The Evolution of Safety at Toyota - Part 2: Toyota Safety Sense for All

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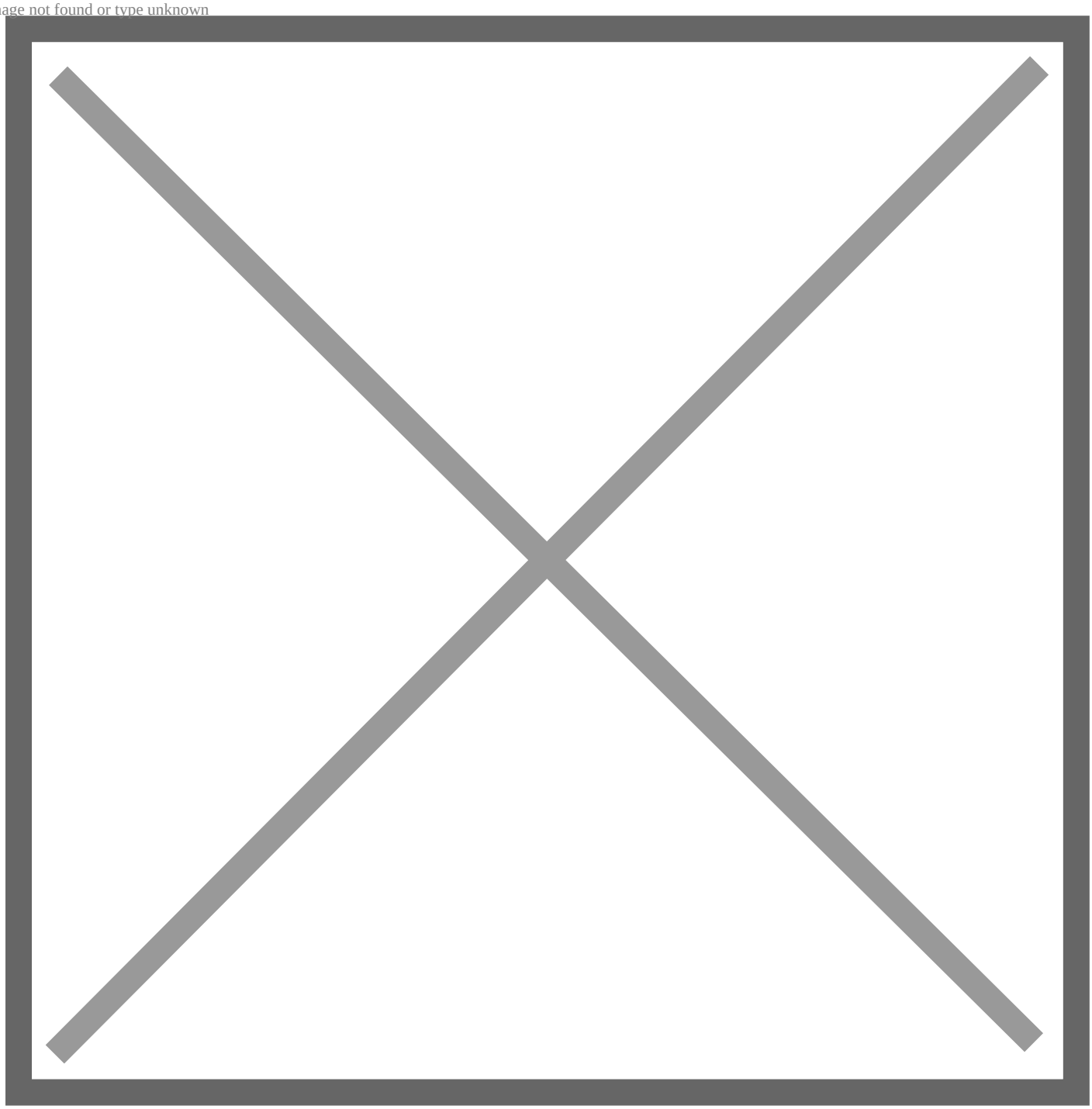
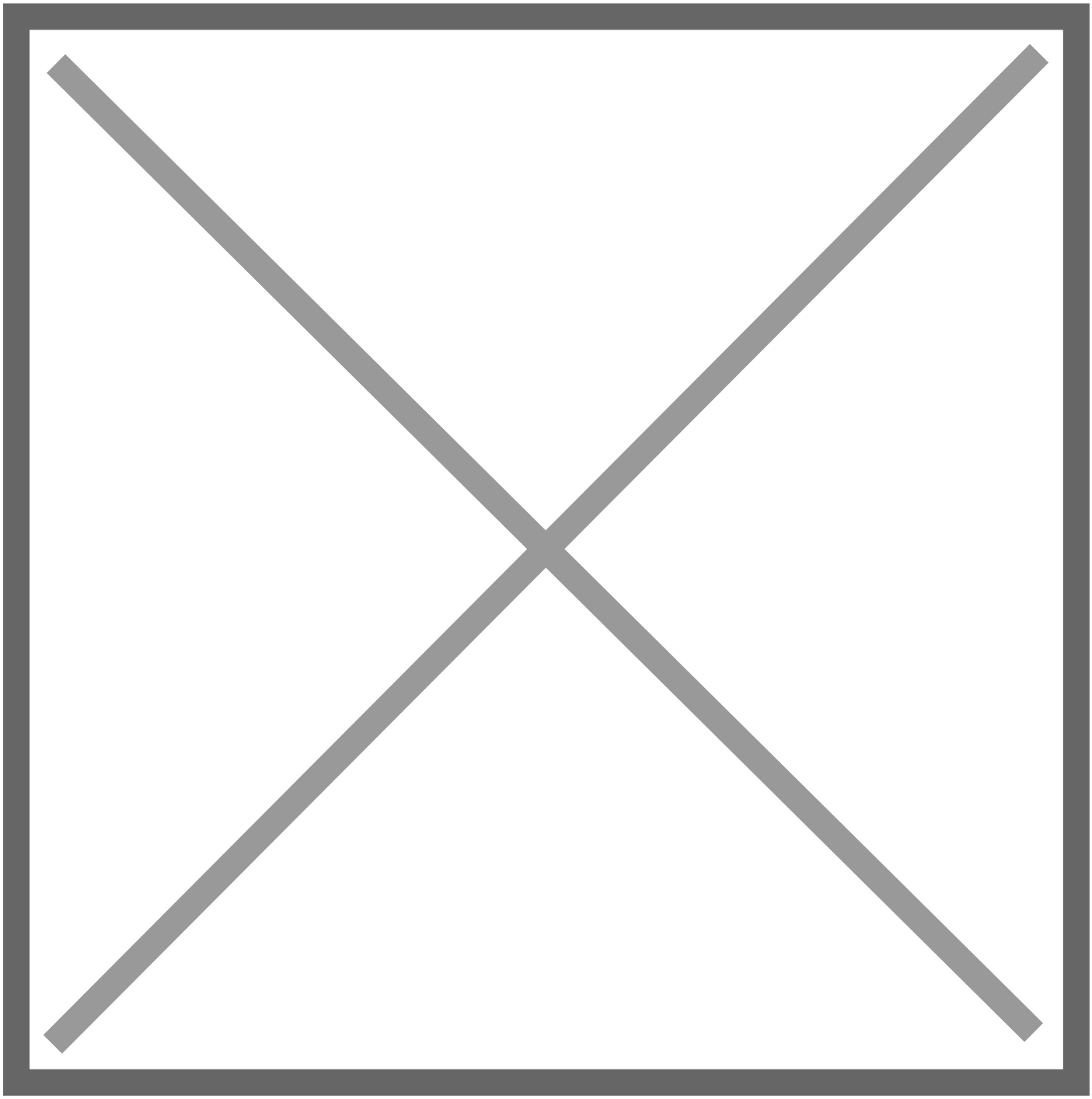


By the time Toyota Safety Sense rolled out in 2015, Toyota had already made decades of safety advancements that were included in its vehicles, including advanced structures, seat belts, and airbags. The first active-safety features, like anti-lock brakes and vehicle stability control, followed soon after.

As Toyota entered the 2010s, dramatic improvements in sensing technology and computing power allowed the company to engage in further development. The equipment needed to make active safety work, like radar and cameras, became smaller, more robust, and more widely available. On-board computer processors became more powerful. Software advanced. It all added up to a leap forward on what cars could do to help mitigate collisions.

This technology enabled Toyota to broaden its safety capabilities to include not only the drivers and their passengers, but other road users as well. By making vehicles more aware of the external environment in real time, Toyota could begin improving safety outcomes for other drivers, pedestrians and bicyclists – others likely to encounter a Toyota car or truck in the real world.

In the years before Toyota Safey Sense (TSS), most Toyota and Lexus models were equipped with the STAR system, a collection of five safety features – Vehicle Stability Control (VSC), Traction Control (TRAC), Anti-lock Brake System (ABS), Electronic Brake-force Distribution (EBD), Brake Assist (BA), and the Smart Stop Technology® (SST). The STAR system had been deployed as standard equipment on new Toyota models when TSS was announced in 2015. TSS uses a forward-facing camera and either a forward-facing radar (TSS-P) or a forward-facing laser (TSS-C) to detect objects, lane markers, and oncoming headlights to help mitigate certain collisions, lane departures, and reduce glare to drivers of oncoming vehicles.

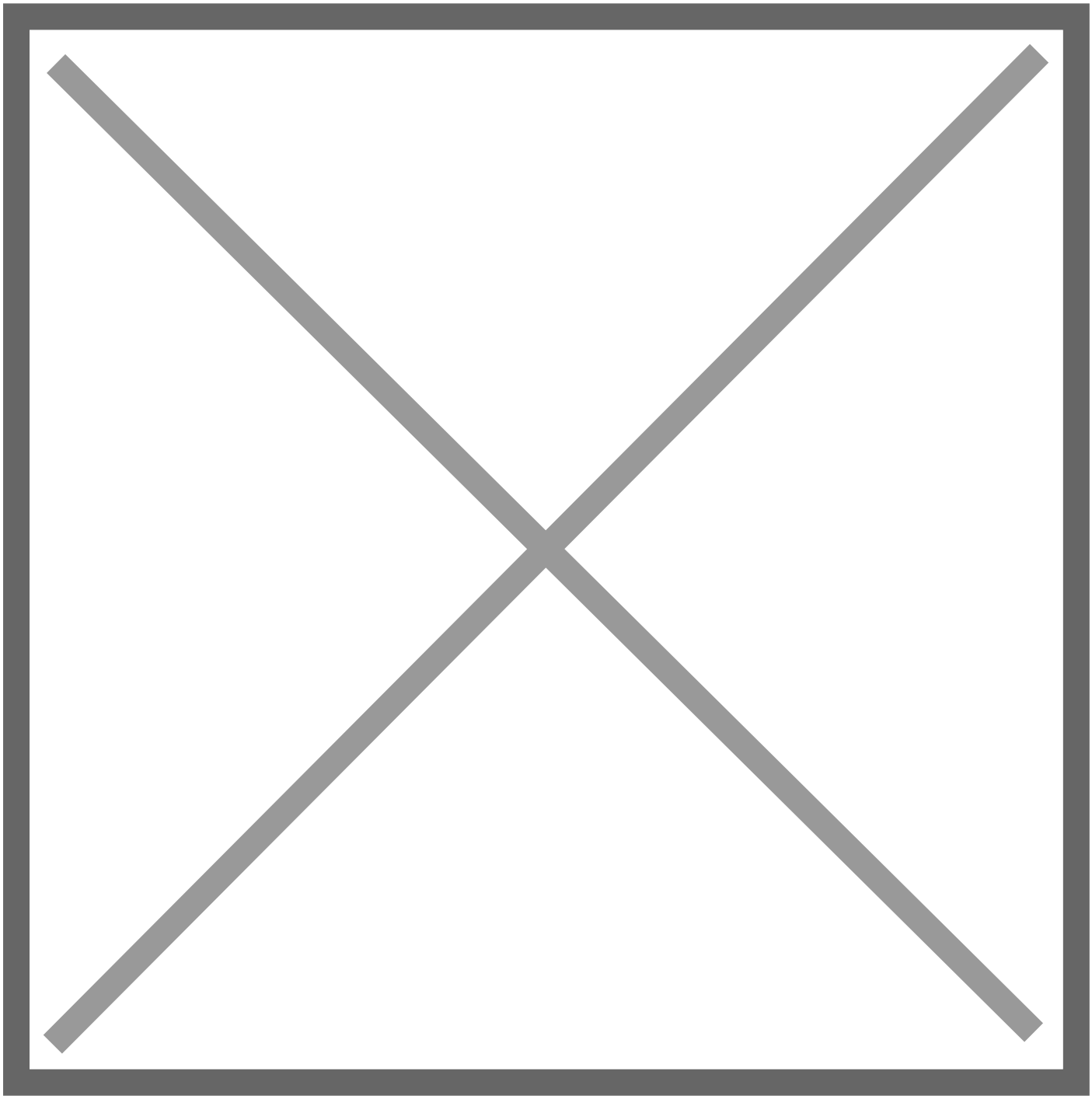


Toyota's Pre-Collision System was the cornerstone of the introductions of TSS-C and TSS-P technology suites.

TSS was introduced on select models in 2015 in 68 countries. It came in two versions: TSS-C for compact cars and TSS-P for mid-sized sedans, minivans, and SUVs. The cornerstone technology was the Pre-Collision System (PCS) that was designed to sense other cars using a camera and either a laser (TSS-C) or a radar (TSS-P). If the car sensed a collision with a preceding vehicle was imminent, the system prompted the driver to brake with alerts. It could also amplify the driver's braking or apply automatic emergency braking (AEB) to avoid or

mitigate the collision under certain conditions.

In these first versions of TSS-C, the Pre-Collision System was designed to apply the automatic emergency brakes in certain emergency situations with other vehicles at speeds as low as 6 mph and as high as 50 mph. TSS-P, adding millimeter-wave radar, enabled crash-mitigation with other vehicles at speeds up to 110 mph. It was also designed to detect pedestrians in daytime conditions up to 50 mph. Both systems also included Automatic High Beam headlamps, and Lane Departure Alert, and TSS-P included Dynamic Radar Cruise Control.

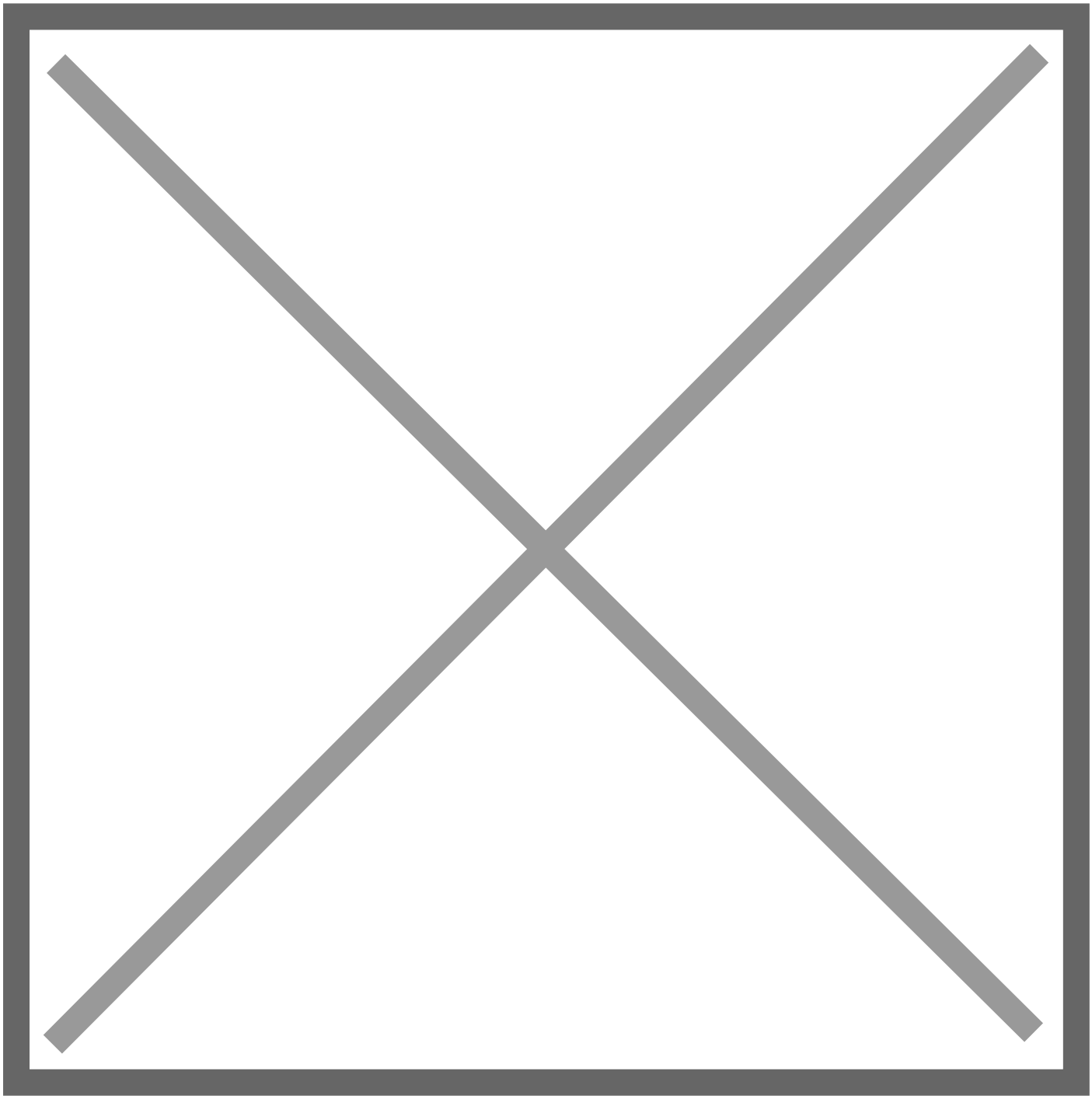


Better sensors like millimeter-wave radar enabled detection of roadside objects at night and in more difficult weather conditions.

The next generation of TSS, TSS 2.0, continued to focus on conditions outside the vehicle with some night-time detection capability for pedestrians and daytime detection of bicyclists. For drivers, it added steering assist functionality and the ability to detect road edges to Lane Departure Alert. Also new was Road Sign Assist.

In versions 2.5, 2.5+ and 3.0, Toyota continued to refine features like PCS. The systems were enhanced further with the ability to detect pedestrians and bicyclists in more situations, like dim lighting and with some capability in turns in intersections. Emergency steering assist was added to enhance the collision avoidance capability for the vehicle and pedestrians during emergency maneuvers around obstacles. With TSS 3.0, Proactive Driving Assist used the front-facing camera and radar to provide gentle braking and steering support on curves and helped the vehicle maintain distance from other vehicles, pedestrians, and bicyclists.

“In the future, we’re hoping to be able to cover more speeds and extend protection to increasingly difficult crash scenarios,” said Derek Caveney, Senior Executive Engineer at Toyota Motor North America.



As TSS continued to evolve, Toyota emphasized making any needed safety interventions feel as natural as possible for a seamless driving experience.

Another important element of TSS is how it feels to the driver. Driver-assistance features that don't seem natural will end up annoying customers to the point that they might disable the technology. That obviously wouldn't help improve safety. To address this concern, Toyota engineers have instilled a culture of discipline around designs that give drivers confidence and earn their trust, said Jarod Duncan of TMNA's Integrated Vehicle

Systems team. Some early developmental versions of pre-collision and lane departure features were more likely to have false activations and weren't as smooth for customers, he said.

"How should the systems behave when I'm in the driver's seat?" Duncan posited. "Is the vehicle reacting naturally? What adjustments can we make to help customers be more confident?"

TSS is an important demonstration of the Toyota Way, said Kevin Ro of TMNA's Carbon Neutrality and Regulatory Affairs team. Respect for people is one of the core tenets of Toyota's philosophy. More than a slogan, the philosophy is applied every day in each team's work.

"Toyota is a research-based company," Ro said. "We're often doing research and getting knowledge from many sources. We go into projects with data to explain our point of view and justify decisions."

This practice of using data as the basis of decisions extends to Toyota's work on safety issues with outside organizations, from regulators like the National Highway Traffic Safety Administration (NHTSA), third-party testing organizations like the Insurance Institute for Highway Safety (IIHS) and independent university researchers. For example, the 14-year-old Collaborative Safety Research Center (CSRC) based in Ann Arbor was created with the goal to advance mobility safety for industry and society through collaborations with universities, hospitals, and other research institutions. The CSRC makes all of its findings public. When dealing with regulators or IIHS, Toyota strives to show up with data and shares its analysis, Ro said.

"Everyone really believes in the culture," Ro said. "That's a part of Toyota culture and is universal: Respect for people.

"Within the company, the Toyota way means that everyone's opinion matters and is valued. That's how the philosophy exists internally. Being transparent with our internal teams provides a way for Toyota to identify issues it might not have known about, which leads to addressing issues that may improve vehicle safety.

"Respect for people is applied outside Toyota too. Safety is part of respect for people. We want our customers to be safe. Each person on our team thinks about their own families being in these vehicles. When they do their work, they take the whole safety aspect very seriously. It runs up and down the company," concluded Ro.

– Story by Jeff Plungis