of the car relative to its central axis and how fast the wheels are turning. When an ESC system detects skids, it attempts to short-circuit them by selectively activating the brakes needed to straighten the car's trajectory. It may also step down the engine's power until the car rights itself.

Studies by Mercedes and Toyota indicate that ESC installation results in a 29 to 35 percent reduction in single-vehicle crashes and from 15 to 30 percent fewer head-on collisions, which in the U.S. translates into thousands of lives and tens of billions of dollars saved annually. The marked success of ESC is highlighted by a recent decision by the NHTSA to make the technology standard equipment by 2012 for vehicles below 10,000 pounds gross weight, reports Kay Stepper of Robert Bosch's Vehicle Motion and Safety Division in Farmington Hills, Mich. An expected benefit of the new rule is that ABS and TCS will become standard on all cars and light trucks.

**Networked Safety**

ESC is, in addition, the key to a new generation of safety systems that take advantage of networked communications among vehicle sensors, actuation devices and computers, Stepper continues. Because ESC uses acceleration, or g-force, sensors that keep watch on the overall motion of the vehicle, it can provide a central monitor-and-controller unit with the information needed to react effectively to looming road threats. "Up until recently, the different safety subsystems in a vehicle have worked independently of one another," he states. "By networking the components together so they can talk to one another, however, we can achieve enhanced capabilities or even totally new functions, often using the same equipment or even less."

Consider an example of this transition: to trigger deployment in a crash, Bosch's current side-impact air-bag system relies on two separate sensors to verify that a side collision is occurring—one in the door that detects pressure and one in the stability-control unit that measures acceleration. "Unfortunately, you have to wait until verification before setting off the air bags, so you lose precious milliseconds, which can be an eternity in a collision," Stepper notes. But in the latest networked approach, a central "black box" controller that monitors vehicle motion can receive information from the ESC's acceleration sensor about yaw—that is, a rotation of the vehicle about its vertical axis that indicates it is sliding sideways—and prepare the side air bags to deploy immediately if the door- pressure sensor goes off.

The automotive industry is just starting to exploit these potential synergies by integrating a number of previously independent safety subsystems into networks so that critical information will be available to all of them. The change, Stepper concludes, should save on costs "because fewer sensors will be needed to accomplish the same tasks."

**Collision Warning**

Among the more exciting of the safety systems are technologies that warn of, and help to avoid, collisions with vehicles or other hazards up ahead—versions of which I tried out in the Ford simulator as well as a couple of times on different test tracks. Forward-collision warning systems are based on the relatively new adaptive cruise-control devices that rely on radar data to maintain a preset distance or time gap between two vehicles.

Newer "stop and go" adaptive cruise controls make riding in slow-moving traffic considerably easier, because they can follow the car ahead precisely as it halts and starts up again. The addition of a camera and sophisticated software-control algorithms makes for a basic collision warning system.

These devices need to combine radars with cameras because each brings a different capability, says Dean McConnell of Continental Automotive Systems in Auburn Hills, Mich. “Radars can tell whether something is out there or not, and they can measure the distance to an obstacle, but they are not so great at classifying what that object is. The video camera system can distinguish between something important, like a car, and something that’s not, say, a manhole cover in the street.” Only together can they determine with confidence when dangerous frontal collisions are likely and that braking is needed, he explains.

In typical installations, McConnell notes, a long-distance, 77-gigahertz, microwave radar sensor monitors out to 400 to 650 feet ahead and a shorter-range, 24-gigahertz, radar unit scans several tens of meters up front. Their wide-angle video cameras can recognize objects that are about 130 to 165 feet away. When a warning system determines that a car is closing in too fast on the one ahead, it jogs the brake pedal, flashes a braking alert or activates other signals, and prepares the brakes for instantaneous activation by prepressurizing the hydraulic brake lines. If the driver takes no action and collision is imminent, then the system slows the vehicle automatically to at least reduce the impact of any collision. Many liken the technology to extending the car’s crush zone forward.

**Automatic Braking**

Today’s collision warning systems point the way toward future active safety systems that automatically hit the brakes or steer cars back into their lanes to avoid accidents altogether. But successfully fielding fail-safe, all-speed versions of such technologies is considerably more problematic and still five or 10 years away.

Volvo has taken an initial swipe at automated braking in its XC60 model with the City Safety feature, a low-speed collision avoidance and mitigation system that operates below 20 miles per hour. City Safety is intended to address the issue of slow—often urban, hence the name—fender benders, which in many places, account for around three quarters of all car collisions, says Thomas Broberg of Volvo in Gothenberg, Sweden. Most fender benders are caused by distracted drivers. Although these accidents result in few deaths, they often cause whiplash and, Broberg notes, “are very costly to society.”

City Safety has an infrared laser range finder that sends out beams and looks for reflections from objects that are 20 to 25 feet in front of the vehicle. A receiver measures the speed at which the two bodies are closing in on each other and, if necessary, prepares the emergency brakes to respond quickly. “If the driver does not do anything in this situation, the system will brake automatically,” Broberg says. “It does not give a warning at this point, because it would only confuse the driver.” Afterward the system notifies the driver that City Safety has kicked in.

Moving up to a full-on, all-speed autonomous braking system will be difficult, Broberg says, because ensuring that any action it takes in a critical situation is the right move is challenging. “It’s easy to make a car brake automatically,” he observes. “The trick is to ensure that it doesn’t brake when it’s not supposed to” and to ensure that “it will take the correct action every time.” So far Volvo, other automakers and safety system suppliers are still testing to be sure that their systems are ultrareliable. For example, they are putting the systems into cars—often owned by regular customers—in different environments all over the world. Most of the time the new systems are inactive, but they record whether the correct decisions would have been made.

**Keeping in the Lane**

Front-facing video cameras serve as key components in devices that warn the driver when the vehicle is leaving its lane. The cameras track lane markers and note when the vehicle deviates from the pathway they define.

Nissan, which was one of the first car manufacturers to introduce such technology, is bringing out an upgraded lane-keeping technology, reports Alex Cardinali of Nissan North America in Nashville, Tenn. “Our new lane-departure prevention system stops drivers from inadvertently drifting out of their lanes because, for example, of inattention, distraction or drowsiness. It intervenes by providing brake input on one side of the car, which creates a yawing motion that brings the car back into the lane.” Besides monitoring the lane markings with a camera mounted above the rearview mirror, the unit takes into consideration both the vehicle’s speed and the driver’s steering manipulations.

I had a chance to demo a similar system during a drive just outside of Bosch’s U.S. test facility in the softly rolling countryside south of Detroit. With a trio of Bosch engineers sitting in the passenger seats, we plied a nearly empty stretch of arrow-straight, two-lane roadway. When the coast was clear, the researcher beside me engaged the system with a few laptop keystrokes. Then I steered the car into the next lane, and the steering wheel and seat started shaking as if we had just driven onto a “washboard” dirt road. The message was clear: get back in your lane. We went on to try out several similar implementations of the same basic concept, except that the alarm signals were beeps, chimes and dashboard lights. Flipping the turn signal overrides the lane-keeping function.

I soon found out that I was most comfortable with the slot-car-like action of what the researcher called “bathtub mode,” referring to the sloping sides of a graph of the machine’s responses to steering deviations on his laptop screen. Each time I turned the wheel to point the car out of my lane, a countervailing force very smoothly directed the vehicle back into my lane. The engineers smiled with satisfaction when I remarked that I would find it “very easy to get used to riding in the center of the bathtub.”

**Avoiding Being Blindsided**

A counterpart to lane-keeping systems are blind-spot detection systems, which use side-mounted ultrasonic or radar sensors to view the adjacent lanes and notify drivers of vehicles in their blind spots. In most such systems now on the market, warning lights in the side-view mirrors switch on when the vehicle occupies those zones. McConnell says that blind-spot detectors are gaining in popularity among drivers who have tried them, but the technology “might actually develop faster in the commercial market, because all trucks have big blind spots."

An extension of the blind-spot technology is lane-change assistance provided by a system that tells drivers when cars in adjacent lanes are rapidly gaining on them and even prevents them from steering into the lanes. In this case, McConnell says, the sensing area is expanded "to a couple of car lengths, maybe 165 feet, behind." A related technology is designed to avoid the horrific situation when a driver backs a car over a small, unseen child, often playing in the driveway. These backover protection systems can detect the child or an object before contact and halt the vehicle. He reports that the NHTSA is conducting discussions with the automakers and their suppliers to address these terrible, but—thankfully—fairly rare incidents.

McConnell predicts that the future will see safety systems that identify and avoid pedestrians and animals, such as deer, on the roadway, even at nighttime, as well as traffic-sign recognition systems that, for example, prevent drivers from running stop signs and lights.

The combination of all these advanced sensor systems, particularly if they were networked, could establish a virtual "safety bubble" around a vehicle, one that could detect nearly any hazard in the vicinity. But such an onboard system would probably be complex and costly, perhaps more than car owners would want to spend.

**Car Talk**

Because of the expense, a number of auto manufacturers are investigating an alternative, lower-cost approach that involves linking vehicles and the roadway infrastructure through wireless communications not much more sophisticated than text messaging. Rather than relying on a car's own onboard sensor suite, says Alan Taub, executive director of General Motors Research and Development, "why not just find out what's happening in the neighborhood by querying other vehicles and nearby road signs and intersections?"

Such vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems "would allow drivers to see beyond the visual horizon. For example, say there's a vehicle stopped in the street ahead, but it's just around the corner," Taub says. "The onboard system may not sense it in time, but a nearby passing car probably would." Or an intersection management system with a built-in wireless communications node could inform an inattentive driver that his or her car is about to run a red light. It could even apply the brakes, if that were desirable.

Part of the genius of the concept is that it is low-tech: cars and roadways would be fitted with just basic sensors such as Global Positioning System (GPS) location devices, some computing power, and compatible wireless short-range radio transmitter and receiver units. And not every vehicle needs to be so equipped at first, Taub notes: "You get some safety benefits even from only 5 or 10 percent penetration into the vehicle population."

But the approach has drawbacks as well. Both systems require that all the car companies that sell vehicles in a country agree to consistent communications standards, which at the very least will take time to establish. And although outfitting cars to operate in roadway V2I networks would not cost too much, installing the needed devices across the entire road infrastructure would probably be expensive. One estimate indicates that a nationwide V2I system in the U.S. would cost a trillion dollars to build.

Nevertheless, talks on V2V technology are ongoing among the interested parties, including Toyota, General Motors, Nissan and others, and research organizations in Japan and China, in particular, are developing V2I prototypes.

**Driving on Auto**

Once the safety systems and autonomous navigation technologies now under development achieve truly bulletproof reliability and drivers come to fully accept them, it is not much of a jump to foresee vehicles that can drive themselves. Indeed, researchers have already shown that such cars are feasible.

In 2007 a tricked-out Chevrolet Tahoe nicknamed "Boss" and several similar driverless vehicles successfully navigated through a realistic city streetscape in Victorville, Calif., one complete with other cars and even traffic jams. The autonomous cars and trucks were competing in the Defense Advanced Research Projects Agency's Urban Challenge, a race designed to demonstrate that robot road vehicles can become practical. Soon afterward General Motors CEO G. Richard Wagoner, Jr., predicted his company will market autonomous vehicles within 10 years. That prognostication may be a bit optimistic, but his statement surely points the way to real robotic cars in the not too distant future.

*Note: This article was originally printed with the title, "Driving toward Crashless Cars".*

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