EMBARGOED UNTIL 12:01 AM *EDT*, TUESDAY AUGUST 14, 2012

# Status Report

Insurance Institute for Highway Safety | Highway Loss Data Institute


## Small overlap crashes

New consumer-test program aims for even safer vehicles


**A new Institute crash test evaluates how well vehicles protect people in frontal crashes involving 25 percent of a vehicle's front end. Most cars in this inaugural round earn marginal or poor ratings.**

**The small overlap front test** replicates what happens when the front corner of a car collides with another vehicle or object. Twenty-five percent of the vehicle's front end strikes a 5-foot-tall rigid barrier at 40 mph. A 50th percentile Hybrid III dummy representing an average-size male is belted in the driver seat.

Only 3 of 11 midsize luxury and near-luxury cars evaluated earn good or acceptable ratings in the Institute's new small overlap frontal crash test, the latest addition to a suite of tests designed to help consumers pick the safest vehicles.

The Acura TL and Volvo S60 earn good ratings, while the Infiniti G earns acceptable. The Acura TSX, BMW 3 series, Lincoln MKZ and Volkswagen CC earn marginal ratings. The Mercedes-Benz C-Class, Lexus IS 250/350, Audi A4 and Lexus ES 350 earn poor. All of these cars are 2012 models.

In the test, 25 percent of a car's front end on the driver side strikes a 5-foot-tall rigid barrier at 40 mph. A 50th percentile male Hybrid III dummy is belted in the driver seat. The test is designed to replicate what happens when the front corner of a car collides with another vehicle or an object like a tree or utility pole. Outside of some automakers' proving grounds, such a test isn't currently conducted anywhere else in the United States or Europe.

"Nearly every new car performs well in other frontal crash tests conducted by the Institute and the federal government, but we still see more than 10,000 deaths in frontal crashes each year," Institute President Adrian Lund says. "Small overlap crashes are a major source of these fatalities. This new test program is based on years of analyzing real-world frontal crashes and then replicating them in our crash test facility to determine how people are being seriously injured and how cars can be designed to protect them better. We think this is the next step in improving frontal crash protection."

The number of drivers of 0-3-year-old passenger vehicles involved in fatal frontal crashes has fallen 55 percent since 2001. Much of the improved outlook is due to the success of consumer information testing like the New Car Assessment Program begun by the National Highway Traffic Safety Administration (NHTSA) in 1978 and crashworthiness evaluations the Institute started in 1995. In NHTSA's frontal test, passenger vehicles crash at 35 mph into a rigid barrier covering the full width

of the vehicle. In the Institute's 40 mph offset frontal test, now called a moderate overlap frontal test, 40 percent of the total width of a vehicle strikes a deformable barrier on the driver side.

In a 2009 Institute study of vehicles with good ratings for frontal crash protection, small overlap crashes accounted for nearly a quarter of the frontal crashes involving serious or fatal injury to front seat occupants. Another 24 percent of the frontal crashes were moderate overlap crashes, although they likely occurred at much higher speeds than the Institute's moderate overlap test (see *Status Report*, March 7, 2009; on the web at iihs.org). An additional 14 percent occurred when passenger vehicles underrode large trucks, SUVs or other high-riding passenger vehicles. The Institute is exploring countermeasures for large truck underride crashes and in other research has found that the problem of crash incompatibility between cars and SUVs is being reduced (see *Status Report*, March 1, 2011, and Sept. 28, 2011).

## Structural integrity

The key to protection in any crash is a strong safety cage that resists deformation to maintain survival space for occupants. Then vehicle restraint systems can do their jobs to cushion and protect people.

"It's Packaging 101. If you ship a fragile item in a strong box, it's more likely to arrive at its destination without breaking. In crashes, people are less vulnerable to injury if the occupant compartment remains intact," Lund explains.

Most modern cars have safety cages built to withstand head-on collisions and moderate overlap frontal crashes with little deformation. At the same time, crush zones help manage crash energy to reduce forces on the occupant compartment. The main crush-zone structures are concentrated in the middle 50 percent of the front end. When a crash involves these structures, the occupant compartment is protected from intrusion, and front airbags and safety belts can effectively restrain and protect occupants.

Small overlap crashes are a different story. These crashes primarily affect a car's outer edges, which aren't well protected by the crush-zone structures.

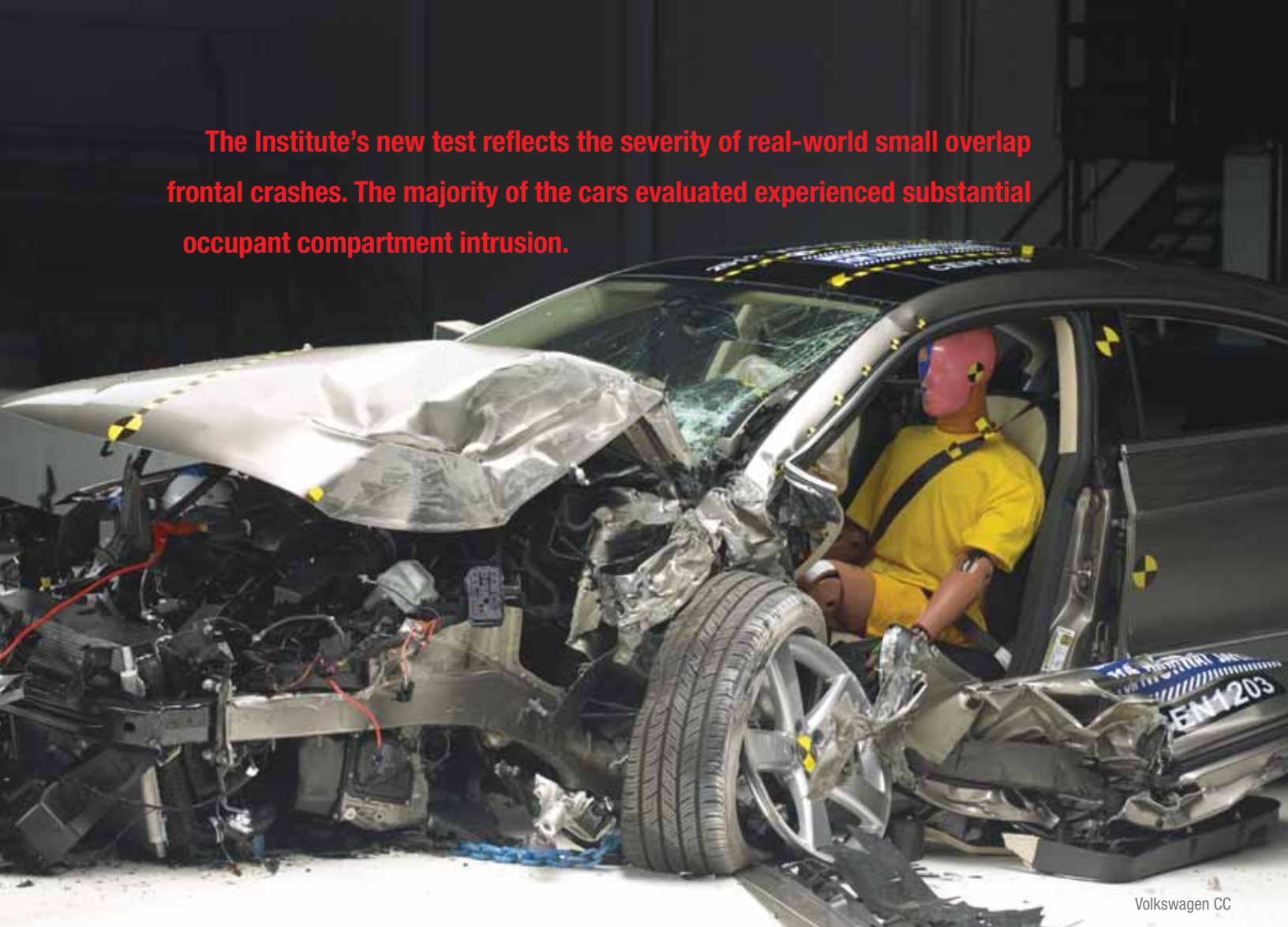
## Small overlap frontal ratings

| | Overall | Structure | Restraints & Kinematics | Dummy Injury Measures: Head & neck | Chest | Hip & thigh | Lower leg & foot |
|---|---|---|---|---|---|---|---|
| Acura TL | G | A | G | G | G | G | G |
| Volvo S60 | G | G | A | G | G | G | G |
| Infiniti G | A | M | G | G | G | G | G |
| Acura TSX sedan/Sport Wagon | M | M | M | G | G | G | P |
| BMW 3 series | M | M | M | G | G | G | P |
| Lincoln MKZ | M | P | M | G | G | G | A |
| Volkswagen CC | M | M | P | G | G | A | G |
| Mercedes C-Class | P | P | M | G | G | G | P |
| Lexus IS 250/350 | P | P | P | G | G | G | P |
| Audi A4 | P | P | P | G | G | P | G |
| Lexus ES 350 | P | P | P | G | G | M | P |

good G acceptable A marginal M poor P


**Survival space for the driver** wasn't well maintained in the Lexus IS (far left) crash test. The A-pillar bent and the footwell collapsed as the left front wheel and tire were forced rearward. The dummy's feet were entrapped by intruding structures. Results for the Volvo S60 (near left) were very different. The S60's occupant compartment held up well, with only minor intrusion.

**The Institute's new test reflects the severity of real-world small overlap frontal crashes. The majority of the cars evaluated experienced substantial occupant compartment intrusion.**



Volkswagen CC

BMW 3 series

Mercedes-Benz C-Class

Crash forces go directly into the front wheel, suspension system and firewall. It is not uncommon for the wheel to be forced rearward into the footwell, contributing to even more intrusion in the occupant compartment and resulting in serious leg and foot injuries. To provide effective protection in small overlap crashes, the safety cage needs to resist crash forces that aren't tempered by crush-zone structures. Widening these front-end structures also would help.

"These are severe crashes, and our new test reflects that," Lund says. "Most automakers design their vehicles to ace our moderate overlap frontal test and NHTSA's full-width frontal test, but the problem of small overlap crashes hasn't been addressed. We hope our new rating program will change that."

**Above:** The Volkswagen CC is the first vehicle the Institute has ever evaluated to lose a door in a crash test. **Top left:** Substantial intrusion in the BMW 3 series meant that left lower leg injury risk was high. **Bottom left:** In the Mercedes-Benz C-Class, the dummy's right foot was wedged beneath the brake pedal.

Vehicle test performance varied widely in the three rating categories: structure, restraints and kinematics, and dummy injury measures. The majority of the cars had lots of occupant compartment intrusion, which contributed to their low overall rating. Occupant motion varied greatly as well, with the dummy missing the airbag in some cases. In others, safety belts allowed the dummy's head and torso to move too far forward toward the A-pillar. Forces measured on the dummy indicated high risk of injury for the legs and feet in several vehicles.

Structurally, the Volvo S60 was best. With only a few inches of intrusion, the occupant compartment looked much the same as it did in a prior moderate overlap

test. Reinforcement of the S60's upper rails and a steel cross member below the instrument panel helped to keep the safety cage intact. Volvo has performed similar small overlap crash tests as part of its vehicle safety development process since the late 1980s, taking the results into account when designing new models.

The Lexus IS had up to 10 times as much occupant compartment intrusion as the Volvo. In the IS test, the car's A-pillar bent and the footwell collapsed as the left front wheel and tire were forced rearward. The dummy's left foot was entrapped by intruding structure, and its right foot was wedged beneath the brake pedal. Entrapment also was an issue with the Mercedes C-Class. The dummy's right foot ended up wedged beneath the brake pedal as the left front wheel was forced rearward into the footwell.

When the Volkswagen CC was put to the test, the driver door was sheared off its hinges. The CC is the first vehicle the Institute has ever evaluated to completely lose its door. An open door results in an automatic downgrade to poor for restraints and kinematics, as also was the case with the Audi A4, whose door opened but remained attached to the car. Doors should stay closed in a crash to keep people from being partially or completely ejected from vehicles.

### Restraint systems' key role

Safety belts and airbags are important in any crash configuration, and they are especially taxed in small overlap frontal crashes. When cars strike the test barrier they tend to move sideways away from it, and the interior structures including the driver door, side window and A-pillar move in the same direction. The test dummy, however, keeps moving forward into the path of the sideways-moving interior structures. At the same time, the steering column and driver airbag move inboard in many vehicles because of the way the front end and occupant compartment deform. If the dummy misses the airbag or slides off it, the head and chest are unprotected.

Front airbags are calibrated to deploy in these types of crashes. Side airbags, including head-protecting curtains and chest-protecting torso airbags, don't always deploy because they are designed mainly for true side impacts — think so-called T-bone crashes at intersections. When they do deploy, they don't always do so early enough or extend far enough forward to adequately protect people. The result is an airbag gray zone with gaps between what front airbags cover and what side airbags do — if they deploy at all.

Without airbag protection, people in real-world small overlap frontal crashes can sustain head injuries from direct contact with the A-pillar, dashboard or window sill or by hitting trees, poles or other objects. Chest injuries happen when people contact the steering wheel, door or other intruding structures.

Every luxury car and near-luxury car the Institute evaluated earns good ratings for head, neck and chest injury risk based on measurements from the dummy's sensors. This is true even though there are many cases of serious upper body injuries in real-world crashes with similar vehicle damage.

One possible reason for the differing results is that real people move more during a crash and are prone to be out of position at the start, compared with relatively stiff and precisely positioned crash test dummies. Not all drivers are the same size as the dummy or seated exactly the same way. A close call for the dummy could mean an actual injury for a person. In several crash tests, the dummy's head barely missed the intruding structure of the vehicle, where a real person may have made contact and sustained an injury. Another reason is that the frontal crash dummy the Institute uses in the small overlap test is not good at measuring risks from lateral forces. Side crash dummies do a better job of this but can't "sense" — or record — much of the frontal action in these tests.

Side curtain and torso airbags deployed in the Acura TL and Volvo S60, although the S60's torso airbag fired too late in the crash to protect the dummy's chest from

## Real-world small overlap crash results in driver facial injuries

Hollyn Mangione knows first hand the risks of a small overlap frontal crash. Driving her 2012 Kia Soul to a friend's house on a clear evening last November, Mangione, 48, encountered an oncoming 1999 GMC Yukon that had veered into her lane on a rural road in Hanover County, Virginia.

"I looked up and saw the other vehicle coming toward me, and I remember thinking, is there someplace I can go? Can I get off the road? I took my foot off the accelerator trying to buy myself some time to make a decision. There wasn't anywhere to go on this narrow road because it was tree-lined, and there was a big ditch.

"I remember thinking, please just stay in your lane," she recalls. "Once I heard the boom and felt it, I was unconscious." Afterward, she says "I remember the EMT holding my head and my telling her, 'That really hurts.' And saying to them, 'But I'm stuck over here where my knee is pinned in the car.' And then I don't remember anything until they were putting IVs in, in the ambulance."

Mangione, who was using her safety belt, sustained facial injuries from contact with the Kia's door frame. She had a left facial fracture and laceration, concussion, whiplash, left eye injury and dental injuries. Crash damage to Mangione's small car was similar to damage patterns in the Institute's small overlap crash test. The driver's space was compromised by intruding structure. The A-pillar, hinge pillar and forward portion of the window frame were driven rearward and inboard as the wheel and tire were forced rearward. The side curtain and torso airbags didn't deploy. ■



**Top left:** The test dummy's head and chest missed the front airbag as the steering column moved to the right in the Lincoln MKZ. The side curtain airbag deployed but didn't have sufficient forward coverage to protect the head. **Middle:** The Acura TL's front and side curtain airbags did a good job of protecting the dummy's head.

**Safety belts and airbags are especially taxed in small overlap frontal crashes. Gaps in airbag coverage or too much belt slack can leave occupants vulnerable to injuries.**


**Above:** The Volvo S60 was a top performer. The sedan's occupant compartment held up better than any of the other cars. Volvo runs small overlap crash tests as part of its vehicle safety development program.

potential contact with side structures. One or both of the curtain and torso airbags didn't deploy in seven of the cars evaluated. Of the six curtains that deployed, four didn't provide sufficient forward coverage. The Institute lowered restraint and kinematics scores if side airbags didn't deploy or coverage was lacking.

"Side curtain airbags and torso airbags are designed to deploy in side impacts, but they can be beneficial in small overlap frontal crashes as well," Lund says. "If they do deploy, curtain airbags also need to extend far enough forward to protect the head from contact with side structures and outside objects."

For example, in the Lincoln MKZ test, the dummy's head and chest completely missed the front airbag as the steering column moved to the right. The side curtain airbag deployed but didn't extend far enough forward to protect the dummy's head. In comparison, the Acura TL's front and side curtain airbags worked well together to keep the head from coming close to any stiff structures or objects that could cause injury.

Engineers at some manufacturers have indicated that they are adjusting airbag algorithms across their fleet to deploy side airbags in small overlap frontal crashes.

Another restraint and kinematics issue Institute engineers flagged was excessive forward movement of the driver dummy caused by too much shoulder belt webbing spooling out of the retractor. This was the case with the BMW, Mercedes and Volkswagen. Like most new vehicles, these cars have safety belts equipped with load limiters that allow occupants' upper bodies to move forward in frontal crashes when belt loads exceed a specific threshold. Load limiters allow some belt spoolout after the initial impact to reduce belt-force-related thoracic injuries such as rib fractures by allowing people to "ride down" deflating front airbags. However, too much spoolout can compromise belt effectiveness by allowing belted occupants to move enough to strike hard surfaces inside the vehicle. This concern is greater in small overlaps where occupants may load only a small part of the front airbag or miss it completely.

## Tougher award criteria

The Institute's *TOP SAFETY PICK* award recognizes passenger vehicles that do the best job of protecting people in front, side, rollover and rear crashes based on ratings in Institute evaluations. The front rating is based on the moderate overlap test.

The Institute plans to make the top award criteria more stringent by adding the small overlap frontal test to its battery of evaluations. The existing criteria will continue for the 2013 award cycle, but vehicles that excel in the new test will be recognized.

"We won't have evaluated many vehicles in the small overlap test in time for the 2013 award," Lund explains. "Models meeting the current award criteria still offer outstanding protection in most crashes, and they will continue to earn *TOP SAFETY PICK* in 2013. However, those vehicles that also do well in the new test will get to claim a higher award level that will be announced later this year."

The Institute has tightened award criteria twice since the first winners were announced for 2006 models. Good rear test results and availability of electronic stability control became a requirement starting with 2007 models, and a good roof strength rating became a deciding factor for 2010 models (see *Status Report*, March 24, 2009). Stability control is no longer a separate requirement since all 2012 and later vehicles must have the feature as standard under federal rules.

Automakers have been quick to rise to the occasion whenever the Institute has added a new evaluation to its vehicle test program, and the small overlap test should be no exception.

"Manufacturers recognize that this crash mode poses a significant risk to their customers and have indicated that they plan structural and restraint changes to improve protection in small overlap frontal crashes," Lund says.

Next, the Institute will assess midsize moderately priced cars, including such top-selling models as the Ford Fusion, Honda Accord and Toyota Camry. ■

# Truck tractors, buses could get standard ESC under NHTSA proposal

Electronic stability control (ESC), a crash avoidance feature required on 2012 and newer model passenger vehicles, could become standard on new large truck tractors and certain large buses if the National Highway Traffic Safety Administration (NHTSA) adopts a proposed rule announced in May.

Analysis of the real-world experience of ESC indicates the technology is saving lives by helping to prevent rollovers and loss-of-control crashes in cars, minivans, pickups and SUVs (see *Status Report*, Sept. 28, 2011; on the web at iihs.org). Researchers haven't yet been able to quantify ESC's real-world effect for large trucks.

NHTSA has been conducting extensive research on stability control systems for truck tractors and large buses since 2006. The agency has sponsored studies of crash data to help examine the potential safety benefits, conducted test track studies to understand how the systems respond in different maneuvers, and undertaken simulator evaluations to understand how drivers might use the systems. NHTSA also has evaluated data on dynamic test maneuvers from truck makers and brake suppliers. The agency used this information to develop test maneuvers that define what systems must do to comply with the proposed regulation and to predict the effectiveness of stability control systems.

The agency estimates that ESC on truck tractors could prevent 40 to 56 percent of untripped rollovers and an additional 14 percent of loss-of-control crashes each year. Requiring ESC for all truck tractors and certain buses with a gross vehicle rating of more than 26,000 pounds would prevent as many as 2,329 crashes and as many as 858 injuries, plus save as many as 60 lives annually. NHTSA based its estimates for truck tractors and large buses on an initial target crash population of 10,313 crashes (5,510 rollovers and 4,803 loss-of-control crashes), 327 fatalities (111 rollover and 216 loss of control) and 3,358 injury crashes (2,217 rollover and 1,141 loss of control).

There are two kinds of stability control systems available for truck tractors: ESC and roll stability control. Roll stability control systems automatically intervene if sensors monitoring a truck tractor's lateral acceleration and wheel speed detect a high rollover risk. Tractor-based systems can selectively apply brakes on the tractor's drive axle and the trailer, plus modulate engine power to slow down the truck and keep it upright. Trailers can have roll stability control, too, but trailer systems only control trailer brakes, not the tractor's, and can't reduce engine power. Roll stability control can reduce rollovers but isn't meant to help drivers maintain directional control. That ability is unique to ESC.

ESC incorporates all of the features of roll stability control but with the added benefit of a steering-angle sensor and a yaw sensor to measure the tractor's directional stability. These sensors help mitigate severe oversteer and understeer conditions. If measures exceed specific thresholds, ESC reduces engine power and can selectively apply brakes on multiple tractor axles in order to bring the vehicle back into line, plus apply the trailer brakes as needed to slow down the truck.

"We support NHTSA's decision to require ESC rather than roll stability control," says Anne McCartt, Institute senior vice president for research. "Although it's more costly, ESC affects a wider range of rollover and loss-of-control collisions than roll stability control."

About 26 percent of 2012 model truck tractors and 80 percent of new buses have ESC, NHTSA estimates. If adopted, the rule would take effect within two years of publication. The agency isn't requiring in-service truck tractors and buses to be retrofitted but seeks comments on a future ESC retrofit mandate.

Single-unit trucks aren't included in the current proposal because NHTSA needs to determine how effective ESC would be for these vehicles. The agency plans a feasibility study and could consider a future ESC requirement. Estimating the technology's potential benefits for single-unit trucks is challenging, NHTSA says. Compared with truck tractors, the single-unit truck fleet varies by model in terms of weight, wheelbase, axles, cargo type and other factors that affect the calibration and performance of stability control systems. Another issue is that because multiple suppliers handle the design and building of each vehicle, chassis suppliers who fit brakes and potentially stability control often don't know the vehicle's ultimate function. NHTSA also notes that stability control systems are more widely available for air-braked vehicles, including truck tractors, than for hydraulic-braked single-unit trucks. Only about 1 percent of new single-unit trucks have these systems now, NHTSA says.

"We commend the agency for moving ahead with an ESC mandate for new truck tractors and large buses independent of its ongoing research on single-unit trucks," McCartt says. "We encourage NHTSA to expedite this research and also to explore the feasibility of a retrofitting requirement so a bigger proportion of the fleet benefits from ESC." ■

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