TRB SPECIAL REPORT

The Safety Promise and Challenge of Automotive Electronics

Insights from Unintended Acceleration

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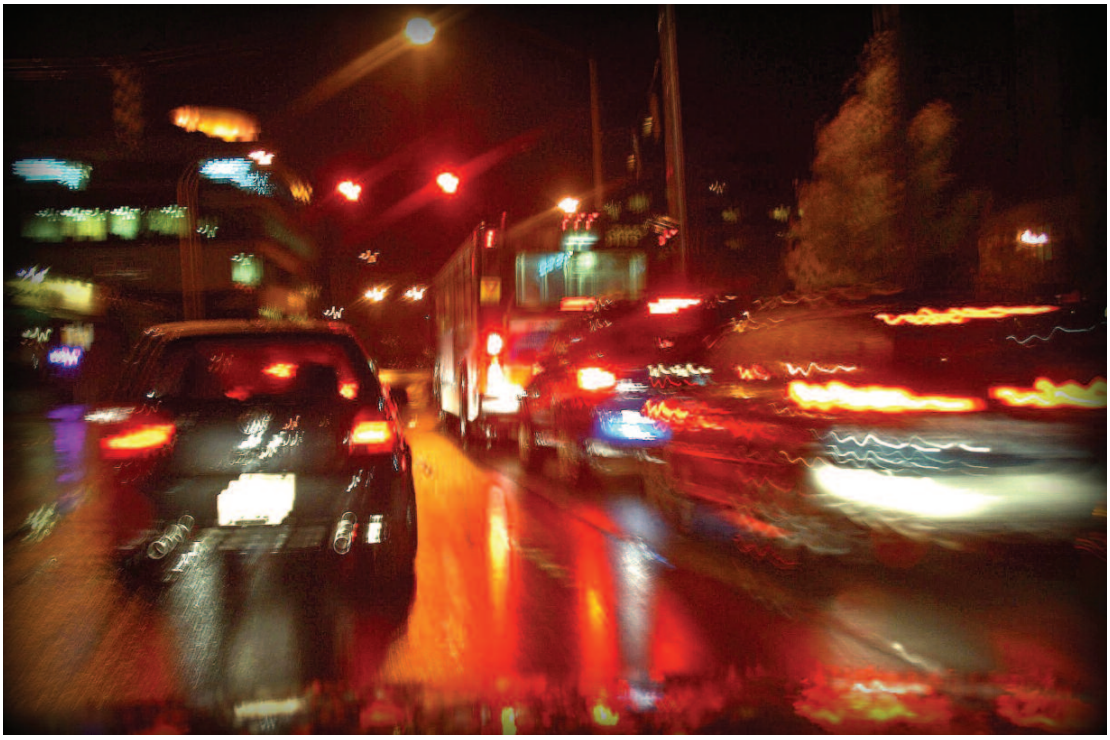

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From summer 2009 through spring 2010, the reports captured national media attention: drivers were claiming that their cars had accelerated unintentionally. The nature of the claims varied. Some involved moving vehicles that did not slow down when pressure on the accelerator pedal was released. Others involved stopped or slowly moving vehicles that sped up abruptly with high engine power. Some drivers described fluctuations in engine idling, hesitation, and shuddering. Others asserted that degraded or failed braking capacity accompanied the unintended acceleration.

Toyota Motor Corporation, whose vehicles were the subject of many of the complaints, issued recalls for millions of vehicles to address accelerator pedals that could be entrapped by floor mats and to fix pedal assemblies that were susceptible to sticking. In the wake of the highly publicized Toyota recalls, many individuals with expertise ranging from human factors to electronics hardware and software offered theories on other possible causes. The electronics in the automobile throttle control system were at the center of many of these theories.

Commissioning Studies

During the peak of the controversy in March 2010, the National Highway Traffic Safety Administration (NHTSA)—the U.S. regulatory agency that oversees federal standards for motor vehicle safety and monitors the fleet for safety defects—enlisted the National Aeronautics and Space Administration (NASA) to conduct an in-depth examination of the Toyota electronic throttle control systems (ETCs), looking for the potential for vulnerabilities in the electronics. NHTSA also requested a National Research Council (NRC) study to review investigations of unintended

acceleration and to recommend ways to strengthen the agency's safety oversight of automotive electronics systems. NRC appointed a 16-member committee of experts under the auspices of the Transportation Research Board (TRB), the Board on Energy and Environmental Systems, and the Computer Science and Telecommunications Board (see box, page 45).

The NRC committee's findings, published in TRB Special Report 308, *The Safety Promise and Challenge of Automotive Electronics: Insights from Unintended Acceleration*, reveal how the electronics systems incorporated into automobiles present many opportunities to make driving safer but at the same time present new demands for ensuring the safe performance of increasingly complex vehicle technologies. The increased demands on safety assurance affect both the automotive industry's development and deployment of electronics systems and NHTSA's fulfillment of its safety oversight role.

The NRC committee recommends that NHTSA give explicit consideration to the oversight challenges that arise from automotive electronics and develop and articulate a long-term strategy for meeting the challenges. A successful strategy would reduce the chances of a recurrence of the kind of controversy that drove NHTSA's response to questions about the relationship between electronics and unintended acceleration. As electronics systems proliferate to provide more vehicle functions, neither industry nor NHTSA can afford such recurrences—nor can motorists.

Investigating Claims

In 2007, NHTSA noted an increase in driver complaints about unintended acceleration in certain Toyota models. NHTSA investigated and attributed the complaints to drivers who inadvertently pressed the accelerator pedal instead of the brake and to pedals that were obstructed by floor mats or that were prone to sticking. NHTSA's investigations did not uncover any reason to suspect faulty electronics in the vehicles' ETCs as the cause. The conclusions led NHTSA to decide against more in-depth investigations of possible faults in the ETCs of the Toyota vehicles that were recalled for pedal entrapment and sticking.

Questions about the decision persisted, however, leading to the requests for the NASA and NRC studies. In its detailed analysis, the NASA team of engineering and safety specialists concluded that vulnerabilities and faults in the ETC did not present a plausible explanation for the high-power unintended acceleration reported in consumer complaints. The NASA investigators confirmed NHTSA's conclusion that the ETC could not disable the brakes or cause the immediate and catastrophic loss of braking capacity, as reported by many of the drivers who had experienced unintended acceleration.

Without evidence of a safety-related defect in Toyota's ETC, NHTSA elected to close its investigation into this system as a suspected cause of high-power unintended acceleration. The agency affirmed its earlier conclusions that cited pedal misapplication, entrapment, and sticking as the likely causes.

Through NASA's work, the causes of unintended acceleration by Toyota vehicles are clearer today than they were in 2010. Nevertheless, whether the technical justification for suspecting electronics systems in this particular instance warranted the attention given, including the commissioning of the detailed NASA study, deserves consideration because of the potential for electronics systems to be implicated in yet other safety issues.

Needed Oversight Capacity

The NRC study focused on how NHTSA can strengthen its regulatory, research, and defects investigation programs to meet the safety assurance and oversight challenges that arise from the expanding functionality and use of automotive electronics. The committee gave special consideration to NHTSA's responses to the concerns about errant electronics as a possible cause of reported cases of unintentional acceleration. The committee examined NHTSA's initiatives and reviewed the programs more generally, and examined the agency's effectiveness in overseeing the safe performance of automotive electronics.

The committee found NHTSA's decision to close the investigation justified, citing the agency's initial investigations, corroborated by follow-up analyses of thousands of consumer complaints, examinations of event data recorders in vehicles suspected to have crashed because of unintended acceleration, and the findings from the NASA study. The committee raises concern, however, that NHTSA could not answer convincingly the questions about the safety of the electronics systems that some had associated with unintended acceleration.

ETCs are simple and mature technologies com-

PHOTO: DAVID SADDLER

In 2007, when NHTSA investigated the unintended acceleration of some models of Toyota vehicles, driver error and pedal obstruction were determined to be the likely causes.

PHOTO: WADE BARTLETT, WIKIMEDIA COMMONS

Downloading information from an event data recorder after a crash. The increased use of electronics systems in automobiles creates opportunities to improve performance and safety, as well as to diagnose and remedy problems.

pared with the newer electronics systems in development. The deployment of more complex and interacting electronics systems increases the prospect that vehicle electronics will be suspected and possibly implicated in unsafe vehicle behaviors.

The committee recommends actions that can help NHTSA prepare for the needed capacity to detect possible defects in complex electronics systems, assess the causes, propose remedies with confidence, and make prudent decisions about when to seek technical assistance from outside experts, such as NASA.

Safety Assurance Challenges

The committee noted that electronics systems are critical to the functioning of the modern automobile. Proliferating and increasingly interconnected electronics systems are creating opportunities to improve vehicle performance, safety, and reliability, and to address system safety and cybersecurity. By introducing many new vehicle capabilities and changing many familiar driver interfaces, electronics systems present challenges for system design. Through site visits to several automotive manufacturers, the committee learned about the many processes built into product design, development, and manufacturing to ensure that electronics systems function safely and interact effectively with drivers.

Nevertheless, with the growth of automotive electronics, NHTSA's Office of Defects Investigation (ODI) can expect to devote an increasing amount of time and resources to recognizing and investigating potential defects involving electronics systems and to assessing the corrective actions proposed by manufacturers for recalls involving these systems. Failures associated with electronics systems may be related to software programming, dual and intermittent electronics hardware faults, and electromagnetic disturbances—these may not leave physical evidence to aid investigations into observed or reported unsafe vehicle behaviors.

Similarly, the contributing causes of many errors by drivers using or responding to new electronics systems may not leave a physical trace. The absence of physical evidence has complicated investigations of incident causes—such as the causes of unintended acceleration—and may become more problematic for ODI as the number, interconnectivity, and complexity of electronics systems grow.

A challenge facing NHTSA is to further the use and effectiveness of electronics technologies to aid safe driving and mitigate hazardous behaviors—and to ensure that the technologies perform as intended. NHTSA regularly updates a multiyear plan that explains the rationale for its near-term research and regulatory priorities. The plan, however, does not address strategic considerations, such as developing new capabilities for the regulation, research, and surveillance and investigation of defects related to the safety of the electronics-intensive vehicle.

Standards and Expertise

As vehicles become more dependent on electronics systems for critical functions, NHTSA's regulatory, research, and investigation programs will need to keep pace with the safety demands. The committee's recommendations are intended to support the industry's efforts to ensure the safe performance of vehicle electronics systems and to strengthen NHTSA's ability to identify and respond to safety problems arising from deficiencies in the systems.

The committee recommends that NHTSA become more familiar with and engaged in standard-setting and other efforts involving industry, to strengthen the means by which manufacturers ensure the safe performance of electronics systems. Through such cooperative efforts, NHTSA can extend its understanding of how manufacturers seek to prevent safety problems and can help agency personnel gain technical knowledge about the electronics systems being added to vehicles and the strategies manufacturers use to ensure

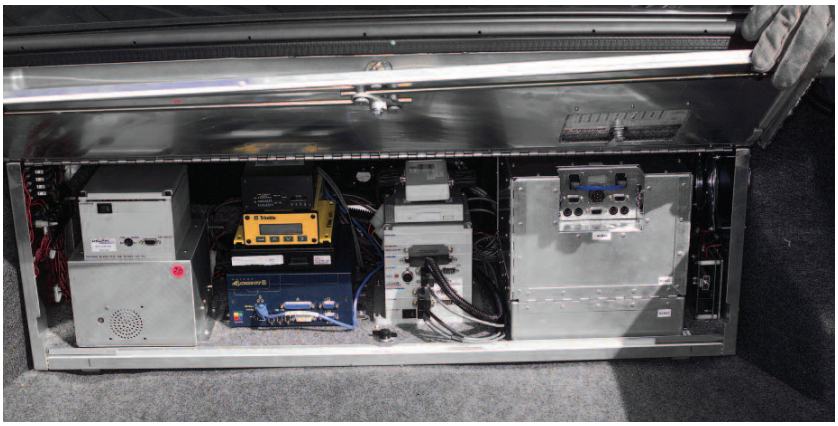

PHOTO © GENERAL MOTORS

A General Motors study in 2003 tested forward collision warning and adaptive cruise control technology. The NRC study committee recommended that NHTSA collaborate with industry in human factors research to examine system capabilities and interface design.

safe operation. The committee recommends that NHTSA collaborate with industry in conducting human factors research to inform manufacturers' decisions about the design of system interfaces that enhance safe performance by the driver.

To obtain access to additional technical expertise, the committee recommends that NHTSA convene a standing technical advisory panel comprising individuals with backgrounds in the disciplines central to the design, development, and safety assurance of automotive electronics systems, including software and systems engineering, human factors, and electronics hardware. NHTSA would consult the expert panel on technical matters that arise in any of the agency's vehicle safety programs, including regulatory reviews, defect investigations, and research needs assessments.

The committee recommends that NHTSA undertake a comprehensive review of the capabilities that ODI will need in monitoring and investigating safety deficiencies in electronics-intensive vehicles. The review should consider the use of agency research to strengthen ODI's capabilities, particularly the detail, timeliness, and analyzability of consumer complaints and early warning data that are important in defects surveillance and investigation.

The committee recommends that NHTSA strive to make electronic event data recorders commonplace in all vehicles; these can assist ODI investigators in determining the causes of vehicle crashes. The utility and feasibility of equipping vehicles with more advanced recording systems that can log a range of data deserve further study.

Strategic Planning

The committee concludes that NHTSA needs to give explicit consideration to how developments in automotive electronics are creating new safety challenges that will necessitate changes in the scope, direction, and capabilities of agency regulatory, research, and defect investigation programs. Accordingly, the committee recommends that NHTSA initiate a strategic planning effort to identify the safety challenges arising from vehicle electronics and to develop an agenda for meeting the challenges.

The committee states that the planning should be (*a*) prospective in considering the safety challenges arising from the electronics-intensive vehicle, (*b*) introspective in considering the implications of these challenges for NHTSA's vehicle safety role and programs, and (*c*) strategic in guiding critical decisions concerning the most appropriate regulatory approaches and the associated requirements for research and resources.

The committee further recommends that NHTSA's next three-year plan include the development and completion of the strategic plan as a priority. NHTSA should communicate the purpose of the planning effort, define its development and implementation in accordance with the committee's advice, and establish a definite schedule for completion. The plan should be made public, because it will guide key policy decisions—from budgetary to legislative—that will determine the scope and direction of the agency's vehicle safety programs.

The long-term importance of strategic planning is obvious: the technological transformation of the automobile will continue, and being prepared is preferable to reacting to the safety concerns that will arise. The committee observes that NHTSA researchers are working with the automotive industry, universities, and other government agencies to examine crash avoidance concepts, such as vehicle-to-vehicle and vehicle-to-infrastructure communications systems. These systems will enable greater vehicle autonomy and necessitate advances in vehicle electronics well beyond the systems now being deployed. Ongoing strategic planning will position NHTSA to meet the safety demands likely to accompany technological advances.

Acknowledgments

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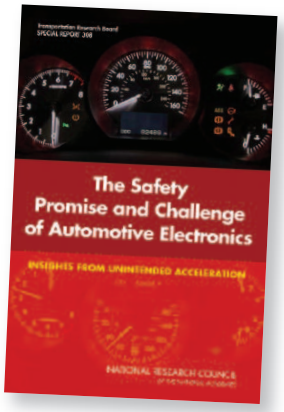

TRB Special Report 308, *The Safety Promise and Challenge of Automotive Electronics: Insights from Unintended Acceleration*, is available from the TRB online bookstore, www.trb.org/bookstore; to view the book online, go to http://onlinepubs.trb.org/onlinepubs/sr/sr308.pdf.