U.S. Department
Of Transportation

National Highway
Traffic Safety
Administration

Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems

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EXECUTIVE SUMMARY

The National Highway Traffic Safety Administration (NHTSA) issues this report to present our studies and findings concerning unintended acceleration (UA)[1] in vehicles manufactured by Toyota. This report should be read in conjunction with the report issued by the National Aeronautics and Space Administration (NASA) concerning the electronic throttle control (ETC) system[2] in Toyota vehicles. In March 2010, NHTSA enlisted the support of NASA in analyzing the Toyota ETC system to determine whether it contained any vulnerabilities that might realistically be expected to produce UA in a consumer's use of those vehicles. NASA did not find an electronic cause of large throttle openings that can result in UA incidents. NHTSA did not find a vehicle-based cause of those incidents in addition to those causes already addressed by Toyota recalls.

In addition to enlisting NASA to identify any vulnerabilities in the Toyota ETC system, NHTSA has obtained the services of the prestigious National Academy of Sciences (NAS) to examine the broad subject of UA across the automotive industry, and the safety implications of electronic control systems that are increasingly common in motor vehicles. NHTSA expects to receive recommendations from NAS in the fall of 2011 on how NHTSA might use its research, rulemaking, and enforcement authority to address any such implications identified by the panel.

NHTSA has conducted several investigations into causes of the alleged UA in Toyota vehicles and, in 2010, conducted an additional in-depth study of that subject in connection with the NASA study. This report presents details regarding those investigations, as well as NHTSA's most recent study and results of those efforts. The report concludes by outlining the current and future work that the agency is conducting in an effort to develop countermeasures to ensure that the risk of future fatalities and injuries resulting from UA are minimized. Several potential

[1] In this report, "unintended acceleration" refers to the occurrence of any degree of acceleration that the vehicle driver did not purposely cause to occur. Contrast this with the term "sudden acceleration incident," which refers to "unintended, unexpected, high-power accelerations from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness." *An Examination of Sudden Acceleration,* DOT-TSC-NHTSA-89-1 at v. As used here, unintended acceleration is a very broad term that encompasses sudden acceleration as well as incidents at higher speeds and incidents where brakes were partially or fully effective, including occurrences such as pedal entrapment by floor mats at full throttle and high speeds and incidents of lesser throttle openings at various speeds.

[2] In an ETC system, the vehicle's throttle is controlled electronically based on signals transmitted from the accelerator pedal. In a mechanical system, a physical linkage between the accelerator and throttle controls acceleration.

causes of UA were investigated, including vehicle-based defects, such as mechanical or electrical failures, and other causes, such as electromagnetic interference and pedal misapplication.

Through analysis and investigations, NHTSA identified two types of vehicle-based mechanical defects as causes of UA. Those were related to pedal entrapment and "sticky pedal." At the urging of NHTSA, Toyota has already recalled more than seven million vehicles because those defects could result in UA. To determine whether the scope of the pedal entrapment and sticky pedal recalls was sufficiently broad to include all of the vehicles subject to these defects and to address all vehicle-based causes of UA known to Toyota, NHTSA initiated a recall query (RQ) in February 2010 and analyzed tens of thousands of Toyota documents. NHTSA's examination of the voluminous data did not reveal any previously unknown potential causes of UA.

NHTSA's vehicle characterization analysis and testing supported NASA's review. NHTSA found no previously unknown defects in the test vehicles and determined that their braking systems were capable of overcoming all levels of acceleration, including wide open throttle. As explained in this report, under certain conditions the vacuum assist that helps drivers apply brake pedal force can be diminished; such as by prolonged and repeated rapid use of the brakes. Therefore, where the accelerator pedal is stuck in a high throttle position (as can occur in a pedal entrapment situation), it is possible that brakes can lose their ability to stop a vehicle.

After conducting the most exacting study of a motor vehicle electronic control system ever performed by a government agency, NASA did not find that the ETC electronics are a likely cause of large throttle openings in Toyota vehicles as described in consumers' complaints to NHTSA. NASA found that many safety features are designed into the ETC system to prevent UA and, if faults are detected, to cause the initiation of safe modes of operation that limit acceleration (e.g., limp home, fuel cut strategies). NASA found no flaws in the software code controlling the Toyota ETC system that would cause UA. NASA also found that electromagnetic compatibility (EMC) testing at exposure levels well above current certification standards did not produce an open throttle. NASA found no evidence that any failures of the ETC system had an effect on the performance of the braking system.

NASA's study confirmed that there is a theoretical possibility that two faults could combine under very specific conditions to affect the ETC systems so as to create an unintended UA, but

did not find any evidence that this had occurred in the real world or that there are failure mechanisms that would combine to make this occurrence likely. NASA identified certain aspects of the ETC system that could produce very small throttle openings (less than 5 degrees) that are readily controlled by minimal braking force and pose no appreciable safety risk. NASA also identified certain apparently rare conditions that could lead to a fail safe mode that may involve small, irregular throttle openings in vehicles equipped with potentiometer pedal sensors that experience a particular kind of resistive short circuit. However, in these very rare events, simply releasing the accelerator pedal closes the throttle and the brakes are fully operational. NHTSA does not find these minor, controllable conditions to constitute significant safety risks. Of course, NHTSA will continue to monitor all UA complaints and address any such risks that may emerge.

NHTSA and NASA both reviewed relevant consumer complaints and warranty data in great detail. Both agencies noted that publicity surrounding NHTSA's investigations, related recalls, and Congressional hearings was the major contributor to the timing and volume of complaints. Both also noted that the vast majority of complaints involved incidents that originated when the vehicle was stationary or at very low speeds and contained allegations of very wide throttle openings, often with allegations that brakes were not effective. NHTSA's analysis indicated that these types of complaints generally do not appear to involve vehicle-based causes and that, where the complaint included allegations that the brakes were ineffective or that the incident began with a brake application, the most likely cause of the acceleration was actually pedal misapplication (i.e., the driver's unintended application of the accelerator rather than, or in addition to, the brake).[3]

The results of NHTSA's field inspections of vehicles involved in alleged UA incidents during 2010 supported this analysis. Those vehicle inspections, which included objective evidence from event data recorders, indicated that drivers were applying the accelerator and not applying the brake (or not applying it until the last second or so), except for one instance involving pedal entrapment.

[3] Pedal misapplication is a known cause of unintended acceleration. Perhaps the most tragic example was a July 16, 2003 incident in Santa Monica, California that resulted in 10 fatalities and 63 injuries (occurring over the course of 750 feet of vehicle movement). The National Transportation Safety Board's report on the incident is available at http://www.ntsb.gov/publicIn/2004/har0404.pdf. A more recent report from the board examines pedal misapplication in large vehicles. See http://www.ntsb.gov/publictn/2009/SIR0902.pdf.

However, NHTSA does not have reason to believe that pedal misapplication is a cause of the relatively few, prolonged, high speed UA incidents that present the greatest safety risk. NHTSA believes that those incidents are most likely the result of pedal entrapment by a floor mat that holds the accelerator pedal in an open throttle position.

In summary, the combined work of NASA and NHTSA identified no electronic cause of UA incidents involving large throttle openings and no reason to believe that any failure of the ETC system would affect a vehicle's braking system. Based on NASA's findings, observations, and recommendation and its own work, NHTSA has decided to take several actions aimed at diminishing the risk of UA and strengthening the agency's ability to address current and future issues related to the safety of electronic control systems:

- NHTSA will consider initiating rulemakings on brake override systems, keyless ignition systems, and event data recorders. Brake override systems may prevent or mitigate some UA incidents by ensuring that, when the brake is applied, the braking system has priority over the throttle. NASA observes in its report (Observation O-2) that such a system "provides a broad overarching defense against unintended engine power" from a wide range of causes. Keyless ignition systems can exacerbate UA incidents (particularly prolonged incidents involving a stuck accelerator pedal) if the driver cannot determine how to shut off the engine quickly. Event data recorders can provide crash investigators objective information relevant to UA incidents that result in crashes sufficient to trigger the devices.
- NHTSA will begin preliminary research on the reliability and security of electronic control systems by examining existing industry and international standards for best practices and relevance to automotive applications. In this research, NHTSA will give full consideration to NASA's recommendation that NHTSA consider controls for managing safety critical functions as currently applied to the railroad, aerospace, military, and medical sectors. NHTSA will also give full consideration to NASA's findings and observations as they relate to the use of diagnostic trouble codes in conveying safety-critical information to drivers, safety-critical software design and validation methodologies, and robust fail-safe strategies that protect against two-fault scenarios (including those involving resistive short circuits and latent faults). The agency

anticipates that the NAS panel will offer recommendations on these subjects and wishes to enhance its own understanding of the subject area.

- NHTSA will begin research on the placement of accelerator and brake pedals and driver usage of pedals. NHTSA is interested in learning whether pedal misapplication can be significantly reduced through pedal placement specifications and operational characteristics.
- Along with NASA, NHTSA will brief the National Academy of Sciences panel that is conducting a broader study of UA and electronic control systems to ensure that the panel has the benefit of the work done by the two agencies.
- NHTSA will continue its plans to enhance its knowledge and capabilities in the area of safety-critical vehicle electronics, including electronic control systems, both by ensuring that current staff continues to be well informed on the developing technologies and potential safety issues and by hiring (as agency needs dictate and funding permits) more staff with the necessary expertise.