Status Report

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Reality check

Research, deadly crashes show need for caution on road to full autonomy

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The road to full driving autonomy is paved with good intentions: Reduce crashes, reduce deaths, reduce congestion, increase mobility. That is the bright future the industry is chasing. Like the evolution of any nascent technology, however, there have been glitches and misfires along the way. Even deaths.

The idea of self-driving cars has garnered so much press that consumers can almost be forgiven for thinking the latest cars can drive themselves.

While it is true that many new vehicles can assist drivers in performing certain tasks, such as maintaining following distance and lane centering, no car can handle every driving task on a full range of roads and conditions.

This special issue of *Status Report* is a follow-up to the November 2016 special issue on autonomous vehicles.

New IIHS research based on track tests and on-road experiences with Level 2 driver assistance uncovers some of the inherent challenges with partial automation.

The deadly crash of a Tesla Model X on a California highway in March demonstrates the limits of the technology and the propensity of some drivers to misuse it.

A HLDI analysis of Tesla insurance losses reveals benefits for the combined crash avoidance features on the Model S, while the benefit of adding “Autopilot” is limited to lowering collision claims.

The Uber crash in Arizona that took the life of a pedestrian in March shows the hazards of beta testing self-driving vehicles on public roads. IIHS researchers explore how automatic emergency braking and better headlights might have helped prevent this tragedy.

Finally, a patchwork of state laws and voluntary federal policy guidelines lacks the safeguards needed to protect everyone on the road as fully autonomous vehicles are tested and eventually deployed in the U.S. ■

Road, track tests to help IIHS craft ratings program for driver assistance features

On-road and track tests are helping IIHS craft a consumer ratings program for advanced driver assistance systems. Evaluations of adaptive cruise control and active lane-keeping show variable performance in typical driving situations, such as approaching stopped vehicles and negotiating hills and curves. The early results underscore the fact that today's systems aren't robust substitutes for human drivers.

One of the questions researchers looked to answer is, do the systems handle driving tasks as humans would? Not always, tests showed. When they didn't perform as expected, the outcomes ranged from the irksome, such as too-cautious braking, to the dangerous, for example, veering toward the shoulder if sensors couldn't detect lane lines.

Adaptive cruise control (ACC) maintains a set speed and following distance from the vehicle in front. It is designed to slow for cars ahead and can come to a full stop but may not react to already-stopped vehicles. ACC doesn't react to traffic signals or other traffic controls. Active lane-keeping provides sustained steering input to keep the vehicle within its lane, but drivers must continue to hold the wheel.

On SAE International's scale of zero autonomy to Level 5 full autonomy, the combination of ACC and active lane-keeping is Level 2. They can assist with steering, speed control and following distance, but the human driver is still in charge and must stay on task.

"The new tests are an outgrowth of our research on Level 2 autonomy," says Jessica Jermakian, IIHS senior research engineer. "We zeroed in on situations our staff have identified as areas of concern during test drives with Level 2 systems, then used that feedback to develop road and track scenarios to compare vehicles."

The 2017 BMW 5-series with "Driving Assistant Plus," 2017 Mercedes-Benz E-Class with "Drive Pilot," 2018 Tesla Model 3 and 2016 Model S with "Autopilot" (software versions 8.1 and 7.1, respectively) and 2018 Volvo S90 with "Pilot Assist" were evaluated. All five have automatic emergency braking systems rated superior by IIHS.

Adaptive cruise control

Engineers evaluated ACC systems in four different series of track tests to see how they handle stopped lead vehicles and lead vehicles exiting the lane, and how the systems accelerate and decelerate.

One series involved driving at 31 mph toward a stationary vehicle target with ACC off and autobrake turned on to evaluate autobrake performance. Only the two Teslas hit the stationary target in this test.

The same test was repeated with ACC engaged and set to close, middle and far following distance in multiple runs.

With ACC active, the 5-series, E-Class, Model 3 and Model S braked earlier and gentler than with emergency braking and still avoided the target. The cars slowed with relatively gradual decelerations of 0.2-0.3 gs, braking in the same manner no matter the distance setting. Braking before impact was earlier for the Teslas than for the 5 series and E-Class.

The S90 braked more abruptly than the other models with ACC active, similar to its autobrake performance. In the ACC test, the S90 braked at a forceful 1.1g, just 1.1 seconds before impact to avoid the collision.

Curves and hills can challenge active lane-keeping systems. The Tesla Model 3 performed well in these on-road tests.

A third scenario involved following a lead vehicle that slows down to a stop and then accelerates. Every ACC system decelerated smoothly in this test.

A fourth scenario involved the test vehicle following a lead vehicle, which then changed lanes to reveal a stationary inflatable target vehicle in the path ahead when the time to collision was about 4.3 seconds.

None of the vehicles crashed into the target, and the 5 series, E-Class and Teslas all braked earlier and gentler than the S90, similar to the active ACC test.

Track tests are good for evaluating capability and performance in a controlled environment but not for assessing performance in traffic. Under ideal conditions, advanced driver assistance systems may »

(« *from p. 3)* function better than they do in more complex driving situations.

A case in point is the stopped-vehicle ACC tests. On the track, the 5 series, E-Class and Teslas braked to avoid the target vehicle. This was the case even though the owner's manuals for all the test vehicles warn that ACC may not brake when it encounters vehicles that are already stopped when they come into sensor range.

Out on the road, engineers noted instances in which each vehicle except the Model 3 failed to respond to stopped vehicles ahead.

IIHS can't say yet which company has the safest implementation of Level 2 driver assistance, but it is important to note that none of these vehicles are capable of driving safely on their own. A production autonomous vehicle that can go anywhere, anytime isn't available at the local car dealer and won't be for quite some time.

Jermakian recounts her experience with the E-Class on U.S. 33 near the IIHS-HLDI Vehicle Research Center (VRC). Traveling about 55 mph with ACC and active lane-keeping engaged but not following a lead vehicle, the E-Class system briefly detected a pickup truck stopped at a traffic light ahead but promptly lost sight of it and continued at speed until she hit the brakes.

"At IIHS we are coached to intervene without warning, but other drivers might not be as vigilant," Jermakian says. "ACC systems require drivers to pay attention to what the vehicle is doing at all times and be ready to brake manually."

Unnecessary or overly cautious braking is an issue IIHS noted in the Model 3. In 180 miles, the car unexpectedly slowed down 12 times, seven of which coincided with tree shadows on the road. The others were for oncoming vehicles in another lane or vehicles crossing the road far ahead.

"The braking events we observed didn't create unsafe conditions because the decelerations were mild and short enough that the vehicle didn't slow too much. However, unnecessary braking could pose crash risks in heavy traffic, especially if it's more forceful," Jermakian says.

"Plus, drivers who feel that their car brakes erratically may choose not to use adaptive cruise control and would miss out on any safety benefit from the system."

The outlook is promising for the potential safety benefits of ACC. The technology is often bundled with forward collision warning and autobrake, and research by IIHS and HLDI has found crash-reduction benefits for these systems combined. A federally sponsored study found that drivers using ACC have longer, safer following distances than drivers who don't use ACC. Still, IIHS tests indicate that current ACC systems aren't ready to handle speed control in all traffic situations.

Active lane-keeping

Engineers focused on two situations that challenge active lane-keeping systems — curves and hills — in tests on open roads with no other vehicles around. They also observed how the systems performed in traffic.

All five systems provide steering assistance that centers the vehicle within clearly marked lanes. They also may use a lead vehicle as a guide when traveling at lower speeds or when the lead vehicle is blocking the system's view of the lane markers ahead.

To test active lane-keeping on curves, engineers conducted six trials with each vehicle on three different sections of road with radii ranging from 1,300 to 2,000 feet.

Only the Model 3 stayed within the lane on all 18 trials. The Model S was similar but overcorrected on one curve, causing it to cross the line on the inside of the curve in one trial. None of the other systems tested provided enough steering input on their own to consistently stay in their lane, often requiring the driver to provide additional steering to successfully navigate the curve.

The E-Class stayed within the lane in 9 of 17 runs and strayed to the lane marker in five trials. The system disengaged itself in one trial and crossed the line in two. The 5 series stayed within the lane in 3 of 16 trials and was more likely to disengage than steer outside the lane. The S90 stayed in the lane in 9 of 17 runs and crossed the lane line in eight runs.

When trying out new vehicles in hilly Central Virginia, home to the VRC, engineers noted early on that advanced driver assistance systems that rely on seeing road markings to keep vehicles in their lanes were sometimes flummoxed by hills. As a vehicle crests a hill, the lane markers on the road beyond are obscured.

For the on-road tests, engineers mapped out a course that included three hills with different slopes. Drivers made six trial runs on each hill in each vehicle.

The E-Class stayed in its lane in 15 of 18 trials and on the line in one trial, continuously providing steering support without erratic moves when lane lines weren't visible. The Model 3 also stayed in the lane in all but one trial, when it hugged the line.

In contrast, the 5-series, Model S and S90 struggled. The 5-series steered toward or across the lane line regularly, requiring drivers to override the steering support to get it back on track. Sometimes the car disengaged steering assistance on its own. The car failed to stay in the lane on all 14 valid trials.

The Model S was errant in the hill tests, staying in the lane in 5 of 18 trials. When cresting hills, the Model S swerved left and right until it determined the correct place in the lane, jolting test drivers. It rarely warned them to take over as it hunted for the lane center. The car regularly veered into the adjacent lanes or onto the shoulder.

When drivers intervened to avoid potential trouble, the active lane-keeping system disengaged. Steering assistance only resumed after drivers re-engaged Autopilot.

The S90 stayed in the lane in 9 of 16 trials. The car crossed the lane line in two trials and in four trials disengaged steering assistance when it crested hills but automatically re-engaged when the system once again detected the markings.

One issue drivers noted among some of the vehicles was a propensity to follow a lead vehicle into the exit lane in slow-moving traffic, even though the driver intended to stay the course. When a car is traveling too slow to track lane lines, active lane-keeping systems use the vehicle in front as a guide. If the lead vehicle exits, the trailing car might, too.

The evidence for safety benefits of active lane-keeping systems isn't as pronounced as for ACC. Still, the potential to prevent crashes and save lives is large. IIHS research shows that preventing lane-departure crashes could save nearly 8,000 lives in a typical year (see *Status Report*, May 20, 2010). Lane-departure warning systems are associated with an 11 percent reduction in the rates of single-vehicle, sideswipe and head-on crashes of all severities and a 21 percent reduction in the rates of injury crashes of the same types (see *Status Report*, Aug. 23, 2017).

More research before ratings

IIHS continues to run track and on-road tests as it moves toward a consumer rating system for advanced driver assistance systems. Apart from questions about whether the systems perform as drivers expect, one of the many factors to consider is how much of the driving task can safely be handed over to technology without drivers checking out altogether?

"Designers are struggling with tradeoffs inherent in automated assistance," says David Zuby, IIHS chief research officer. "If they limit functionality to keep drivers engaged, they risk a backlash that the systems are too rudimentary. If the systems seem too capable, then drivers may not give them the attention required to use them safely."

Real-world crashes involving vehicles with Level 2 automation demonstrate the matter isn't settled.

"We're not ready to say yet which company has the safest implementation of Level 2 driver assistance, but it's important to note that none of these vehicles is capable of driving safely on its own," Zuby says. "A production autonomous vehicle that can go anywhere, anytime isn't available at your local car dealer and won't be for quite some time. We aren't there yet." ■

Fatal Tesla crash highlights risks of partial automation

The deadly crash of a Tesla Model X on a Mountain View, Calif., highway in March demonstrates the operational limits of advanced driver assistance systems and the perils of trusting them to do all of the driving, even though they can't.

The driver, Walter Huang, had used the "Autopilot" feature continuously in the final 18 minutes and 55 seconds before his car crashed into a highway divider, the National Transportation Safety Board (NTSB) stated in its preliminary report.

The system gave Huang two visual alerts and one auditory alert to place his hands on the wheel during this period. In the final 6 seconds before impact, his hands weren't detected on the wheel, and the Tesla didn't make any emergency braking or steering maneuvers to avert the crash.

The Model X had been following a lead vehicle and traveling in the second lane from the left at about 65 mph 8 seconds before the crash, the NTSB report states. Traffic-Aware Cruise Control was set to 75 mph on the 65-mph highway. At 7 seconds out, the SUV began a left steering movement into the paved gore area dividing the main travel lane from an exit ramp. At 4 seconds out, the Tesla was no longer following the lead vehicle. At 3 seconds out, the SUV accelerated from 62 mph to 70.8 mph before slamming into the barrier at about 71 mph. The Model X rotated counterclockwise, collided with two other cars and caught fire. Huang died of his injuries.

Photo courtesy of S. Engleman

A Tesla Model X struck a barrier in Mountain View, Calif., on U.S. Highway 101 where lanes diverge. The driver had used "Autopilot" for nearly 19 minutes before his fatal crash.

The circumstances are similar to a September 2017 single-vehicle crash in Hayward, Calif., involving a Model S operating on Autopilot. The car struck a lane-separating divider on U.S. Highway 92 and sustained damage similar to what occurs in the IIHS passenger-side small overlap front crash test. The driver was uninjured.

IIHS test drives of the Model S on public roads suggest Autopilot may be confused »

Photo by Florida Highway Patrol investigators

The first fatal crash in the U.S. of a Tesla in "Autopilot" mode occurred in Florida in May 2016. Neither the Model S (above) nor the driver braked for a tractor-trailer crossing the car's path. Several other Tesla crashes have made headlines, including one in Laguna Beach, Calif. (right).

(« *from p. 5)* by lane markings and road seams where the highway splits.

David Aylor, IIHS manager of active safety testing, has logged many miles in a Model S in Autopilot mode. He has observed instances in which the car lost track of lane markings and began to drift or even attempt to run off the road before he intervened. The car has crossed lines without warning the driver to take over.

Aylor points to one YouTube video by a Chicago area driver who filmed himself on a freeway in a Model S with Autopilot engaged. The driver abruptly drops his phone as his car is about to plow into a median barrier as the roadway splits, just as the freeway does in the Mountain View crash.

"For human drivers, road splits like these can be tricky to maneuver," Aylor says. "In this case, Autopilot was controlling the vehicle and it proved no better at avoiding the same mistakes human drivers might make."

IIHS engineers have observed similar issues with Level 2 systems from other manufacturers. These systems are intended for use on limited-access highways with no at-grade intersections.

Some systems can "read" speed limit signs and adjust speeds accordingly, but they aren't programmed to respond to traffic signals. While all Level 2 systems control speed in free-flowing traffic, they vary in their ability to slow or stop smoothly when encountering much-slower moving or stopped traffic.

Other manufacturers' Level 2 vehicles likely have been involved in crashes while drivers were using advanced driver assistance features, but none of them have grabbed headlines like Tesla.

Since the first fatal crash of a Tesla operating on Autopilot in Florida in May 2016, in which a Model S struck a tractor-trailer turning into the car's path, there have been several other high-profile Tesla crashes.

In a May crash in Utah, a Model S driver reportedly ran a red light and struck the back of a firetruck without slowing down.

The driver, who sustained a broken ankle, told police that "she had been using the 'Autopilot' feature in the Tesla" and "admitted that she was looking at her phone prior to the collision," the South Jordan Police Department said in a statement.

Police Sergeant Samuel Winkler added this caution: "As a reminder for drivers of semi-autonomous vehicles, it is the driver's responsibility to stay alert, drive safely, and be in control of the vehicle at all times."

It is good advice for any driver, but especially one who may be lulled into a false sense of security by automated systems that appear to handle parts of the driving task with ease but can quit at any moment.

On May 29, a Tesla operating in Autopilot mode struck a parked police department SUV on Laguna Canyon Road in Laguna Beach, Calif. The Tesla driver sustained minor injuries, local police reported.

The crash occurred in a marked exit lane where vehicles also park. Confusing lane markings may have come into play. ■

Fewer physical damage, injury liability claims for Model S with advanced features

The combined crash avoidance features on the Tesla Model S are reducing third-party physical damage and injury liability claims, while the benefit of adding "Autopilot" is limited to lowering collision claims.

HLDI compared the claims experience of 2014–16 Model S cars equipped with version 1 of Tesla's sensing hardware with the 2012–14 Model S sans the technology. Analysts also examined Model S claims before and after Autopilot was enabled to try to isolate the incremental effects of the system and its related features.

Version 1 hardware supports forward collision warning, automatic emergency braking and blind spot warning. It also supports Autopilot and its associated features, Autopark, Autosteer, Lane Assist and Lane Change. These require an optional upgrade.

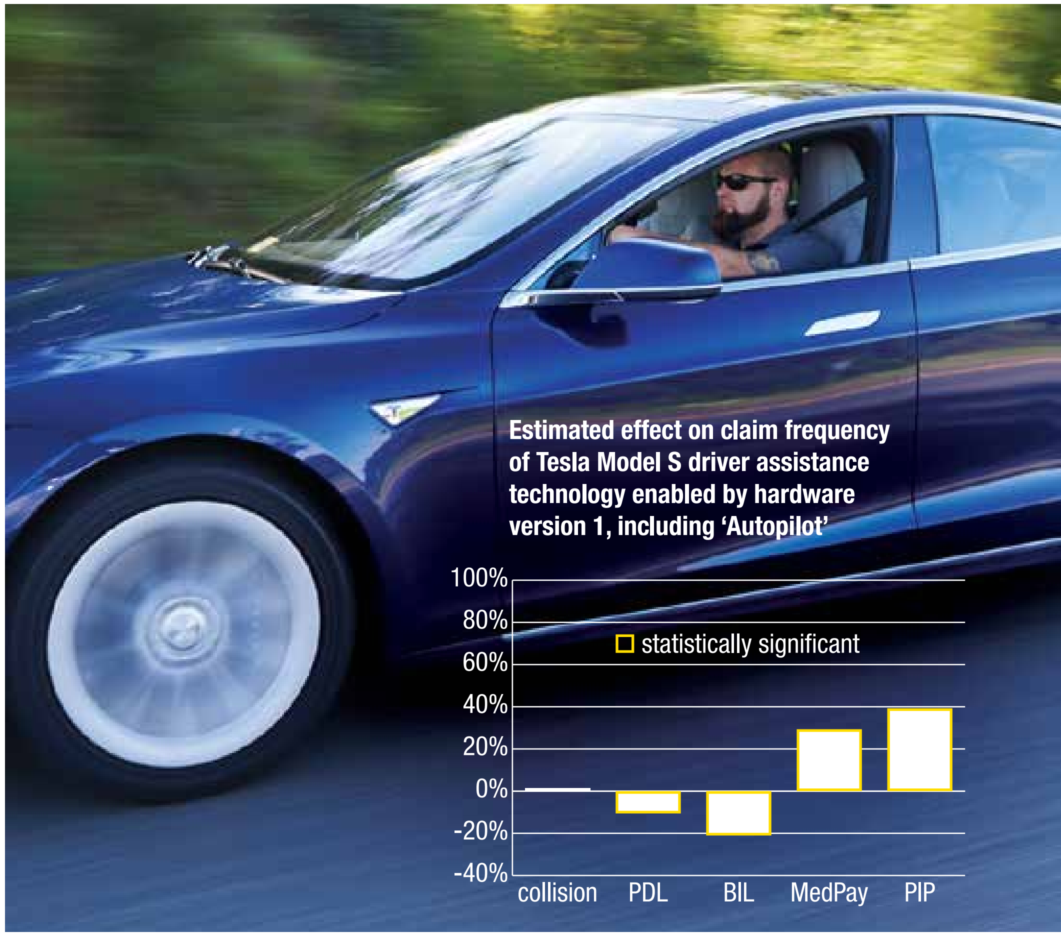
The combined driver assistance features on the 2014–16 Model S lowered the frequency of claims filed under property damage liability (PDL) coverage by 11 percent and the frequency of claims under bodily injury (BI) liability coverage by 21 percent, compared with the 2012–14 Model S without the technology, HLDI found.

PDL coverage pays for damage that an at-fault driver causes to another vehicle. BI pays for injuries that an at-fault driver causes to occupants of other vehicles or others on the road.

Looking at first-party injury coverage types, HLDI found a 29 percent increase in the frequency of claims under medical payment (Medpay) coverage and a 39 percent increase in the frequency of personal injury protection (PIP) claims.

MedPay covers injuries to an at-fault driver or passengers in that driver's vehicle, while PIP coverage is sold in states with no-fault insurance systems. This coverage pays for injuries to occupants of the insured vehicle, no matter who is at fault.

Claim frequency is the number of claims for a group of vehicles divided by the exposure for that group, expressed in the study as claims per 1,000 insured vehicle years for injury claims and per 100 insured vehicle years for physical damage claims. An insured vehicle year is one vehicle insured for one year or two vehicles insured for six months each.



HLDI didn't find a significant effect on the frequency of collision claims for the combined driver assistance features. Collision coverage pays for damage to a driver's vehicle if he or she is at fault in a crash.

The findings for PDL, BI and collision claims are in line with prior HLDI research on forward collision warning, autobrake and blind spot monitoring. For MedPay and PIP, it is unclear why the driver assistance technologies are associated with increased claim frequency.

One hallmark of Tesla models is the ability to wirelessly receive software updates to enable driver assistance and other features if equipped with the needed hardware.

Tesla activated the software for Traffic-Aware Cruise Control, forward collision warning and automatic high beams for models with version 1 hardware, starting in January 2015. Autobrake and blind spot warning were activated in March 2015, followed by Autopilot and its associated systems in October 2015.

Tesla touts Autopilot as a safety upgrade, so HLDI analysts were eager to zero in on the benefits of it alone. However, several things limited their ability to conduct a comprehensive analysis.

Since Autopilot is an optional feature, analysts couldn't discern which vehicles had Autopilot and whether it — and other available driver assistance features — was on at the time of the crash. The limitation forced HLDI to compare losses for the Model S with hardware version 1 before »

(« *from p. 7)* and after Autopilot was enabled instead of comparing vehicles with and without the system over a specific time frame. The pre-Autopilot period included only the nine months of data after Tesla activated forward collision warning and before it enabled Autopilot.

In this limited analysis, HLDI found that the frequency of claims filed under PDL, BI, MedPay and PIP didn't change once Autopilot was enabled, but the frequency of collision claims fell by 13 percent.

"To get a better picture of how Autopilot is affecting claims, we need more data on how many Teslas are equipped with Autopilot and how often it is used," says Matt Moore, HLDI's senior vice president. "The reductions in the frequency of third-party physical damage and injury liability claims associated with Tesla's version 1 hardware are in line with the benefits HLDI has documented for comparable systems from other manufacturers."

Moore adds, "When we evaluated Teslas with the version 1 hardware after the Autopilot software was deployed, we saw a significant reduction in collision claim frequency but no other changes."

For a copy of HLDI Bulletin Vol. 34 No. 30, "Tesla Model S driver assistance technologies," email publications@iihs.org. ■

Fatal Uber crash shows risks of testing on public roads

Self-driving cars are supposed to be better at averting crashes than human drivers, but tests of prototype vehicles on public roads so far indicate that they aren't always up to the task. Absent regulatory oversight, the race to deploy autonomous vehicles risks jeopardizing public trust and safety and the lifesaving promise of the technology.

The National Transportation Safety Board (NTSB) on May 24 issued a four-page preliminary report on the first fatal crash involving a pedestrian and a self-driving vehicle operating under the control of a computer, not a person.

Until the March 18 tragedy, Uber Technologies Inc. had done extensive testing of its fleet of prototype autonomous vehicles in Arizona. That testing has since been shelved in the state.

The details of the March 18 crash in Tempe, Arizona, are by now well-known. What wasn't known publicly until the NTSB report's release, however, is that while an Uber experimental vehicle operating in self-driving mode is capable of detecting impending conflicts, it isn't programmed to brake or warn the test operator to take action.

"According to Uber, emergency braking maneuvers are not enabled while the vehicle is under computer control, to reduce the potential for erratic vehicle behavior," the NTSB report states. "The vehicle operator is relied on to intervene and take action. The system is not designed to alert the operator."

Elaine Herzberg, 49, was walking her bicycle across a four-lane arterial road around 10 p.m. when she was struck by a 2017 Volvo XC90 modified with Uber's sensors and software to operate in autonomous mode. Herzberg had crossed more than three lanes before she was struck by the SUV at about 39 mph. Dash cam video released by Tempe police shows Herzberg didn't look in the SUV's direction until just before it hit her.

In the Uber, the lone test operator at the wheel wasn't watching the road just before impact, according to the NTSB report and the dash cam video. The operator told investigators that she had been monitoring the system interface in the center console. Tempe police in June released a report indicating that the operator's smartphone was streaming a TV show in the 42 minutes preceding the crash.

The NTSB report indicates that the Uber self-driving system first detected Herzberg about 6 seconds before impact, initially classifying her as an unknown object, then a vehicle and then as a bicycle. At 1.3 seconds before impact, the report states, the system "determined that an emergency braking maneuver was needed to mitigate a collision." Less than a second before impact, the test operator took the wheel and started to brake just after hitting Herzberg.

The Uber self-driving system was operating normally at the time of the crash, with no faults or diagnostic messages.

"What's chilling is that the engineers behind Uber's software program disabled the system's ability to avoid a life-or-death scenario while testing on public roads," says David Zuby, the Institute's chief research officer. "Uber decided to forgo a safety net in its quest to teach an unproven computer-control system how to drive."

Autobrake with pedestrian detection

Institute staff have logged more than 80,000 combined highway miles behind the wheels of cars and SUVs equipped with advanced driver assistance technologies to gauge the performance and quirks of each system and how drivers interact with and view them (see *Status Report*, March 29, 2018, and Nov. 10, 2016, at iihs.org).

For the past several years, IIHS and HLDI researchers have studied the crash avoidance technologies that are the precursors of autonomous driving systems, analyzing data in insurance claims and police reports and conducting test track, on-road and lab evaluations (see *Status Report*, Feb. 22, 2018, Aug. 23, 2017, June 22, 2017, Nov. 17, 2016, and Nov. 10, 2016).

The XC90 is among the vehicles IIHS researchers have tested.

Photo courtesy of the National Transportation Safety Board

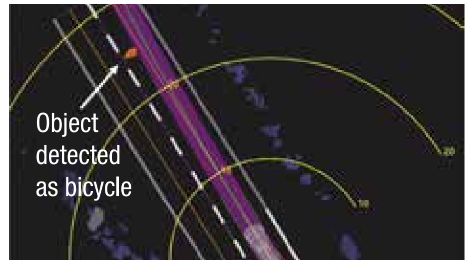


Photo courtesy of the National Transportation Safety Board

At 1.3 seconds before impact, Uber's system determined that emergency braking was needed but took no action, the NTSB found.

The model involved in the Uber crash was equipped with Volvo's automatic emergency braking and pedestrian detection system designed to prevent or mitigate pedestrian crashes. On conventional Volvos, the default is always "on" for the technology.

"The crash avoidance system on the XC90 would have prevented or mitigated this crash, but it was never given the opportunity to intervene or even alert the test driver," Zuby says.

The NTSB report states that "All these Volvo functions are disabled when the test vehicle is operated in computer control but are operational when the vehicle is operated in manual control."

In IIHS tests, the XC90 earns the highest rating of superior for front crash prevention. IIHS doesn't yet rate autobrake systems for pedestrian detection but has done extensive research tests. In 35 mph track tests of an XC90, the Volvo system proved extremely capable of avoiding hitting a pedestrian.

Euro NCAP gave the same pedestrian detection system on a 2017 XC60 high marks for its ability to completely avoid collisions with pedestrians at speeds up to about 37 mph. And a test in the U.K. by Thatcham indicates that Volvo's system is capable of braking for a pedestrian walking a bicycle across the vehicle's path in the dark.

Braking when the Uber's sensors first detected something in the road would have »

Why good headlights matter

The ability for drivers to see the road ahead at night — and other drivers and pedestrians to see oncoming vehicles, too — is an important area of IIHS research that may have come into play in Tempe.

About half of traffic deaths occur either in the dark or at dawn or dusk, and the proportion of pedestrians killed in low light conditions is even greater. It is crucial that drivers, whether human or machine, have a good view of the road at night to drive safely. That is the role of headlights, especially on roads without street lighting.

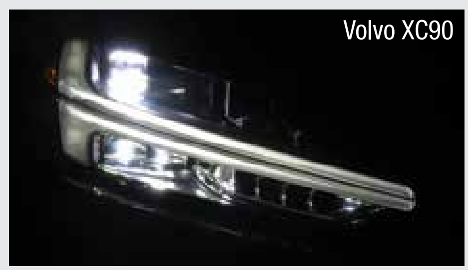
The Uber that struck and killed Elaine Herzberg had a variety of sensors to help it "see" the road and its surroundings. These included light detection and ranging (lidar) sensors, radar sensors and cameras. While lidar and radar sensors don't depend on ambient light to see, cameras, like human eyes, do.

The high-contrast video recorded by the Uber dash camera makes the road appear to be in almost total darkness. The pedestrian was wearing dark clothes, and the bicycle she was pushing didn't have side reflectors. There are streetlights along this section of road, but the crash site wasn't directly illuminated.

According to the NTSB preliminary report, Uber's lidar and radar first detected Herzberg 6 seconds before impact but didn't know what to make of her. It is possible that with better lighting the cameras could have helped confirm she was a pedestrian.

Velodyne Lidar Inc., which supplies the sensors Uber uses, says lidar was capable of detecting a pedestrian with a bicycle, but decisions about whether to brake or take evasive action were left to Uber's software.

The crash involved a specially outfitted 2017 Volvo XC90. Its headlights are rated poor because they don't provide sufficient low-beam light in IIHS evaluations. Good-rated headlights would have illuminated twice as much of the road ahead for an attentive driver. That means extra time to see the pedestrian and act to avoid the crash or lessen its severity.



Crash reports don't indicate whether the XC90's low beams or high beams were in use. The SUV has high-beam assist, which automatically switches between high beams and low beams, depending on the presence of other vehicles. Research shows drivers rarely turn on their high beams. High-beam assist ensures that they do.

"Headlights probably don't come to mind when you think of autonomous vehicles, but they are important safety equipment, and we intend to continue our evaluations to encourage automakers to improve them," IIHS President David Harkey says. ■

(« *from p. 9)* given the system more time to identify Herzberg as a pedestrian and Herzberg more time to finish crossing the road.

"At 6 seconds out, the automated driving system had a range of choices it could make," Zuby says. "Just like humans might ignore something unexpected and unclear moving toward their path, Uber's system didn't react despite sophisticated sensors and artificial intelligence. That's unacceptable. To be better than human drivers, automated systems have to make safer choices."

According to Uber, emergency braking maneuvers are not enabled while the vehicle is under computer control, to reduce the potential for erratic vehicle behavior, the NTSB report states. The vehicle operator is relied on to intervene and take action.

Deadly inattention

In lieu of intervention from an autobrake system with pedestrian detection, an alert human driver may have been able to slow down the vehicle enough to reduce the severity of the crash.

In the dash cam video, the pedestrian appears about 80 feet before impact. A best-case driver reaction time is about one second. At 40 mph the XC90 would have traveled 60 feet before the driver initiated braking at 20 feet, reducing the SUV's speed by roughly 10 mph and the impact speed to 30 mph. The driver still would have struck the pedestrian, but the reduced speed may have raised her chances of survival.

The video shows the Uber operator looking down approximately 9½ seconds of the 12½-second video. At 40 mph, the SUV covered 750 feet during that short period. The driver was distracted for all of the last 5½ seconds, or 330 feet, before impact.

Experimental studies have shown that drivers can lose track of what automated systems are doing, fail to notice when something goes wrong and have trouble retaking control. Some companies require two operators in autonomous vehicles undergoing testing on public roads. Uber had used two operators in earlier road tests but had recently scaled back to one.

"Looking at the center stack takes the operator's eyes off the road," Zuby points out. "Two operators in the vehicle might have allowed one to monitor the system computer and the other to focus on the road ahead." ■

Lax U.S. oversight of industry jeopardizes public safety

A patchwork of state laws and voluntary federal guidelines is attempting to cover the testing and eventual deployment of autonomous vehicles in the U.S. It is a decidedly pro-technology approach that lacks adequate safeguards to protect other road users.

"We don't want to hamstring the development of autonomous vehicles but do want to ensure that all motorists, bicyclists and pedestrians sharing the road are protected," says David Harkey, IIHS president.

"The industry needs to take precautions when operating experimental vehicles on public roads and should share data on crashes, near-crashes and system disengagements with the public," Harkey says.

Beyond issuing policy guidelines (see *Status Report* Nov. 10, 2016, at iihs.org), the National Highway Traffic Safety Administration (NHTSA) hasn't attempted to regulate self-driving vehicles. At the time of this writing, legislation regarding their development, testing and deployment was stalled in Congress.

The U.S. House of Representatives passed the SELF DRIVE Act in September 2017, but the Senate version, dubbed the AV START Act, is on hold. The act would preempt state laws on autonomous vehicles and drastically lift caps on the number of vehicles sold each year that can be exempt from federal safety standards.

A broad coalition of consumer and safety advocates has appealed to Senate leaders not to advance the bill until the National Transportation Safety Board completes its investigations of recent fatal crashes. They say the bill lacks comprehensive safeguards, sufficient government oversight and industry accountability.

The coalition calls for the bill to limit the size and scope of exemptions from federal safety standards, provide for adequate data collection and consumer information, apply safety critical provisions to Level 2 systems, boost funding for NHTSA, ensure access and safety for people with disabilities, and maintain state and local regulations absent federal rules on automated vehicles.

At the same time, an industry coalition of automakers, suppliers, tech firms and other groups is urging swift passage of the bill in the name of safety and mobility.

States forge ahead

As of August, 31 states and the District of Columbia have enacted legislation or taken executive action on driving automation. The laws in 11 of those states authorize a study, define key terms or authorize funding.

Nine states authorize testing, while 11 states and D.C. authorize full deployment. Some states impose substantial restrictions on operators developing, testing and deploying driverless cars on public roads, while others welcome testing and deployment with little legislative or regulatory burden/impediment.

For example, four states require the operator to carry at least $5 million in insurance or surety bond while testing or deploying automated vehicles on public roads. Six states and D.C. authorize testing or deployment without imposing any special financial requirements.

California, Connecticut, Massachusetts, Michigan, New York, Ohio, Pennsylvania and Washington require operators to share a safety plan or assessment and/or some level of data, such as disengagement reports or incident records, with the state regulator. California, Nevada and Pennsylvania also require a testing permit, while New York requires testing under state police supervision.

Laws allowing the operation of automated vehicles initially required a human operator to be present and capable of taking over in an emergency. However, 12 states — Arizona, California and Michigan among them — allow testing or deployment without a human operator in the vehicle, although some limit it to certain defined conditions. Nine states don't always require an operator to be licensed.

Crash data should be public

IIHS has encouraged regulators to require companies to share information about every crash and disengagement of

an automated driving system that occurs during testing on public roads.

IIHS has called on states to advise companies to share this information for every crash involving a vehicle with driving automation when operating in manual mode or automated mode, regardless of severity, and to publicly share the collected data.

"While disengagements of automated driving systems are not as safety-relevant as crashes, they can provide key information concerning the performance and limitations of the technology," IIHS told the Pennsylvania Department of Transportation.

As fully autonomous vehicles deploy, knowing which ones are equipped with automated technology — and which are exempt from federal safety standards —will help policymakers, insurers and researchers understand the safety impact.

To that end, IIHS strongly advises NHTSA to create and maintain a nationwide public database of vehicles with automated driving systems and those exempt from safety standards that is indexed and searchable by vehicle identification number (VIN). Currently, VINs aren't required to encode information about optional crash avoidance and automation features.

New regulations needed

So far, NHTSA has focused on removing regulatory barriers to enable automated driving. The AV Start Act as proposed would require the agency to update the human-specific safety standards to account for self-driving vehicles. Currently, NHTSA grants exemptions on a case-by-case basis.

For example, by law all passenger vehicles must have manual driver controls, but what happens when human drivers are no longer needed to operate vehicles?

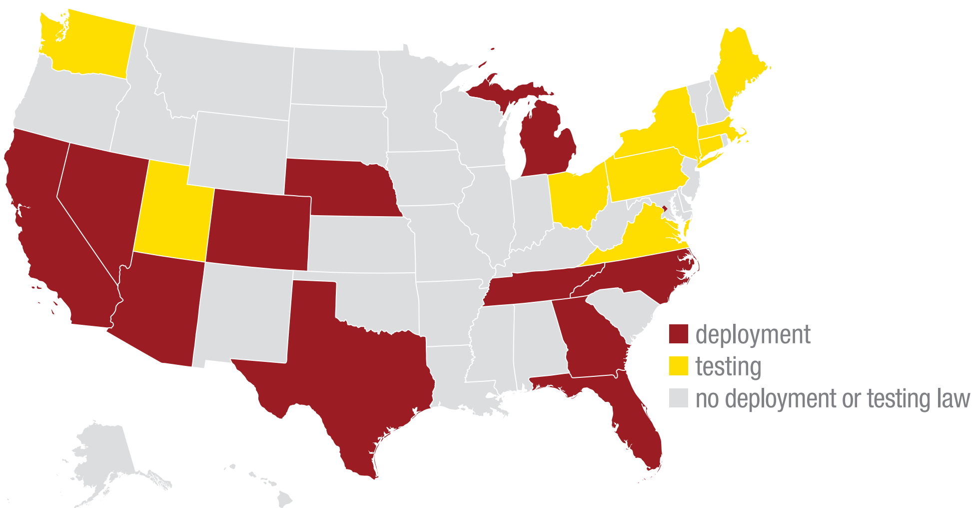
General Motors, for one, hopes to ditch the steering wheel and brake and accelerator pedals in a self-driving Cruise AV to test in a ride-sharing fleet. GM petitioned NHTSA to exempt up to 2,500 of these electric cars from more than a dozen safety standards, including the manual control requirements.

As it weighs which regulations to amend, NHTSA also should consider new ones to ensure that automated driving is safe for all road users. Recording vehicle data is one area that needs to be addressed.

IIHS has asked the agency to require event data recorders to encode information on the performance of automated driving systems in the moments before, during and after a crash. This information would help determine whether the human driver or vehicle was in control and the actions each entity took prior to the event.

In addition, autonomous vehicles should be programmed to take themselves out of service when the status of critical vehicle systems can't support a safe trip. ■

State laws on the operation of automated vehicles on public roads



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