Collision Between a Sport Utility Vehicle Operating With Partial Driving Automation and a Crash Attenuator
Mountain View, California
March 23, 2018
HWY18FH011

This is a synopsis from the NTSB’s report and does not include the Board’s rationale for the conclusions, probable cause, and safety recommendations. NTSB staff is currently making final revisions to the report from which the attached conclusions and safety recommendations have been extracted. The final report and pertinent safety recommendation letters will be distributed to recommendation recipients as soon as possible. The attached information is subject to further review and editing to reflect changes adopted during the Board meeting.

Executive Summary

On March 23, 2018, at 9:27 a.m., a 2017 Tesla Model X P100D electric-powered sport utility vehicle (SUV), occupied by a 38-year-old male driver, was traveling south on US Highway 101 (US-101) in Mountain View, Santa Clara County, California. At this location, US-101 has six southbound traffic lanes, including a high-occupancy vehicle (HOV) exit lane to State Route 85 (SR-85) southbound on the far left. As the SUV approached the US-101–SR-85 interchange, it was traveling in the lane second from the left, which was an HOV lane for continued travel on US-101.

While approaching a paved gore area dividing the main travel lanes of US-101 from the SR-85 left-exit ramp, the SUV moved to the left and entered the gore. The vehicle continued traveling through the gore and struck a damaged and nonoperational crash attenuator at a speed of about 71 mph. The crash attenuator was positioned at the end of a concrete median barrier. As a result of the collision, the SUV rotated counterclockwise and the front body structure separated from the rear of the vehicle. The Tesla was involved in subsequent collisions with two other vehicles, a 2010 Mazda 3 and a 2017 Audi A4.

The Tesla’s high-voltage battery was breached in the collision and a postcrash fire ensued. On-scene witnesses found the Tesla driver in his seat with his lap/shoulder belt buckled. They removed him from the vehicle before it was engulfed in flames. The driver was transported to a local hospital, where he died from blunt-force trauma injuries. The driver of the Mazda sustained minor injuries, and the driver of the Audi was uninjured.

System performance data downloaded from the Tesla indicated that the driver was operating the SUV using the Traffic-Aware Cruise Control (an adaptive cruise control system) and Autosteer system (a lane-keeping assist system), which are advanced driver assistance systems in Tesla’s “Autopilot” suite. As part of this investigation, the NTSB reviewed its previous investigations involving the Tesla Autopilot system in Williston, Florida; Culver City, California;
and Delray Beach, Florida, to examine common issues regarding the safety of advanced driver assistance systems that provide partial driving automation (both lateral and longitudinal control).

The investigation identified the following safety issues:

- **Driver Distraction.** The Tesla driver was likely distracted by a gaming application on his cell phone before the crash, which prevented him from recognizing that Autopilot had steered the SUV into a gore area of the highway not intended for vehicle travel. The driver was using a company-supplied phone, but his employer, Apple Inc., did not have a policy preventing cell phone use while driving. Strong company policy, with strict consequences for using portable electronic devices while driving, is an effective strategy in helping to prevent the deadly consequences of distracted driving. Additionally, an engineering solution to the distracted driving problem is needed. Electronic device manufacturers have the capability to lock out highly distracting functions of portable electronic devices when being used by an operator while driving, and such a feature should be installed as a default setting on all devices.

- **Risk Mitigation Pertaining to Monitoring Driver Engagement.** The Tesla Autopilot system did not provide an effective means of monitoring the driver’s level of engagement with the driving task, and the timing of alerts and warnings was insufficient to elicit the driver’s response to prevent the crash or mitigate its severity. Requirements are needed for driver monitoring systems for advanced driver assistance systems that provide partial driving automation (SAE Level 2 systems), and Tesla needs to develop applications that more effectively sense the driver’s level of engagement and that alert drivers who are not engaged.

- **Risk Assessment Pertaining to Operational Design Domain.** Crashes investigated by the NTSB continue to show that the Tesla Autopilot system is being used by drivers outside the vehicle’s operational design domain (the conditions in which the system is intended to operate). Despite the system’s known limitations, Tesla does not restrict where Autopilot can be used. Tesla should incorporate system safeguards that limit the use of partial driving automation systems (Autopilot) to those conditions for which they were designed. Additionally, the National Highway Traffic Safety Administration has failed to develop a method for verifying that manufacturers of partial automation systems are incorporating system safeguards that are critical to ensuring the safety of the motoring public.

- **Limitations of Collision Avoidance Systems.** The Tesla’s collision avoidance assist systems were not designed to, and did not, detect the crash attenuator. Because this object was not detected, (a) Autopilot accelerated the SUV to a higher speed, which the driver had previously set by using adaptive cruise control, (b) the forward collision warning did not provide an alert, and (c) the automatic emergency braking did not activate. For partial driving automation systems to be safely deployed in a high-speed
operating environment, collision avoidance systems must be able to effectively detect potential hazards and warn of potential hazards to drivers.

- **Insufficient Federal Oversight of Partial Driving Automation Systems.** The US Department of Transportation and the National Highway Traffic Safety Administration (NHTSA) have taken a nonregulatory approach to automated vehicle safety. NHTSA plans to address the safety of partial driving automation systems through enforcement and a surveillance program that identifies safety-related defect trends in design or performance. This strategy must address the risk of foreseeable misuse of automation and include a forward-looking risk analysis. Additionally, NHTSA should complete a further evaluation of the Tesla Autopilot system to ensure the deployed technology does not pose an unreasonable safety risk.

- **Need for Event Data Recording Requirements for Driving Automation Systems.** Advanced driver assistance systems that provide partial automation collect significant safety relevant data that can be used for crash analysis and risk assessment. Currently, manufacturers provide limited access to this data and there is no standardization of retrievable data parameters. This report describes NTSB’s previous safety recommendations and the inaction of federal regulators to address this important issue area that is needed to foster system safety improvements.

- **Highway Infrastructure Issues.** As part of this crash investigation, the NTSB issued a safety recommendation report addressing systemic problems related to the timely repair of traffic safety hardware in California. Investigators found that on the day of the collision, the crash attenuator at the US-101–SR-85 interchange was in a nonoperational damaged condition because of a previous crash, which had occurred 11 days earlier on March 12, 2018. The Mountain View report briefly summarizes the findings of the safety recommendation report and the actions taken by the state of California to address this safety issue.

**Findings**

1. None of the following were factors in the Tesla driver’s actions in this crash: (1) driver licensing or qualification; (2) familiarization with the vehicle and roadway; (3) medical conditions, fatigue, or impairment by alcohol or other drugs; or (4) weather conditions.

2. The emergency response to the crash was timely and adequate.

3. The Tesla electric vehicle postcrash fire and related damage to the lithium-ion battery presented unusual fire and electrical hazards to first responders.

4. The Tesla’s Autopilot lane-keeping assist system steered the sport utility vehicle to the left into the neutral area of the gore, without providing an alert to the driver, due to limitations of the Tesla Autopilot vision system’s processing software to accurately maintain the appropriate lane of travel.
5. The Tesla’s collision avoidance systems were not designed to, and did not, detect the crash attenuator at the end of the gore, nor did the National Highway Traffic Safety Administration require such capability; consequently, the forward collision warning system did not provide an alert and the automatic emergency braking did not activate.

6. The driver did not take corrective action when the Tesla’s Autopilot lane-keeping assist system steered the vehicle into the gore area, nor did he take evasive action to avoid the collision with the crash attenuator, most likely due to distraction by a cell phone game application.

7. Distracted driving due to portable electronic device use remains persistently high, and additional countermeasures are needed.

8. A technological solution, such as a lock-out function or application that automatically disables highly distracting features of a portable electronic device while driving, is an effective countermeasure for eliminating portable electronic device distraction while driving.

9. Strong company policy, with strict consequences for using portable electronic devices while driving, is an effective strategy in helping to prevent distracted driving crashes, injuries, and fatalities.

10. Although the Occupational Safety and Health Administration has guidelines for companies to reduce motor vehicle crashes by prohibiting the use of portable electronic devices while driving, the guidelines lack specificity, are not widely adopted by companies, and are seldom enforced—limiting their impact in addressing the hazards of distracted driving.

11. The Tesla Autopilot system did not provide an effective means of monitoring the driver’s level of engagement with the driving task.

12. Although the lack of gore area roadway striping at the Mountain View crash location likely did not contribute to the crash, ongoing research led by the Federal Highway Administration can help identify what highway infrastructure changes may be needed in the future to accommodate automated vehicles.

13. The crash attenuator was in a damaged and nonoperational condition at the time of the collision due to the California Highway Patrol’s failure to report the damage following a previous crash and systemic problems with the California Department of Transportation’s maintenance division in repairing traffic safety hardware in a timely manner.

14. If the crash attenuator at the US Highway 101–State Route 85 interchange had been repaired in a timely manner and in a functional condition before the March 23, 2018, crash, the Tesla driver most likely would have survived the collision.

15. Because monitoring of driver-applied steering wheel torque is an ineffective surrogate measure of driver engagement, performance standards should be developed pertaining
to an effective method of ensuring driver engagement in SAE Level 2 partial driving automation systems.

16. If Tesla Inc. does not incorporate system safeguards that limit the use of the Autopilot system to those conditions for which it was designed, continued use of the system beyond its operational design domain is foreseeable and the risk for future crashes will remain.

17. The National Highway Traffic Safety Administration’s failure to ensure that vehicle manufacturers of SAE Level 2 driving automation systems are incorporating appropriate system safeguards to limit operation of these systems to the operational design domain compromises safety.

18. In order for driving automation systems to be safely deployed in a high-speed operating environment, collision avoidance systems must be able to effectively detect and respond to potential hazards, including roadside traffic safety hardware, and be able to execute forward collision avoidance at high speeds.

19. The National Highway Traffic Safety Administration’s approach to the oversight of automated vehicles is misguided, because it essentially relies on waiting for problems to occur rather than addressing safety issues proactively.

20. It is essential that the National Highway Traffic Safety Administration’s surveillance and defect investigation program closely examine issues related to foreseeable misuse of automation and perform a forward-looking risk analysis to identify partial driving automation system defects that pose an unreasonable risk to safety.

21. The National Highway Traffic Safety Administration’s Office of Defects Investigation has failed to thoroughly investigate the Tesla Autopilot design regarding the degree to which drivers are currently misusing the system, foreseeable consequences of continued use by drivers beyond the system’s operational design domain, and the effectiveness of the driver monitoring system in ensuring driver engagement.

22. Vehicle performance data associated with activation and engagement of partial driving automation systems on vehicles involved in crashes are not required nor available on most event data recorders.

23. A standardized set of retrievable data is needed to enable independent assessment of automated vehicle safety and to foster automation safety improvements.

**Probable Cause**

The National Transportation Safety Board determines that the probable cause of the Mountain View, California, crash was the Tesla Autopilot system steering the sport utility vehicle into a highway gore area due to system limitations, and the driver’s lack of response due to distraction likely from a cell phone game application and overreliance on the Autopilot partial driving automation system. Contributing to the crash was the Tesla vehicle’s ineffective monitoring of driver engagement, which facilitated the driver’s complacency and inattentiveness.
Contributing to the severity of the driver’s injuries was the vehicle’s impact with a crash attenuator barrier that was damaged and nonoperational at the time of the collision due to the California Highway Patrol’s failure to report the damage following a previous crash, and systemic problems with the California Department of Transportation’s maintenance division in repairing traffic safety hardware in a timely manner.

Recommendations

As a result of its investigation, the NTSB makes the following nine new safety recommendations:

To the National Highway Traffic Safety Administration:

1. Expand New Car Assessment Program testing of forward collision avoidance system performance to include common obstacles, such as traffic safety hardware, cross-traffic vehicle profiles, and other applicable vehicle shapes or objects found in the highway operating environment.

2. Evaluate Tesla Autopilot-equipped vehicles to determine if the system’s operating limitations, foreseeability of driver misuse, and the ability to operate the vehicles outside the intended operational design domain pose an unreasonable risk to safety; if safety defects are identified, use applicable enforcement authority to ensure that Tesla Inc. takes corrective action.

3. For vehicles equipped with Level 2 automation, work with SAE International to develop performance standards for driver monitoring systems that will minimize driver disengagement, prevent automation complacency, and account for foreseeable misuse of the automation.

4. After developing the performance standards for driver monitoring systems recommended in Safety Recommendation H-20-X, require that all new passenger vehicles with Level 2 automation be equipped with a driver monitoring system that meets these standards.

To the Occupational Safety and Health Administration:

5. Review and revise your distracted driving initiatives to increase employers’ awareness of the need to develop strong cell phone policy prohibiting the use of portable electronic devices while driving.

6. Modify your enforcement strategies to increase the use of the general duty clause cited in 29 United States Code section 654 against those employers who fail to address the hazards of distracted driving.

To SAE International:

7. For vehicles equipped with Level 2 automation, work with the National Highway Traffic Safety Administration to develop performance standards for
driver monitoring systems that will minimize driver disengagement, prevent automation complacency, and account for foreseeable misuse of the automation.

To Manufacturers of Portable Electronic Devices (Apple, Google, HTC, Lenovo, LG, Motorola, Nokia, Samsung, and Sony):

8. Develop a distracted driving lock-out mechanism or application for portable electronic devices that will automatically disable any driver-distracting functions when a vehicle is in motion, but that allows the device to be used in an emergency; install the mechanism as a default setting on all new devices and apply it to existing commercially available devices during major software updates.

To Apple Inc.:

9. Develop and implement a company policy that bans the nonemergency use of portable electronic devices while driving by all employees and contractors driving company vehicles, operating company-issued portable electronic devices, or using a portable electronic device to engage in work-related communications.

Previously Issued Recommendations Reiterated in The Report

As a result of its investigation, the NTSB reiterates the following two safety recommendations (currently classified “Open—Unacceptable Action”):

To the National Highway Traffic Safety Administration:

Develop and apply testing protocols to assess the performance of forward collision avoidance systems in passenger vehicles at various velocities, including high speed and high velocity-differential. (H-15-4)

Develop a method to verify that manufacturers of vehicles equipped with Level 2 vehicle automation systems incorporate system safeguards that limit the use of automated vehicle control systems to those conditions for which they were designed. (H-17-38)

Previously Issued Recommendations Reiterated and Reclassified in The Report

As a result of its investigation, the NTSB reiterates and reclassifies the following five safety recommendations:

To the US Department of Transportation:

Define the data parameters needed to understand the automated vehicle control systems involved in a crash. The parameters must reflect the vehicle’s control status and the frequency and duration of control actions to adequately characterize driver and vehicle performance before and during a crash. (H-17-37)
Safety Recommendation H-17-37 is reclassified from “Open—Await Response” to “Open—Unacceptable Response.”

To the National Highway Traffic Safety Administration:

Use the data parameters defined by the U.S. Department of Transportation in response to Safety Recommendation H-17-37 as a benchmark for new vehicles equipped with automated vehicle control systems so that they capture data that reflect the vehicle’s control status and the frequency and duration of control actions needed to adequately characterize driver and vehicle performance before and during a crash; the captured data should be readily available to, at a minimum, National Transportation Safety Board investigators and National Highway Traffic Safety Administration regulators. (H-17-39)

Safety Recommendation H-17-39 is reclassified from “Open—Acceptable Response” to “Open—Unacceptable Response.”

Define a standard format for reporting automated vehicle control data and require manufacturers of vehicles equipped with automated vehicle control systems to report incidents, crashes, and vehicle miles operated with such systems enabled. (H-17-40)

Safety Recommendation H-17-40 is reclassified from “Open—Acceptable Response” to “Open—Unacceptable Response.”

To Tesla Inc.:

Incorporate system safeguards that limit the use of automated vehicle control systems to those conditions for which they were designed. (H-17-41)

Safety Recommendation H-17-41 is reclassified from “Open—Await Response” to “Open—Unacceptable Response.”

Develop applications to more effectively sense the driver’s level of engagement and alert the driver when engagement is lacking while automated vehicle control systems are in use. (H-17-42)

Safety Recommendation H-17-42 is reclassified from “Open—Await Response” to “Open—Unacceptable Response.”

Previously Issued Recommendations Reclassified in The Report

As a result of its investigation, the NTSB reclassifies the following two safety recommendations:
To the Consumer Electronics Association (now the Consumer Technology Association):

Encourage the development of technology features that disable the functions of portable electronic devices within reach of the driver when a vehicle is in motion; these technology features should include the ability to permit emergency use of the device while the vehicle is in motion and have the capability of identifying occupant seating position so as not to interfere with use of the device by passengers. (H-11-47)

Safety Recommendation H-11-47 is reclassified from “Open—Await Response” to “Closed—No Longer Applicable.”

To the California State Transportation Authority:

Develop and implement a corrective action plan that guarantees timely repair of traffic safety hardware and includes performance measures to track state agency compliance with repair timelines. (H-19-13)

Safety Recommendation H-19-13 is reclassified from “Open—Initial Response Received” to “Open—Acceptable Response.”