An Examination of the National Highway Traffic Safety Administration and the National Aeronautics and Space Administration Engineering Safety Center Assessment and Technical Evaluation of Toyota Electronic Throttle Control (ETC) Systems and Unintended Acceleration

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Executive Summary

This report is an examination of *Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems* and *Technical Support to the National Highway Traffic Safety Administration on the Reported Toyota Motor Corporation Unintended Acceleration Investigation*, released by Secretary of Transportation Ray LaHood on February 8, 2011. Our response has been months in the making – in part, because we wanted to interview experts in the scientific and vehicle electronics community for their assessments. But the delay is primarily because the National Highway Traffic Safety Administration (NHTSA) has made it extremely difficult for any independent expert or organization to determine how NHTSA and its contract agency, the NASA Engineering and Safety Center (NESC), reached its conclusions. NHTSA did not release the report to the public before the press conference, and many areas were redacted or unavailable, so reporters could not question its specific contents. Secretary LaHood mischaracterized its findings as an exoneration of Toyota's electronics in a colorful, quote-worthy fashion, and then later publicly complained that his critics had not read the report. And, the twin reports' supporting materials have been released quietly and slowly, months after the conclusions.

Here is a brief summary of our findings:

- The NESC report shows that Toyota's main defense in previous unintended acceleration investigations is false. The team found scenarios in which engine speed can be increased, RPMs can surge, and the throttle can be opened to various degrees in contradiction to the driver's command and not set a Diagnostic Trouble Code (DTC).
- The NESC team found several ways that Toyota's electronic throttle control system could cause a UA event. Among those was one real-world cause of electronic malfunction in some Toyota vehicles: tin whiskers in the Accelerator Pedal Position Sensor (APPS) of potentiometer-type pedals. Tin whiskers are hair-like structures which can cause electrical shorts. The team found the presence of this well-known electronics phenomenon in virtually every potentiometer accelerator pedal assembly inspected. They linked it to a real-world complaint of a UA event. This suggests that the presence of tin whiskers is widespread and deserves further study.
- The NESC team uncovered numerous design inadequacies in Toyota's electronic architecture, but failed to probe them any further to discern how these deficiencies fit into the problem of unintended acceleration.

- The NESC report is not a thorough inquiry into unintended acceleration in Toyota vehicles. It is a collection of observations on the narrow question of: How could Toyota's ETCS-i open the throttle without driver input and without setting a Diagnostic Trouble Code? Even as a tightly circumscribed study, the report fails to probe the critical role of torque in oft-described scenarios in which drivers report that braking failed to overcome the throttle. The team did not address the interplay of other important torque requestors.
- Any circumstance or incident involving an unintended acceleration outside of the narrow definition was not considered by these investigators – even though many such complaints exist.
- These reports are not the products of independent and disinterested investigators. They have been directed by an agency that has exonerated Toyota's electronics in the past and has relied solely on the automaker's representations. (A detailed review of the NHTSA investigations can be found in Safety Research & Strategies' prior reports.[1] [2] [3]) Toyota was heavily involved in guiding the research of both reports.
- NHTSA relied on Exponent, a science-defense firm specifically retained by Toyota's counsel for the purpose of defending the company against a class-action lawsuit, to perform an analysis of warranty claims without identifying Exponent as the source of the analysis. This analysis was used by NHTSA and NESC investigators to dismiss the significance of tin whiskers – the physical evidence they discovered in potentiometer-type pedals.
- The NESC and NHTSA teams did not engage independent engineers with expertise in vehicle engine management design, validation and testing to assist them in evaluating Toyota's system. This knowledge gap rendered them unable to challenge the assertions of Toyota and Exponent.
- The data do not support NHTSA and NESC's claim that media hype is responsible for generating a surge of baseless UA reports. An independent analysis shows that prior to any news reports, owners of Camrys equipped with ETCS-i reported UA at significantly greater rates than owners of Camry vehicles without ETCS-i.

As we have maintained from the outset, unintended acceleration in Toyota vehicles is a problem that results from a number of root causes – and it is generally a rare event. It is *not* the most pressing safety issue facing the agency or the motoring public, but it is very significant because thousands of motorists have reported problems and Toyota's mechanical remedies appear to address only a narrow segment of UA events. On August 28, 2009, when a California Highway Patrolman and his family died in a very public crash blamed on unintended acceleration NHTSA was ill-prepared and policy was overtaken by politics. We do not know the total cost of this effort, but it seems fair to say that the agency has devoted a significant chunk of limited resources to addressing this issue. These reports, while outlining some very serious deficiencies in Toyota's

[1] Toyota Sudden Unintended Acceleration**;** Safety Research & Strategies; Feb. 5, 2010
[2] Report Addendum: Exclusion of Camry Deaths Hamper Later Investigation; Safety Research & Strategies; Feb. 17, 2010
[3] Update Report: Toyota Sudden Unintended Acceleration; Safety Research & Strategies; Oct. 25, 2010

electronic architecture, have not accomplished that goal. Rather, they have left many open questions about Toyota's electronics, potential root causes of unintended acceleration, and above all, the agency's lack of a regulatory baseline for safety-critical electronics, its investigative process and its independence.

Replication is the heart of the scientific process. Yet the NHTSA and NESC reports do not permit a real peer review. Many areas have been redacted – including some that serve no legitimate protection of business secrets – NHTSA's stated reason for the many black-outs. Its data analyses did not employ standard statistical methodologies. Important information about the processes NHTSA and NESC employed remain shrouded. Their conclusions can not be fully and scientifically examined, and therefore, cannot be accepted as definitive.

If unintended acceleration is a rare problem, why does Toyota matter? Its relative infrequency does not render it a harmless "drivability" problem. A vehicle that a driver cannot control or that reacts in unexpected ways is a danger to drivers, passengers and pedestrians – and all three have died during UA events – some of which have no known or plausible mechanical or driver induced explanation. The government effort to find answers for this stubborn problem has laid bare large gaps in the agency's core competencies. NHTSA's well-honed ability to ferret out mechanical problems did not serve it well in investigations centering on electronic systems. Its past inspections of vehicles that have experienced UA events and NHTSA's vehicle characterization study show that the agency does not know what to do after completing a physical examination of the mechanical components and running a basic computer scan of the engine management system. Federal investigators must display more diagnostic sophistication than the average automotive technician and possess the ability to challenge the assertions of its target. They must thoroughly understand the designs and the vehicle mitigation testing needed to determine the safe performance of these systems.

Finding the root causes of Toyota unintended acceleration and determining an appropriate countermeasure has implications for all rulemakings and defect investigations involving automotive electronics going forward. The era of solely mechanical and safety-critical primary vehicle functions – opening the throttle, applying the brakes, steering – is swiftly passing into history. The federal agency tasked with regulating this transition and reducing hazards as automakers innovate away from cables to computers must not be compromised by a lack of knowledge. As we have discovered from Toyota unintended acceleration investigations stretching from 2003 to today, automakers can exploit this technical ignorance at the expense of consumers and public safety. The Secretary of Transportation's assertion that electronics have been ruled out sets the stage for ill-advised policy that harms motorists and shifts vehicle design problems from the automaker to the driver, who must compensate for poor engineering.

In the meantime, electronics remain a largely unregulated area of vehicle safety, even as they dominate vehicle systems fleetwide. Seven years ago, NHTSA abandoned its effort to upgrade the 1972 Federal Motor Vehicle Safety Standard 124 Accelerator Controls, after the auto industry protested. In 2004, the agency said that it would resume rulemaking after more study, but no further action has been taken. The Toyota unintended acceleration problem presented the agency with a rare chance to devote time and money to understanding, as Secretary LaHood said, "getting into the weeds" of vehicle electronics – to understand its operational nuances and potential for unanticipated failure modes. These reports do not provide evidence that the agency has made the most of this opportunity.

Introduction

On February 8, the National Highway Traffic Safety Administration (NHTSA) released two reports in a tightly controlled media event. The press conference featured Secretary of Transportation Ray LaHood, who declared in no uncertain terms that "the verdict is in. There is no electronic-based cause for unintended, high-speed acceleration in Toyotas."[4] The content of these documents do not support this claim, although LaHood went on to repeat it, with even more conviction, in other venues.

The first report written by the NHTSA staff, *Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems*, drew less optimistic conclusions than the Secretary of Transportation.[5] It nonetheless characterized the NHTSA-NESC effort as "the most exacting study of a motor vehicle electronic control system ever performed by a government agency."[6] The second report, *Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation*, was authored by the National Aeronautics and Space Administration's (NASA) NASA Engineering and Safety Center (NESC) under a time- and resources-limited contract to NHTSA.[7]

It did not exonerate Toyota's electronics.

In fact, this report uncovered numerous deficiencies in Toyota's engine systems. It showed how faults *could* result in an uncommanded open throttle, without the engine computer taking note and setting a Diagnostic Trouble Code (DTC). This document also more clearly delineated the difficulties in isolating the causes of such a complex multi-root cause problem:

> "Due to system complexity which will be described and the many possible electronic hardware and software systems interactions, it is not realistic to attempt to 'prove' that the ETCS-i cannot cause UAs. Today's vehicles are sufficiently

[4] U.S. Department of Transportation Releases Results from NHTSA-NASA Study of Unintended Acceleration in Toyota Vehicles; National Highway Traffic Safety Administration (NHTSA); Press Release; Feb. 8, 2011
[5] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; National Highway Traffic Safety Administration (NHTSA); Feb. 2011
[6] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. vii; National Highway Traffic Safety Administration (NHTSA); Feb. 2011
[7] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

> complex that no reasonable amount of analysis or testing can prove electronics and software have no errors. Therefore, absence of proof that the ETCS-i has caused a UA does not vindicate the system."[8]

The NESC report, however, is much less than the sum of its parts. *Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation* is essentially a collection of observations – exploring a selection of the elements related to the problem, but concluding very little. From the Vehicle Owner Questionnaire complaint analyses to the technical assessments, the NESC team, under NHTSA's direction, appeared to look past the data. A failure modes and effects analysis (the backbone of NASA's reliability fault detection approach) was never conducted. It did concede that a malfunction of Toyota's Electronic Throttle Control System could result in an unintended acceleration event, but that the likelihood of electronically induced UA was low. Potential failure mechanisms across the complete electronics systems were never identified. Indeed, the probability of a UA event in an individual vehicle may be low. Unstated, but critically more important, is the number of unintended acceleration events happening within a fleet of millions of vehicles. When the problem is re-framed, even a low probability may affect thousands of vehicles.

It is not surprising that NESC issued no criticisms of Toyota electronics. *Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation* is part of a political response to the calls for action generated by the media and Congressional hearings, after eight failed defect investigations and a high-profile death of a California Highway Patrol officer and his family. It represents an answer to critics of NHTSA's handling of the Toyota UA problem, illustrating the agency's willingness to consider third-party research related to the issue.

However, these reports are not the result of independent investigation. The NESC effort was a work for hire, paid by its client NHTSA, and directed by NHTSA's Senior Associate Administrator for Vehicle Safety, Daniel Smith, along with Office of Defects Investigation lead engineer Jeffrey Quandt. These are the same officials who presided over previous Toyota UA investigations, and served as the agency's liaisons with the NESC. Accompanying the NESC team every step of the way was Toyota. The NESC team, which did not contain anyone with an expertise in automotive electronics and engine management, leaned heavily on Toyota engineers to understand the system it was charged with examining. Exponent, a science-for-hire firm employed by Toyota's counsel to defend the automaker in a class-action lawsuit, conducted a warranty analysis for NHTSA and NESC, which the agencies used to dismiss one of the most significant pieces of physical evidence of electronics' malfunction.

[8] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 20; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

No independent investigator can rely on the unquestioned representations of its target and produce a credible result. Both Toyota and NHTSA have strong motivations – financial and reputational – to preserve the findings of past investigations. These substantial conflicts of interest were ignored.

Safety Research & Strategies (SRS) has been monitoring the incidence and potential causes of Toyota unintended acceleration since 2009, when some of the first deaths in runaway Camrys equipped with Toyota's ETCSi resulted in civil lawsuits. Our previous reports examined the history of Toyota UA investigations, data, recalls and the technical issues in detail.[9] [10] [11] Our evaluation of the NHTSA-NESC effort is not an attempt to embarrass either agency, or to call out specific people for any alleged improprieties. However, the details of the actions of those involved in the investigations must be part of any discussion of the complex confluence of factors surrounding Toyota UA. In this context, it is also important to understand the limited resources and enormously difficult job federal regulators and investigators face in keeping pace with technology. NHTSA has already fallen years behind in regulating and investigating complex automotive electronic systems. The now-dead auto safety bill, which would have required the establishment of a center of advanced technology, is long overdue and a necessity for an agency that intends to maintain relevance in the 21st century.

The Toyota UA issue is not one of the most pressing motor vehicle safety issues, such as mitigation of harm from side-impact or rollover crashes, which together cause nearly 20,000 deaths annually. And yet, Toyota UA matters – and it merits the resources devoted to understanding this apparently rare, multi-faceted, multi-root cause problem, because the results will have a lasting effect on future regulations, investigations, recalls, and designs involving safety critical electronics, ergonomics, and consumer concerns.

Toyota UA represents the first large-scale hazard associated with vehicle safety-critical electronic controls – years into a migration from mechanical to electronic controls. An electronic throttle may look and feel like the conventional mechanical arrangement, but it is a radically different system. Toyota UA also underscores the problems associated with the shift to non-standard vehicle controls. Gone are the traditional interfaces between vehicle and driver. In their place are new shift lever patterns and detent locations, "smart keys' and on-off operation/emergency shut-downs, and emergency torque-limiting features like brake-override.

Yet, NHTSA has made little effort to assess or promulgate regulations to ensure that safety-critical systems and new non-traditional controls meet a minimal level of robustness. Too many regulations remain rooted in the mechanical era, and the agency has not developed the necessary expertise in electronic safety-critical controls. Manufacturers understand this all too well. The internal Toyota communications that

[9] Toyota Sudden Unintended Acceleration**;** Safety Research & Strategies; Feb. 5, 2010
[10] Report Addendum: Exclusion of Camry Deaths Hamper Later Investigation; Safety Research & Strategies; Feb. 17, 2010
[11] Update Report: Toyota Sudden Unintended Acceleration; Safety Research & Strategies; Oct. 25, 2010

have been made public tell the story of an agency hunting for help in closing UA investigations.

In 2004, during the agency's only defect investigation into Toyota's electronic throttle control system (PE04021), Toyota manager Christopher Tinto describes Toyota's good fortune in having ODI investigator Robert Young in attendance, because he had closed so many SUA investigations in the past:

> "Mr. Young was shown all on the failure modes of the ETC system, and was clear in expressing that none of the modes felt 'unsafe' to him, and he felt that the modes were unrelated to sudden acceleration Mr. Young also drove the vehicle in such a way that he was able to apply both the accelerator and the brake pedal at the same time. He referred to this as "Dual Pedal Application." He expressed his opinion that the complaints that the agency has received were most 1ikely dual pedal application (i.e. not vehicle malfunction related). He also stated that it was very difficult to achieve this dual pedal application condition because the Camry has utilizes a wide (i.e. good) spacing between the accelerator pedal and the brake pedal."[12]

In 2009, one of Toyota's Washington staffers described helping NHTSA quash the latest defect petition from a Lexus owner:

> "I have discussed our rebuttal with them, and they are welcoming of such a letter, They are struggling with sending an IR [Information Request] letter, because they shouldn't ask us about floormat issues because the petitioner contends that NHTSA did not investigate throttle issues other than floormat-related. So they should ask us for non-floormat related reports, right? But they are concerned that if they ask for these other reports, they will have many reports that just cannot be explained, and since they do not think that they can explain them, they don't really want them. Does that make sense? I think it is good news for Toyota."[13]

Industry has filled the vacuum with a patchwork of designs and practices, many of which are proprietary. The lack of minimum required standards, combined with complicated electronic components produced at a commodity level, can result in the installation of systems that lack basic protections. NHTSA's neglect has left the marketplace and litigation to sort this out. In 1995, when the agency sought to address these new systems by upgrading Federal Motor Vehicle Safety Standard 124 Accelerator Controls, automakers told the agency that they preferred that course:

> "In general, the comments of vehicle and engine manufacturers did not address the specific questions in the notice. Instead, they voiced a preference for rescinding the standard altogether, suggesting that market forces and litigation

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[12] Camry Electronic Throttle Control Meeting with NHTSA; Christopher Tinto; E-mail; Toyota; June 28, 2004

[13] Re: Defect Petition; Christopher Santucci; E-mail; Toyota; May 5, 2009

pressure are sufficient to assure fail-safe performance without a Federal motor vehicle safety standard."[14]

With this in mind, we interviewed scientists and engineers (including engineers who have designed, tested, and validated modern ETC systems) and examined the public data from the NHTSA-led NESC effort to reach the conclusions described in this report. It is important to continue to evaluate the many complexities that have emerged in this controversial issue to understand what we have really learned, what we need to learn, and what we can do to prevent future negative outcomes for motorists, vehicle manufacturers and regulators.

Our analysis of the publically available data finds:

- NESC and NHTSA's Data Analyses Are Seriously Flawed

    - Analysts did not use standard statistical methodologies to test scientific hypotheses about UA using the consumer complaint and warranty data.
    - The data do not support NHTSA and NESC's claim that media hype is responsible for generating a surge of baseless UA reports. Prior to any news reports, owners of Camrys equipped with ETCS-i reported UA at significantly greater rates than owners of Camry vehicles without ETCS-i, an independent analysis shows.
    - Despite characterizing consumer complaints as unreliable, researchers used them to assume *very* precise degrees of throttle openings in those complaints.

- The NESC Report Contains Substantive Technical Deficiencies

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    - The NESC study was billed as a study of unintended acceleration in Toyota vehicles. It is actually a narrowly construed study of how Toyota's ETCS-i could potentially result in a wide open throttle without setting a Diagnostic Trouble Code. The NESC study demonstrated that this was possible in numerous scenarios.
    - The NESC study does not consider the role of engine torque, nor did it address the role of torque requestors, such as the air conditioner. Nor does it consider the torque multiplying effect of the torque converter when the engine and transmission speeds differ significantly. These are serious omissions. Further, many UA events appear to happen at a less than a 35-percent throttle opening.
    - The NESC study did not fully address throttle learn behavior and the issue of false throttle learns.

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[14] Docket 02–12845; Federal Motor Vehicle Safety Standards; Notice of Proposed Rulemaking; 62 FR 48117; National Highway Traffic Safety Administration (NHTSA); July 23, 2002

- The software analysis was insufficient – NESC did not appear to test the actual source code, nor is it likely that with the limited time and resources a thorough evaluation of 280,000 lines could have been performed.
- The NESC effort did not engage independent experts who have design, validation and testing experience in modern motor vehicle engine torque management systems. Regardless of the core competencies of the engineers involved, evaluating the application of highly sophisticated systems outside of the fields of expertise of those involved, particularly in a limited time, will limit the outcome.
- The NESC report is littered with significant redactions of technical information that prevent complete and independent scientific replication of the process and results. Without the possibility of replication, this report is unscientific.

- The NESC Report pinpoints weaknesses in Toyota's electronic design

  - NESC researchers have pinpointed serious weaknesses in Toyota's electronic architecture that allow faults to occur and go undetected—including those that could cause a UA event.
  - The discovery of the presence of tin whiskers on some accelerator pedal position sensors indicates a real-world manufacturing problem that could explain some UA events.
  - The NESC report confirms the findings of Dr. David Gilbert that show certain ETC system design vulnerabilities and resistive circuit faults that cannot be detected by the ECM.
  - The NESC team revealed that some Toyota vehicles are plagued with inconsistent accelerator pedal response. This is no mere "drivability" issue. A safety-critical system that responds inconsistently to driver input causing surges or lurches beyond a driver's request can result in property damage, injury or death to occupants or pedestrians in the vicinity of the event. It is a safety hazard.
  - Toyota's cruise control system, which has been implicated in some UA events, is an old system carried over to the new electronic architecture that lacks a fuel cut-off feature.
  - The NESC team found a number of scenarios in which engine speed can be increased, RPMs can surge, and the throttle can be opened to various degrees in contradiction to the driver's command and not set a Diagnostic Trouble Code.

Toyota SUA hasn't been scrutinized repeatedly since 2003 simply because the agency took note of the number of drivers who continued to call the agency's hotline about the problem. The agency was forced to confront the issue multiple times because Toyota and Lexus owners actually took the extraordinary step of filing defect petitions – six between

2003 and 2009. Drivers do and will continue to experience these problems – even after the recall remedies are applied. The floor mat and sticky accelerator pedal recalls have not addressed all of the root causes. While these reports may soften the glare of attention, they will not stop the problem from reoccurring, regardless of the amount of effort or the scientific veneer used to obscure it.

The Data Deficiencies

Vehicle Owner Questionnaire (VOQ) Data

NHTSA's VOQ data analyses are problematic in several ways.

First, and foremost, the government analysts did not employ standard practices and methodologies in conducting their studies of Vehicle Owner Questionnaires. VOQs are complaints reported via a government hotline, postal and electronic mail by drivers and their advocates. They contain the date of complaint, a narrative of the problem, the make, model and model year of the vehicle, and the location of the reporter, among other information. NHTSA has traditionally relied on VOQs as a first-line screening tool.

In this instance, government researchers used these data in a variety of ways that are inconsistent. On the one hand, NHTSA justified their selection of the Camry for physical examination and study based on the large volume of VOQ unintended acceleration complaints: "The VOQ records included 831 UA reports for Camry, and the MY [model year] 2005 Camry was selected by the NESC team for detailed analysis."[15]

On the other hand, in searching for an association between electronic throttle control complaints and unintended acceleration, government researchers concluded there was no association in all models:

> "The NESC team did not observe an increase in VOQ reports coincident with the introduction of ETCS-i on all TMC models. Some models show no effect and some models only indicate a small increase, while others show a slight decline in the number of reports received."[16]

This statement, while true, ignores huge increases in VOQ data after the introduction of ETCS-i for some models – particularly Camry, Tacoma and Lexus ES. This increase represents a clear trend in some models that might provide the basis for understanding design, manufacturing or testing differences between this group and other Toyota models. Rather than focus on indications that the introduction of electronic throttle control in some models is a promising route of inquiry, NHTSA looked past those data.

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[15] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 14; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

[16] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 14; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

The NESC team concludes that the VOQ complaints have limited value and are a poor surveillance tool:

> "For regulatory agencies and insurance companies, there is the additional desire to determine whether any particular vehicle model demonstrates a disproportionate likelihood of occurrence (and, ultimately, whether there is a design flaw responsible for this disparity). However, for reasons that will be discussed… it is extremely difficult to extract these answers from available databases."[17]

(In its companion report, NHTSA maintains that despite their limitations: "the consumer complaints are a valuable defect screening tool and play a central role in NHTSA's decisions on whether and when to open an in-depth investigation and, even after a publicity spike, specific complaints offer considerable insight into the circumstances surrounding the various safety defects investigated by NHTSA.")[18]

NESC researchers also observed that "voluntary reporting systems may not allow for accurate quantitative estimates of incident rates or statistical trends."[19] (The lack of accurate data is attributed to the problem of "media hype" obscuring the data. The researchers could have addressed this issue by analyzing a sub-group, comparing complaints gathered before and after periods of publicity to see what the data reveal about the effect of publicity.)

Yet, the NESC researchers used consumers' narrative descriptions to characterize very precise throttle openings in specific reported UA incidents. This key assumption drove paths of engineering and design inquiry.

Despite these contradictory views of the VOQ data, NHTSA and others have used it precisely to "determine whether any particular vehicle model demonstrates a disproportionate likelihood of occurrence (and, ultimately, whether there is a design flaw responsible for this disparity)."[20]

The NESC team did not employ these data in a statistically meaningful and standard way. For example, the team did not use the data to test their hypothesis that publicity generated the volume of complaints, and thereby rendered the data useless for some purposes but not others. The NESC report did not analyze SUA complaint rates, based on vehicle

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[17] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 25; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

[18] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 30; National Highway Traffic Safety Administration (NHTSA); Feb. 2011

[19] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 173; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

[20] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 14; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

exposure, for vehicles with electronic throttle control compared to vehicles without it. There are no actual analyses of changes in unintended acceleration complaint *rates* before and during periods of heightened media publicity for vehicles with electronic throttle control and without electronic throttle control in the NESC report.

The NESC team failed to control for a host of factors that could alter their conclusion about what clues could be found in the defect data. For example, they did not adjust their figures for exposure in terms of vehicle age or fleet size. The NESC team did not assess the strength of their evidence by calculating critical test statistics from the comparative summary data and or assess the probability of such statistics. These are serious omissions of standard statistical methods and would be unlikely to withstand a professional peer review.

In fact, it is possible to calculate accurate estimates of unintended acceleration complaints from consumers to NHTSA in ways that take the potential effects of publicity into account. For example, an independent statistical analysis of the VOQ data regarding Toyota's most troubled vehicle, the Camry, performed by Alice and Randy Whitfield of Quality Control Systems Corporation finds that*: The introduction of electronic throttle control systems in the Toyota Camry resulted in an increase in the rate of reports of unintended acceleration to NHTSA by consumers in vehicles with ECTSi compared to vehicles without ETCSi.*[21] Quality Control Systems Corporation has examined the complaint data on two previous occasions. Both reports examine the relationship between the rise in complaints regarding some vehicles with ETCS-i and the "hype hypotheses."[22] [23] Specifically, Quality Control Systems Corp. compared consumer complaints patterns regarding Toyotas with and without ETCS-i, during periods without widespread news coverage and those with extensive publicity.

One such discrete period occurred in 2004 – before and after NHTSA's investigation PE04021 was announced on March 3. Seven years ago, NHTSA Office of Defects Investigation screeners noted a difference in complaint rates – independent of media reports. According to Chris Tinto's memo memorializing the meeting between Toyota and NHTSA during PE04021, Toyota was called upon to explain the spike:

> "NHTSA explained to the group that their database of complaints shows that the 2002 and 2003 Camry vehicles have more complaints of surges and/or sudden acceleration than the 2000 and 2001 Camry's, and they need to understand why this is so, as it will help in their investigation (i.e it will help them close). TMC agreed to provide an analysis of all complaint warranty claims on the subject vehicles and the pre-ETC Camry vehicles, and TMA believes that providing this

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[21] Potential Safety Defects in Toyota's Electronic Throttle Control System: "The Hype Hypothesis"; Randy and Alice Whitfield; Quality Control Systems Corporation; Feb. 21, 2011

[22] What NHTSA's Data Can Tell Us about Unintended Acceleration and Electronic Throttle Control Systems; Presented to the Transportation Research Board of the National Academies for its Study of Electronic Vehicle Controls and Unintended Acceleration; Randy Whitfield; Quality Control Systems Corporation; Oct. 11, 2010

[23] Electronic Throttle Control Systems In Toyota Consumer Complaints to NHTSA; Randy and Alice Whitfield; Quality Control Systems Corporation; Feb. 3, 2010

> data will show that ETC vehicles are no different than non-ETC vehicles when it comes to 'sudden acceleration' or 'surge'. We believe that the reason data is skewed is because of the drivability issues initially associated with the Camry (hesitation, shift shock, etc.) implementation of ETC."[24]

While Toyota attempted to explain away the spike as the appearance of a "driveability" issue, an analysis of consumer complaints made to NHTSA before any media coverage of unintended acceleration shows statistical evidence that is consistent with at least one acknowledged cause of unintended acceleration (engine surging) involving vehicle electronics. In 2002, Toyota issued Technical Service Bulletin EG017-02 to recalibrate the Engine Control Module.[25]

The QCS analysis of VOQ data shows an increased rate of SUA complaints regarding Camrys equipped with ETCS-i before and during the NESC-identified periods of extensive news coverage. Media reports did not have the same effect on consumer complaints regarding Camrys without ETCS-i. During the same period of publicity, the rate of unintended acceleration complaints for those Camrys dropped.[26] This finding does not support the hypothesis that unintended acceleration in Toyota Camrys largely results from media hype.[27]

Warranty Data

The NESC team used warranty data to dismiss the discovery of tin whiskers in a very large portion of a very small sample (See **Tin Whiskers** section). The NESC team hypothesized that single faults – which do set DTCs – would be more common than double faults, and thus would show up in greater numbers in the warranty data – although they did not identify the threshold that would define the expected difference if their hypothesis were true.

The researchers fail to make this link. Warranty data have key limitations. It provides a brief snapshot, as the NESC team noted:

> "These databases will contain only a subset of UA incidences (i.e., those that led owners to take their vehicle in for a warranty claim. Another critical limitation of these data sets is that vehicles stop contributing input once their warranty expires; thus, most warranty-claim databases offer only a three-year moving window on vehicle issues.)"[28]

[24] Regarding NHTSA Briefing; Christopher Tinto; E-mail; Toyota; June 28, 2004
[25] Technical Service Bulletin TSB EG017-02; Toyota Motor Corp.; Aug. 30, 2002
[26] Potential Safety Defects in Toyota's Electronic Throttle Control System: "The Hype Hypothesis"; Randy and Alice Whitfield; Quality Control Systems Corporation; Feb. 21, 2011
[27] Potential Safety Defects in Toyota's Electronic Throttle Control System: "The Hype Hypothesis"; Randy and Alice Whitfield; Quality Control Systems Corporation; Feb. 21, 2011
[28] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 24; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

The researchers need only look to the consumer who donated her defective pedal to their sample. Her Camry was from the 2003 model year; it failed in 2009 – out of warranty. In fact, every pedal from the six Camry vehicles at the team's disposal, which ranged from 2002-2007, was long out of warranty. (One pedal in its sample came from a junk yard – was it less than three years old?) Warranty data are limited in other ways: owners experiencing a single non-replicable event are unlikely to request and/or have a service performed – warranty repairs depend on dealer service technicians examining and repairing identifiable problems; dealerships may make repairs as a good will; a manufacturer looking to obscure a problem can spread the repairs among other codes; or a repair might be miscoded.

Further, the warranty data, supplied by Toyota, are secret and cannot be evaluated by independent scientists for possible sources of bias. In its companion report, the agency takes credit for this analysis: "NHTSA also analyzed Toyota warranty data to determine whether there was evidence of any trends suggesting a problem related to the ETC system or components." In fact, the analysis of the warranty data was not conducted by NHTSA. A June 28, 2010 e-mail to NHTSA's Jeffrey Quandt reveals that Exponent, Inc. actually performed the warranty analysis for NHTSA.[29]

Toyota engaged Exponent in December 2009,[30] after the public outcry over the Saylor crash. Exponent produced two reports, at the behest of Toyota's outside counsel Bowman & Brooke, purportedly intended to get to the bottom of 37,900 SUA complaints Toyota had received since installing electronic throttle controls. The first report, *Testing and Analysis of Toyota and Lexus Vehicles and Components for Concerns Related to Unintended Acceleration*, was released on February 4, right after the first Congressional hearing on Toyota Sudden Unintended Acceleration. According to the report, Exponent evaluated six Toyota and Lexus vehicles containing various versions of the ETCS-I system, and concluded: "Throughout the evaluation and testing conducted to date, the ETCS-i components and whole vehicles behaved in a manner consistent with published performance characteristics. Exponent has so far been unable to induce, through electrical disturbances to the system, either unintended acceleration or behavior that might be a precursor to such an event, despite concerted efforts toward this goal."

The second report was issued specifically to refute the findings of David Gilbert, an Associate Professor at Southern Illinois University Carbondale. Gilbert's *Toyota Electronic Throttle Control Investigation Preliminary Report* examined Toyota's electronic throttle control system malfunctions and the fail-safe detection capabilities, with a specific focus on the accelerator pedal position sensor, which conveys the driver's desired speed and opens and closes the throttle.[31] As part of an ongoing Congressional investigation into Toyota SUA, the Committee on Energy and Commerce probed the relationship between Exponent and Toyota and found cause for concern.

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[29] ETCS, Warranty Data; Subbaiah Malladi; June 28, 2010

[30] Testing and Analysis of Toyota and Lexus Vehicles and Components for Concerns Related to Unintended Acceleration; Exponent; Feb. 4, 2010

[31] Electronic Throttle Control Investigation Preliminary Report; David Gilbert and Omar Trinidad; Feb. 21, 2010

- Exponent was hired – not in the name of scientific inquiry, as Toyota claimed – but to defend Toyota in a class-action lawsuit.[32]
- Exponent was originally hired – not by Toyota – but by outside counsel Bowman & Brooke, to shield its work from plaintiff's discovery requests. [33]
- All communications between Toyota and Exponent had counsel present.[34]
- Exponent billed Toyota for 11,000 hours of work, yet took no notes, had no written protocols for its work and no interim work product – one document was amended as the project continued, with earlier versions not kept for the record.[35]
- Exponent was unresponsive to the Committee's request for documents.[36]
- Exponent submitted a substantially altered version of a document in direct contradiction to the Committee's instructions.[37]
- Based on the assessments of outside automotive electronics experts, Committee Chairman Rep. Henry Waxman and Rep. Bart Stupak criticized Exponent's work as being incomplete and lacking scientific rigor.[38]
- Exponent has billed the automaker $3,330,552.36 on the SUA investigation since December 7, 2009,[39] and $10.7 million between 2000 and 2009. Last year's revenues were the biggest single year – $2.1 million.[40]

Despite the enormous conflict-of-interest, NHTSA and NESC appear to have accepted Exponent's warranty analysis uncritically. Allowing a company that has been hired to defend Toyota in SUA lawsuits to perform an analysis used to discredit the significance of physical evidence of an electronics problem does not speak well to the independence of the NESC team's conclusions. Not to disclose this fact is disingenuous.

More problematic are the analyses themselves. According to an analysis by Quality Control Systems Corp., NHTSA's and NESC's treatment of the warranty data is rudimentary, lacking even such basic scientific techniques as the calculation of critical test statistics from comparative data and assessments of the probability of such statistics.[41] Nor do these warranty analyses rely on scientific comparisons of the warranty experience of Toyota's Electronic Throttle Control (ETC) systems – neither report offers any analysis of alternative systems utilizing safer designs or safer manufacturing and

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[32] Toyota Class Actions Project No. 0907698.000; Subbaiah Malladi; Exponent; Dec. 7, 2009
[33] Toyota Class Actions Project No. 0907698.000; Subbaiah Malladi; Exponent; Dec. 7, 2009
[34] Interview with Shukri Souri; Don Seckman; Energy and Commerce Committee; May 12, 2010
[35] Interview with Shukri Souri; Pg. 59; Don Seckman; Energy and Commerce Committee; May 12, 2010
[36] Letter from Henry Waxman to James Lentz; Committee on Energy and Commerce; Rep. Henry Waxman; June 29, 2010
[37] Letter from Henry Waxman to James Lentz; Committee on Energy and Commerce; Rep. Henry Waxman; June 29, 2010
[38] Letter from Henry Waxman to James Lentz; Committee on Energy and Commerce; Rep. Henry Waxman; June 29, 2010
[39] Response to May 14, 2010 E-mail; James J. Ficenec; Bowman & Brooke; May 19, 2010
[40] Letter to Bruce L. Braley; Theodore M. Hester; King & Spalding; Mar. 30, 2010
[41] Potential Safety Defects in Toyota's Electronic Throttle Control System: Warranty Claims; Randy Whitfield; Quality Control Systems Corporation; Mar. 4, 2011

testing practices based on identified standards.[42] Finally, NHTSA's exoneration of Toyota's Electronic Throttle Control system relies on the unacceptable practice of statistical comparisons against "standards" set by recalled products with admitted safety defects that present unreasonable risks to consumers.[43]

Event Data Recorder (EDR) Data

The NESC team did not examine Event Data Recorder (EDR) or crashes from which the EDR data were taken. But NHTSA has accepted the results of Toyota Event Data Recorder read-outs, and used those results to conclude that in most cases, drivers in a high-speed event had erred, and had either mistakenly applied the accelerator or had not actually tried to apply the brakes before the crash. The agency's analysis is flawed on two counts: some crashes selected for study appeared to have no factual basis for inclusion in a UA study; and the readouts produced inconsistencies in acceleration and braking data, calling the validity of all readouts into question. Remarkably these inconsistencies are not noted in either report. Further engineering analyses of the EDR data will be addressed in a later report.

In August, NHTSA conducted 58 field inspections of potential long-duration UA events. The vehicles selected for inspection were crashes in which:

> "There was an allegation of unintended acceleration or the possibility of unintended acceleration based on preliminary incident information; the vehicle was still available with the EDR intact; the vehicle contained an EDR with pre-crash data; and the owner of the vehicle was willing to allow NHTSA to read the EDR. It is also important to note that most Toyota models manufactured before 2007 were not equipped with EDRs capable of pre-crash data."

On the basis of those readouts, NHTSA broke down from the data thus:

35 showed no brake application
14 involved partial braking
9 involved braking late in the crash
3 involved early braking
2 involved mid-event braking
1 event was said to have involved pedal entrapment
1 event showed both brake and accelerator application
1 case the EDR contained information related to a separate incident
1 case NHTSA is still working to resolve inconclusive data from the EDR
5 cases resulted in no EDR activation at all[44]

[42] Potential Safety Defects in Toyota's Electronic Throttle Control System: Warranty Claims; Randy Whitfield; Quality Control Systems Corporation; Mar. 4, 2011
[43] Potential Safety Defects in Toyota's Electronic Throttle Control System: Warranty Claims; Randy Whitfield; Quality Control Systems Corporation; Mar. 4, 2011
[44] Ongoing NHTSA Research on Unintended Acceleration & Event Data Recorder (EDR) Readings; National Highway Traffic Safety Administration (NHTSA); Aug. 2010

On this basis, NHTSA determined that it was no closer to discovering any electronic cause of unintended acceleration in Toyota vehicles:

"At this early point in its investigation, NHTSA officials have drawn no conclusions about the additional causes of unintended acceleration in Toyotas beyond the two defects already known – pedal entrapment and sticking gas pedals."[45]

The inclusion of incidents that represent the "possibility of unintended acceleration" further skews what few conclusions can be drawn from the inconsistent EDR data. For example, a vehicle run-off-the-road crash late in the evening with no witnesses may cause family members to question whether unintended acceleration was the cause of the crash. However, absent any forensic evidence or first-hand witnesses, these types of cases should not be characterized as UA events and used as the basis of a study in Unintended Acceleration.

EDR or "black box" data from motor vehicles provide additional information for crash investigators to discern the details of an incident. While these data can be helpful, they are not always accurate, and as any seasoned crash investigator understands, the data must be examined in context of other evidence. Further, the lack of transparency by many manufacturers regarding what data are actually recorded, retrieved and analyzed compounds the difficulty in using EDR data. This creates a conflict-interest when one party controls all of the data – particularly when these data may implicate a vehicle defect.

Toyota has long argued, in public statements and in litigation, that its Event Data Recorder is an unreliable witness to crash events – the company has described its EDR as a prototype, whose operation has not been validated. Yet, the company is not adverse to relying on EDR data if it appears to point to a driver error.

These issues have underscored the necessity of using data retrieved from EDRs in conjunction with physical evidence. In a presentation, GM's Executive Director of Vehicle Safety, Robert C. Lange, noted that when using EDR data, one must always account for and correlate data with physical information.[46] Similarly, the general information section in Toyota's SRS Event Data Recorder Operation Manual specifically states:

> "The accuracy of the memory of Toyota's Event Data Recorder ("EDR") is still being validated, and the readout tool for the EDR is still in the prototype stage. Toyota cannot verify the complete reliability of such information, unless such data can be independently corroborated, e.g., through physical evidence, etc."[47]

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[45] Ongoing NHTSA Research on Unintended Acceleration & Event Data Recorder (EDR) Readings; National Highway Traffic Safety Administration (NHTSA); Aug. 2010

[46] Air Bag Blue Ribbon Panel Public Meeting; Robert Lange; General Motors; May 7, 2007

[47] Toyota SRS Event Data Recorder Operation Manual; Version 2.4.1

In addition, to be relevant, the data also must present a consistent picture of how the vehicle was operating pre-crash. A preliminary review of some of the EDR data gathered from the 58 cases, using basic engineering principles and vehicle specific specifications, shows conflicts between EDR data points regarding braking and acceleration.

For example, Case 3, as designated in NHTSA's report, involves the crash of a 2007 RAV4, in which the driver reported: "Unintentional acceleration while driving home from work, the car sped out of control. I was unable to stop the vehicle because both the brake and gas pedals were compressed. Finally crashed into a brick wall to stop the car."

Toyota EDRs report pedal voltage, vehicle speed, engine RPM, and braking data at 1-second intervals for the five seconds before the crash. Braking is reported only as "on" or "off." Using engineering calculations and vehicle specifications to assess the data recorded in Case 3, the rpm, the pedal voltage and vehicle speed – measured at each individual point in time – appear to be consistent. Case 3 EDR data show the brakes off during the five seconds before the crash. This individual datum, however, do not line up to create a coherent picture of the event. In Case 3, the brakes are not applied, and yet the EDR reports that the vehicle is slowing. If the brakes were off, as the EDR reports, the vehicle should actually be accelerating by +0.3g to +0.5g. The EDR reports that the vehicle is decelerating at 0.25g. This could only occur if the vehicle was travelling on a 25-percent upgrade. More likely is that the driver was applying the brakes during a full open-throttle event.

Inconsistencies such as these abound among the 58 crashes in the NHTSA study – and they strongly challenge the validity of the data. Investigators failed to note the contradictions in the data or to ask the logical questions these data disagreements imply. Were the brakes in Case 3 really off? If they actually were on, as the vehicle speed data suggest, why didn't the EDR record it? If the brakes were applied, what caused the throttle opening – the driver depressing the pedal, or an uncommanded UA event?

Experts raised other questions about the reliability of Toyota's EDR data after the readout of a 2007 Toyota Tundra involved in a crash that fatally injured Chris Eves.[48] Toyota's download of the EDR data indicated that the vehicle was traveling at a speed of at least 74.6 mph and experienced a Delta-V (Change in Velocity) of 177.2 mph. Toyota acknowledged that these readings could not be accurate, because the Tundra could not reach that speed. Later, the automaker said that it found a software error for that specific model vehicle only and changed it. Following the software fix, the data were re-read and the Delta-V was calculated at 1.4mph. Based on the physical evidence in the crash, this reading, too, was an impossible result. A Delta-V of 1.4 mph is a minimal impact that might be expected by a vehicle glancing a curb. This impact wouldn't deploy the airbag and trigger the EDR to record the crash. The Tundra in this crash was totaled by the impact, suffered significant structural crush and the airbags deployed.

Following the software changes, NHTSA re-ran some, but not all, of the 58 EDR reports they generated and found that the data did not change except that the maximum reading

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[48] Crash Victim's Father: "We Now Have the Answers We Want"; Tracy Vedder; KOMO; Aug. 11, 2010

for the Delta-V matched the Delta-V readings in the graph. Although there were no major changes to the data in the NHTSA EDR readouts with the updated Toyota EDR software, there has not been any public information about the errors in the data post-software fix with respect to the Eves crash.

NHTSA made it clear that these data are only a small piece of the puzzle. While driver error is a likely cause of *some* UA events, the EDR data don't make for a compelling case that this is all that's happening – particularly as independent experts *and* Toyota continue to document events in which the vehicle diagnostic systems fail to detect unwanted acceleration events.

Nonetheless, the EDR data discrepancies ought to have instigated more questions and more investigation. Instead, NHTSA accepted the readings uncritically and included the findings as another indication that there are no electronic problems with Toyota vehicles. The EDR discrepancies ought to have been regarded as indications that there *are* problems with Toyota's electronics.

SMART Team Analyses

NESC also relied on data collected by the Toyota Swift Market Analysis Team (SMART) Team. Independent observers of the SMART Team in action have noted that SMART team data were unreliable due to issues with data collection, the skill and experience levels of the team members. In addition, the only tools used for electronic data measurement or observations were the TechStream, and the EDR readers. These are rudimentary tools which provide limited insight into design related issues associated with the vehicles.

The Technical Deficiencies

NESC Report is Narrow in Scope, Missing Key Elements

NESC's charge, as defined in its report was: "Mr. Daniel Smith, Department of Transportation (DOT), Senior Associate Administrator for Vehicle Safety, requested an independent assessment to determine if there are design and implementation vulnerabilities in the Toyota Motor Corporation (TMC) Electronic Throttle Control System Intelligent (ETCS-i) that could cause unintended acceleration (UA)."[49]

The resulting report is a limited step toward that goal. First, the NESC team narrowly defined unintended acceleration to a single condition: large throttle openings, defined as greater than 25 to 35 degrees.

[49] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 9; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

The NESC team noted that Toyota's first version of its electronic throttle control system no longer represents the state of the art: "Since the ETCS-i introduction in 2002, the hardware, software and overall design have continued to evolve." Although the researchers attempted to address these evolutionary changes in the examination of the individual sensors and components, it is clear that the changes overlap.[50] The variations of hardware, software, and design, bring new variables to study, analyze, and evaluate. Each of these evolutionary changes warrants an in-depth study of those specific vehicles to identify vulnerabilities that are particular to that system as well as any correlation to the UA claims in order to untangle potential causes and sources.

Although Secretary LaHood has stated that NHTSA enlisted "the best and brightest engineers"[51] in the search for an electronic cause of unintended acceleration in Toyotas, the agency did not enlist engineers with specific automotive engine management or ECU design background and experience – and their absence shows. The report – although billed as a study of design deficiencies – fails in a fundamental sense to consider the strength of Toyota's system as a whole or compared to other systems. Nor did NASA or NESC follow vehicle mitigation testing protocols designed to examine system reactions under an array of conditions that are used by engine management design and validation engineers. Further, it is increasingly clear that Toyota and Exponent were heavily involved and relied upon for the conclusions found in both reports.

As defined in the NESC Executive Summary, "The goal of the study was to determine if there are design and implementation vulnerabilities in the Toyota Electronic Throttle Control System Intelligent (ETS-i) that could cause UAs and whether those vulnerabilities, if substantiated, could realistically occur in consumers' use of those vehicles."[52] Comparisons of other manufacturers' ETC systems may have proven useful in characterizing the nature and type of design vulnerabilities of the ETC system. Benchmarking might show, for example, that other manufacturers err on the side of safety by including additional safety nets in their electronic architecture, like the incorporation of a secondary diagnostic fault detection system, greater redundancy, or electronic brake override – all which were found to be missing in the Toyota models examined.

Conspicuous in their omission were discussions of issues and design choices that are key to any serious examination of unintended acceleration. They include:

- Physics or a fundamental analysis of vehicle acceleration using mass and force.

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[50] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Table 6.4.3-1 Hardware Configuration Evolution; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[51] U.S. Department of Transportation Releases Results from NHTSA-NASA Study of Unintended Acceleration in Toyota Vehicles; National Highway Traffic Safety Administration (NHTSA); Press Release; Feb. 8, 2011

[52] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 13; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

- The role of engine torque. The throttle does not need a large opening to generate significant engine torque to cause unintended acceleration. Peak engine torque is realized below 30 degree throttle for about half the speed range.
- The torque multiplying effect of the torque converter when the engine and transmission speeds differ significantly.
- Engine output torque curves or capabilities.
- Dynamometer data.
- Torque requestors such as A/C, alternator loads, air/fuel sensor VVT, P/S and other systems that could cause mild UA events that still represent a safety hazard.
- Throttle-learn behavior and false throttle learns.

The lack of discussion about engine torque is particularly troubling. The NESC team confined the scope of its project to VOQ scenarios involving throttle openings of 25 degrees above idle, on the assumption that this condition that would cause loss of vacuum and braking assist, and sufficient torque to overcome brakes, and thus cause an unintended acceleration. However, this analysis is too simplistic for the purpose of proving that there are no electronic problems within the strategy of the Toyota ETCS-i system that could cause an unintended acceleration. Many factors can influence vehicle acceleration, which is caused by torque at the wheels, and there could be other equally hazardous modes at less than 25 degrees above idle. The report also fails to address time sequencing and the possible effects of mistiming in electronic communications.

For example, the NESC team didn't consider at all the effect of Toyota's variable valve timing (VVT) system on these engines. The valve timing, be it advanced or retarded, can have a profound impact on the engine output. This adds another degree of freedom to the engine map. So, there could in effect, be a condition where a 25-degree throttle opening, concurrently at *X* valve retard producing less torque and more vacuum than a 20-degree throttle open at *Y* valve timing advance for the same engine speed. The BMW throttle-less engine, for example, controlled engine torque entirely by valve timing variation. In this system, the camshaft timing took the place of the throttle positioning function for control of engine torque. VVT should have been among the factors weighed in this analysis.

By restricting its consideration to throttle opening only, the NESC team also ignored the role of engine speed (and thus power), transmission gear and torque convertor state, vehicle dynamics – any one or all these are factors in an unintended acceleration. To say that there is no possibility of sudden UA by merely considering what can cause the throttle to open 25 degrees above idle is wholly insufficient.

In addition, the NESC teams' claim of complete testing of 280,000 lines of computer code is suspect. As the NESC team pointed out, Toyota used non-standard code, so it could not be analyzed:

> "The 2005 MY Camry source code required unique code inspection tools and manual inspections due to The TMC software process uses proprietary developed

> coding standard and industry standard static analysis tools provide automated code inspections based upon industry standard code implementation."[53]

This statement suggests that while the team may have examined 280,000 lines of code, they didn't test them. Rather, they tested a model that represented the code and where possible, incorporated actual source code modules for better fidelity. This is not the same as testing the actual code on the actual target ECM.

Further, the report mentions that during software testing on the 2005 Camry, researchers could not find "faults that *unilaterally* cause a UA."[54] Why qualify this as a fault that independently causes UA? Evidence suggests that UA is more likely a combination or combinations of factors.

The report identified serious shortcomings in the design and implementation of Toyota's electronic throttle control system that could lead to unintended acceleration. But the NESC team disregarded its own findings. The team further failed to address each vulnerability, one by one, and show what preventive measures Toyota has taken and how effective the team considers those measures are likely to be. If, for example, Toyota had designed for the possibility of an unrequested acceleration, it might have provided the driver with the means to recover control by cutting off the fuel supply.

Lack of Transparency

A year ago, Secretary Ray LaHood promised the Oversight and Investigations Subcommittee of The House Energy and Commerce Committee a greater devotion to information sharing. This was the continuation of a theme LaHood struck at his Senate confirmation hearings in March 2009. At the February 2010 Toyota hearings, Rep. Edward Markey (D-Mass.) asked the secretary:

> "What do you think about the public in terms of them providing – being provided with more information regarding potential safety defects that automakers tell the department about even before an investigation is opened or a recall is announced?"

LaHood replied: "Need for transparency. The more information we can give the public, the better." [55]

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[53] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 173; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[54] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 172; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[55] Panel III: Hearing Of The Oversight And Investigations Subcommittee Of The House Energy And Commerce Committee Subject: Response By Toyota And The National Highway Traffic Safety Administration To Incidents Of Sudden Unintended Acceleration; Feb. 24, 2010

This need has yet to be fulfilled. In past investigations of Toyota SUA, the agency appears to have given the automaker broad confidentiality. Very little of anything Toyota has ever submitted in 11 investigations has been made available for public view. Response documents that are routinely posted on NHTSA's website during the course of an Office of Defects Investigation (ODI) probe are missing. NHTSA levied more than $40 million in recall timeliness fines, without sharing any of the Toyota information that lead to those penalties – or even the agency's own rationale in the imposition of record fines imposed in TQ01001, 002 and 005. In February 2010, the agency launched Recall Query 10-003 to determine if Toyota had defined unintended acceleration broadly enough in past recalls.

This latest "exacting" effort suffers the same problem. The reports are marred by significant redactions. Hidden from public view was key technical information in the areas of: the electronic throttle motor controller; power errors, especially those related to feeding of sensors; the cruise control; pedal command learning errors; fault trees; diagnostic error codes; the ECM power system; and power supply to pedal sensors.

These literal black holes in the data make a complete independent evaluation of NHTSA and NESC's process, assessments and conclusions impossible. Neither agency has explained the rationale for these redactions. Some of this information is not proprietary; some of it regards systems that are obsolete by today's standards, so why is it hidden from public view? Finally, these reports are taxpayer-sponsored research. The public has a right to the entire report.

(See Appendix A, Redactions)

NESC Report Pinpoints Important Toyota Design Deficiencies

Tin Whiskers

Critics of previous UA research have stated that resistive shorts between ETC circuits would be highly unlikely "under real world field conditions" and that circuit problems of this type "would be visible and ultimately detected" [56] The NESC team's most significant finding shows this argument to be false. The NESC report identifies, complete with photographic evidence of a tin whisker, the presence of a resistive short between two APP signal circuits.

"Destructive physical analysis of this pedal assembly found tin whiskers, one of which had formed the resistive partial short circuit between the pedal signal outputs. A second tin whisker of similar length was also found in this pedal assembly that had not caused an electrical short."[57]

[56] Evaluation of the Gilbert Demonstration; Exponent; Section 4.4; Pgs. 11-12; Mar. 1, 2010
[57] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 16; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

Tin whiskers are microscopic, hair-like structures made of tin that can go undetected even as they wreak havoc on electronics. Tin whiskers have downed commercial satellites, caused nuclear reactor shutdowns and missile misfires and compromised the functioning of heart pacemakers. They are regarded by electronics manufacturers, the U.S. Food and Drug Administration and, in particular, NASA, as a significant reliability problem: "Given the current-carrying capacity and the length that whiskers can grow, the potential for short circuits in electronics is a very real concern" [58]

These tin crystals form needle-like, kinked or spiral structures that grow out of the surface of tin solder joints on printed circuit boards. The "hairs," typically 1-2 microns in width and up to 9 mm in length, can carry 10mA of current, causing electronics to malfunction by bridging circuits to form resistive shorts or by breaking off, linking connectors and causing mechanical damage. Whisker formation was first discovered in the 1940s in cadmium coatings, but the problem intensified in 2003, as manufacturers switched from lead to tin solder to satisfy a European Union directive for environmentally-friendly products. [59]

In eight defect investigations into Toyota UA, NHTSA conducted rudimentary vehicle tests in search of an electronic cause for the complaints, without identifying one. But NESC, with its expertise in tin whiskers, found microscopic tin structures growing in a very large portion of a very small sample.

The NESC team dismisses the significance of this discovery:

> "If a resistive short between the potentiometer accelerator pedal signal outputs exists, the system may be vulnerable to a specific second fault condition that could theoretically lead to UA. However, if resistive faults were occurring during normal use, DTCs would be expected from at least the first ignition key cycle and the following cycles that did not meet the specific criteria. Subsequent review of the warranty data does not support an observable failure signature of pedal-induced DTCs. Electrical measurements on six VOQ vehicles found no indication of the resistive paths necessary for this failure scenario."[60]

This statement is more supposition than fact. There is currently a lot of debate about what factors create an environment for tin whisker growth and about the rate of their growth. The team assumed that it has ferreted out all conditions and consequences of tin whisker growth in Toyota accelerator pedal position sensors, based on a paucity of data.

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[58] Tin Whisker Electrical Short Circuit Characteristics-Part I; IEEE Transactions on Electronics Packaging Manufacturing, Vol. 31, No. 1; Pg. 32; Jan. 2008

[59] Tin Whisker Electrical Short Circuit Characteristics-Part I; IEEE Transactions on Electronics Packaging Manufacturing, Vol. 31, No. 1; Pg. 32; Jan. 2008

[60] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 16; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

The report does not specify how many accelerator pedals the team examined, but a careful reading indicates that they dissected two Hall-effect accelerator pedal position sensors – one manufactured by CTS and one manufactured by Denso[61] – and either three or five potentiometer-type pedals. Nor is it clear how many of the potentiometer pedals examined were housing tin whiskers. In a March 10, 2011 meeting between NHTSA and NESC officials and safety advocates, NESC team leader Michael Kirsch suggested that the team found tin whiskers in 100 percent of a sample of three.[62]

The NESC report, however, states that a total of five potentiometer pedals were examined, but did not clearly state how many housed tin whiskers, how many different potentiometer-type sensor designs were examined, or if they shared a common supplier. Kirsch's memory notwithstanding, the report indicates that tin whiskers were found in four of the five potentiometer pedals – one "failed" pedal retrieved from a consumer who had filed a VOQ complaint in November 2009,[63] and three "non-failed" potentiometer pedals – one randomly obtained from a junkyard and two from vehicles NHTSA purchased for study.[64] In all four instances, tin whiskers were found growing inside the accelerator pedal position sensor – the biggest input to the throttle.

The failed pedal provided the team with the strongest evidence that tin whiskers growing in the accelerator pedal position sensor can cause open throttle events in the real world. In November 2009, the Camry owner filed this complaint:

> "I have a 2003 Camry. On Nov. 8, 2009, I had a very big problem with the accelerator. When stepping on the gas pedal I couldn't get any gas, and then the car would jerk forward at a rapid rate so that I had to apply the brakes. It was totally undrivable. The mechanic replaced the gas pedal assembly, and I have the old part in my possession. The part was $428.01 plus the labor cost. My old Camry I drove for 12 years without any problems. I feel the part was defective and that Toyota should reimburse me for the cost of replacement. Would your agency please look into this for me? *tr updated 11/16/10*bf The mechanic replaced the accelerator pedal assembly the pedal position sensor. Updated 11/19/10"[65]

When the NESC team examined this pedal, it found: "a 248 ohm resistive short between the VPA1 and VPA2 sensor outputs, compromising the isolation between both

[61] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 109; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010
[62] NHTSA / NASA NESC Briefing; Mar. 10, 2011
[63] ODI Number 10304368; National Highway Traffic Safety Administration (NHTSA); Nov. 2009
[64] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 122; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010
[65] ODI Number 10304368; National Highway Traffic Safety Administration (NHTSA); Nov. 2009

sensors."[66] (VPA1 and VPA2 are two circuits located in the Accelerator Pedal Position Sensor (APPS). Earlier research has already shown that theses two circuits are placed close together, with signals that rise and fall in tandem, thus making it possible for a short between the two to create an uncommanded open-throttle event with no DTC set.[67]) The team also found that the tin whiskers in this location could survive the electrical currents generated by the dual circuit:

> "Electrical current needed to melt a whisker of this length and thickness in air is approximately 5 mA, as shown in Figure 6.6.2.3-7. This current raises the temperature to the melting point of tin, 232 C, and increases the resistance of this metal whisker to about 410 ohms. The electrical characteristics of the dual potentiometer circuit cannot place such a large current through this whisker, bridging VPA 1 and VPA2; thus, its survival (i.e., non-melting during the operation of the car) is expected. Electrical analysis by the NESC team determined that less than 1 mA will typically flow in a fault between VPA 1 and VPA2 and a second similar fault to Vc, if it were to occur, would result in a higher current, approximately 5 ma, through that fault, but not enough to ensure melting."[68]

The team also ran some tests using a simulated defective pedal on the V6 MY 2006 and L4 MY 2005 ETC simulators under five scenarios featuring a resistive short and different failure sequences which varied the ignition and drive cycles.[69] (The System Behavior discussion is missing exacting details of the methods of the testing and evaluation done with the simulator. Most researchers would agree that testing methods and findings should be clearly stated in order to be truly validated by others. For example, testing is shown as a 248 ohm resistance on the Table 6.6.2.3-1 Potentiometer Accelerator Pedal Assembly Resistances, and later in the Figure 6.6.2.3-2 Pedal Resistive Fault Event Sequence Diagram as a 240 ohm resistance. Why is this resistance "locked in for testing" at 240 ohms? Tin whiskers may be longer or shorter and vary in resistive value depending on length. In fact, Table 6.6.2.3-2 Tin Whiskers observed on the Tin-Plated Copper Leads Soldered to the PCB shows whiskers of varying lengths.[70])

In four of the sequences, the resistive short would set a diagnostic trouble code or send the vehicle into a limp-home mode. The fifth sequence, however, did neither:

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[66] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 113; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[67] Electronic Throttle Control Investigation Preliminary Report; David Gilbert and Omar Trinidad; Feb. 21, 2010

[68] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 123; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[69] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 114; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[70] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 120; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

"If the resistive short occurs while the vehicle is off, starting the vehicle with the accelerator pedal partially depressed *will not set a DTC*. The accelerator responds as described above," i.e. "the vehicle has a jumpy response, and is capable *of full throttle without throttle brake override*."[71]

This scenario appears to match many complaints about low-speed UA events, especially during parking maneuvers. In fact, the NESC team pointed out that this occurs frequently, as described by consumers: "a significant fraction of the Camry VOQs described events that occurred under parking and low speed conditions where the throttle opens to a degree that driver braking attempts are reported to be ineffective."[72]

Contrary to the NESC team's claims that tin whiskers pose no real problem, the researchers have neatly linked a root cause – the tin whiskers found in all or nearly all of the potentiometer pedals it examined – to a vehicle behavior (a resistive short in the APPS opens the throttle without alerting the ECM). The team then connected this phenomenon to a driving condition – occurring when the ignition is off, succeeded by a partially depressed accelerator pedal – and a significant portion of low-speed UA complaints. Tin whiskers may explain the many UA events that have occurred in instances where a driver is exiting a parking space. Given the presence of tin whiskers in the APPS, did the NESC team look for similar contamination in the throttle sensors and printed circuit boards, where the environment might be expected to be even more conducive to tin whiskers?

These would seem to be promising avenues for further inquiry, yet the trail simply goes cold.

Toyota's safety system is not robust

ETC systems can be better understood by considering the two main areas:

- Demand Side – how the computer decides the driver really wants to "go."
- Delivery Side – how the computer delivers and verifies the "go" request.

Protection of the Demand Side is of the utmost importance and is the biggest challenge of Electronic Throttle Control systems. Protection of the Delivery Side is easier and what makes ETC potentially safer than cable throttles – the ability to detect a stuck throttle condition and use fuel cut and ignition timing to mitigate such a fault.

Analysis of the Toyota system has uncovered deficiencies on both sides.

[71] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 114; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010
[72] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 23; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

On the Demand Side – specifically in the accelerator pedal sensing system – there are four readily available methods to validate the driver's "go" demand. (More methods exist, but these provide a fair comparative basis.)
:

- A second sensor on the pedal.
- A different characteristic on that second sensor – preferably, a different rate-of-change behavior.
- An A/D circuit check on the second sensor.
- Another sensor indicating the brake application status.

Analysis of the Toyota accelerator pedal sensing system shows that it utilizes only the first two mechanisms. Toyota does not use two of the four readily available methods of determination of driver request. By comparison to other OEMs, the Toyota system Demand Side could be considered lax in its ability to ascertain the driver's true intentions.

The Delivery Side concerns itself with making sure that the engine torque requested by the Demand Side is being delivered, and moreover, that it is not over-delivered. This layer of detection can range from identifying a stuck throttle mechanism to delivering a throttle angle that deviates from the target angle. These simple diagnostic tests verify that the electronic throttle mechanism, as a subsystem, is functioning as intended, before and during operation.

The second level of diagnostics is the safety net beneath the first tier of diagnostics, which are those that set the DTCs. The secondary diagnostics check the engine as a system – for example, verifying that the throttle mechanism is performing at, but not above, its desired torque output. The secondary diagnostics would examine the entire system rationality by cross-correlating sensors and performing higher level calculations to ensure that the torque output is not exceeding the request of the Demand Side. In the event a processor error or other undetected fault is missed by a DTC, secondary diagnostics provide an added layer of protection on safety-critical systems, because they have the authority to reduce engine output if needed.

The NESC team plainly stated that the Toyota system is missing a form of secondary safety diagnostics. According to NESC:

> "For ETCS-i, the Sub-CPU only detects and issues diagnostic codes related to Main CPU performance and Throttle Motor Performance. *The Sub-CPU does not run duplicate logic and compare with the Main CPU or run diagnostics on the raw sensor values it receives. The Main CPU and the Sub-CPU share data across the serial interface and these diagnostic comparisons verify proper CPU software operation*" [emphasis added].[73]

[73] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 56; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

These techniques, as described by the NESC team, are commonly used in the automotive industry. Other OEMs utilize secondary sets of critical control logic, coded in a slightly different manner, that serve to "duplicate" this logic in function, but not in implementation. The description highlights that the NESC team was probing for this as an expected feature, but did not find it. This absence has been confirmed in other independent analyses of the Toyota system and represents a safety-critical system that is inadequately protected.

Idle Control

The NESC team noted a design deficiency in the Toyota system's response to coolant temperature sensor fault:

> "The water coolant temperature sensor provides an analog input proportional to temperature, colder temperature is higher resistance. When the sensor has failed to a higher resistance there is a range where the engine speed will increase by 2000 rpm (vehicle in neutral) without generating a DTC."[74]

Commonly known as the Engine Coolant Temperature (ECT) sensor, this sensor does exactly what the name implies. In the NESC report the ECT sensor is referred to as the "hardware label THW."[75] It measures the temperature of the engine coolant, which is basically the operating temperature of the engine. This is an important Engine Control Module (ECM) input for emissions and drivability – particularly for a cold start as more fuel is needed for starting a cold engine. The ECM also uses this temperature input for determining proper engine idle speed, as it is desirable to run a cold engine at a higher speed to prevent stalling and permit a faster warm-up. A fast warm-up is important for emissions, because a warm engine is more efficient and the fuel system can be better managed. Therefore, the ECM uses ECT sensor input to vary engine idle speed according to engine temperature.

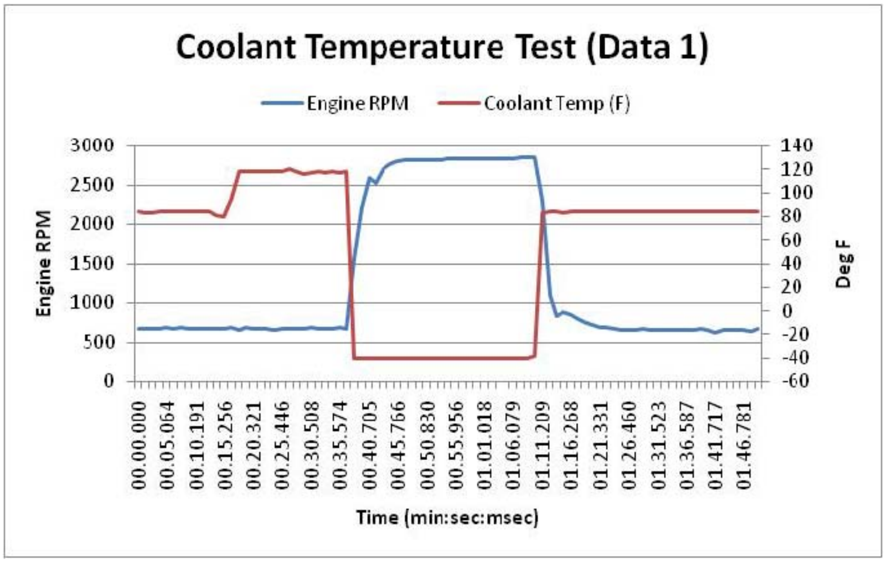
Due to the overall mass of the engine and cooling system, coolant temperatures do not normally change rapidly. It takes some time for the heat to increase or decrease in the engine block and the engine cooling system. This is an important factor in the ECM diagnostics of the ECT sensor and the engine thermostat. Simply put, the engine temperature cannot change instantly – if it does there must be sensing problem and a DTC should be set.

In normal operation of the engine, these ECT values are going to change much slower than what the NESC team found – the coolant temperature used in the determination of

[74] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 131; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[75] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 129; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

throttle opening jumped, when there should be a rate-of-change limit. A coolant temperature model should be used as a comparison. Toyota's On-Board-Diagnostics II (OBD II–an emissions diagnostic testing standard) should use such a model to detect a stuck thermostat. A failed coolant temperature sensor is usually a one-trip electrical fault. There should also be a thermostat rationality fault. The NESC team didn't discuss idle speed DTC's at all – even though they are related. As shown in the Figure 6.6.3.7-1 from the report (below), the ECT sensor input is varied rapidly from approximately 120F to near -40°F resulting in a 2000 RPM change.



This engine temperature change would not happen in the real world. The NESC team mentions this, but later dismisses it. What would happen if this type of circuit fault were to occur with the vehicle in gear? *Significant torque output, unrequested by the driver, causing UA.*

Pedal Sensing Weakness

The NESC report identified several pedal sensing weaknesses in Toyota's electronics. During the Electro-Magnetic Capability/Electro-Magnetic Interference testing a differentially injected signal audio frequency caused an increase in engine speed to 5000 rpm. It has been recognized by experts that the Toyota same slope pedal sensing scheme is blind to such mechanisms.

These two circuits in close proximity allow for potential circuit-to-circuit connection between APP signal circuit VPA2 and 5 volt supply circuit VCPA1. This specific internal design layout could allow for certain types of circuit connections.

A diagnostic known as the A/D test determines if the sensor or related wiring is functional and not shorted in-range. It's an active self-test of the input that the engine controller performs by momentarily, periodically and gently connecting the input to ground. If the controller sees the appropriate response on the A/D conversion it has verification that some kind of external short does not exist and that the circuit appears okay. This gentle grounding is intended to be strong enough to over-power a normally functioning sensor but gentle enough to not overcome an external short.

The secondary pedal sensor circuit's A/D response is tested continuously by the ECM. The ECM grounds the sensor output/analog input for 5 ms 50 times per second. This periodic grounding is a "test-for-echo" scheme. If an external voltage influence is on the line, then the test-for-echo signal will be squelched and the ECM will know there is a problem when the analog input does not show this value. The circuitry uses a weak pull-down resistor, strong enough to overcome the sensor output but not strong enough to overcome the voltage source. It is injected by the engine controller in order to capture any rogue voltages on the signal line. It requires a minor change to the ECM circuit board and some additional software.

Toyota's system does *not* have an A/D test on the second sensor. Other OEM systems do.

NESC Confirms Inherent Dangers of Toyota's Accelerator Pedal Position Sensor Design

The accelerator pedal sensor is the single most important input to the engine controller. The engine output is directly related to the interpretation of this sensor. Ultimately, the ECM opens the throttle in proportion to the primary accelerator pedal sensor output VPA1. The accelerator pedal-based demand is, in the Toyota ETC system, the only path that can open the throttle with full authority.

To check the validity of this command, the ECM looks to a second sensor for confirmation. This secondary sensor is supposed to give the same indication of the true pedal angle but in a slightly different way so that if something affects both sensors, it shows up differently on each one. Normally, the output of these sensors moves in concert with each other according to a given relationship. When this movement is according to the normal relationship the sensors are said to be "coherent."

If this relationship is compromised or "incoherent," the true intention of the signals is in question: they should not be used as the basis for throttle commands given, and the authority of this path should be reduced. It is the job of the pedal diagnostics to make this judgment. The pedal diagnostics are a series of questions the ECM asks about the pedal signal: Is it connected? Is it in range? Is it coherent with the second sensor? Is the second sensor okay? Is it conflicting with the brake indicator signal?

Imperative to the overall safety of any ETC system is the absolute validity of the accelerator pedal's APP sensor input to the ECM. The APP sensor is the most important ECM input to accurately convey the driver's desired engine speed. In recognition of this sensor's safety critical function, automotive manufacturers have painstakingly designed APP sensors to eliminate the possibility of any signal corruption associated with this input. When the ECM receives an APP sensor input that appears to be true and valid, it is logical to expect the ECM electronics to respond with an appropriate command or output to the electronic throttle body.

Because of the supreme importance of APP sensor, ETC system designers have chosen to utilize more than one electronic sensing component to ensure validity. Essentially, the accelerator pedal assembly houses at least two completely separate APP sensors. The fundamental reason for the elaborate use of two redundant sensing circuits is so the ECM can compare the two signal inputs and verify that each APP signal has not been compromised due to a faulty component or circuit failure.

Self-diagnostics of the APP sensor voltage supply, ground, and signal circuits are constantly monitored by the ECM's software for complete integrity and operation. Especially important is the ECM monitoring of the two individual APP signal input circuits. A variety of ETC systems have been developed in the industry with special design attention directed toward short detection between the signal circuits. A common strategy is to design independently varying signal voltages that cannot be shorted together (even at high resistance levels), without exceeding the allowable operational parameters of the diagnostic software and setting a DTC. Generally stated, the two APP signal voltages are purposely varied at different levels throughout the range of accelerator pedal depression.

In his report, *Toyota Electronic Throttle Control Investigation Preliminary Report*, Southern Illinois University Carbondale automotive electronics professor Dr. David Gilbert examined Toyota's electronic throttle control system malfunctions and the fail-safe detection capabilities, with a specific focus on the accelerator pedal position sensor, which conveys the driver's desired speed and opens and closes the throttle.[76]

Dr. Gilbert's work found that Toyota's ECM malfunction detection strategies were not sufficient to identify all types of fundamental APP sensor and/or circuit malfunctions.[77] More importantly, the Toyota detection strategies were unable to identify malfunctions of the APP sensor signal inputs to the ECM. With the two APP sensor signals shorted together through a varying range of resistances, all four Toyota vehicles examined reacted similarly and were unable to detect the abnormality – even though they should have triggered the vehicles' ECM to illuminate a MIL [Malfunction Indicator Lamp] within seconds and set a Diagnostic Trouble Code. The ECM should have then set a DTC, entered the vehicle "fail-safe" mode, and reduced engine speed and/or power. "When the two APP signal circuits are shorted together, the redundancy of the APP circuit design is effectively nullified and lost. In other words, neither of the shorted APP

[76] Electronic Throttle Control Investigation Preliminary Report; David Gilbert and Omar Trinidad; Feb. 21, 2010
[77] Electronic Throttle Control Investigation Preliminary Report; David Gilbert and Omar Trinidad; Feb. 21, 2010

signal circuits can be verified by the ECM as either; correct or incorrect. The condition then exists for a serious concern for driver safety."[78]

Toyota has long defended its system against charges that a malfunction of its electronic throttle control system will always be detected by the computer, which will note the problem and store a code in the engine computer. *The testing of the NESC team showed that it was possible to fool Toyota's system in a number of circumstances involving resistive shorts to two circuits in the accelerator pedal position sensor and the malfunctions of the cruise control.* There are cases is which the VPA1 circuit can be completely opened without setting a DTC or lighting the Malfunction Indicator Light (MIL). Likewise there are conditions under which the VPA2 can be directly shorted to the 5V supply and not cause a MIL or set a DTC.

The NESC team devoted a great deal of effort exploring the issues raised by Dr. Gilbert, and it validated his concerns. The NESC team found that Toyota's ETCS-i system design appears to be severely compromised, as the ECM is diagnostically unable to detect certain signal circuit interconnections through relatively low levels of resistive shorts. In the ETCS-i system, the two APP sensor signal voltages are intentionally designed to move with at same rate of change as the accelerator pedal is depressed. It is this fundamental design element that provides the APP signal circuits to be compromised with a resistive short that may be undetectable by the ECM diagnostic software. *The NASA discovery of tin whiskers effectively shorting the two APP sensor signal circuits, technically identified as VPA1 and VPA2, provides a sobering real world example of a corrupted sensor input*. Without adequate and consistent ECM self-diagnostics, signal separation and redundancy of the two APP circuits cannot be guaranteed in all cases. Coupled with the omission of a standard brake override as part of the original design, a potentially corrupted APP sensor input to the ECM poses a serious safety hazard.

Cruise Control Malfunctions

In addition to problems with the accelerator pedal position sensor, the NESC team uncovered potential failures of Toyota's cruise control system. Consumers have complained about and dealership techs have described UA events that occur when the cruise control is engaged.

Among the VOQ complaints, Safety Research & Strategies has identified 355 complaints in which we determined that cruise control was a key element of a UA complaint that was lodged with NHTSA between 1999 and the present.[79]

One recent example resulted in two fatalities in Utah. The driver Paul Van Alfen, and the left rear passenger, Charlene Lloyd, died of their injuries, after his 2008 Camry rocketed around vehicles stopped at the end of the exit ramp, flew across the road, over a sidewalk curb and into an embankment. Two surviving witnesses in the Camry said that Van Alfen

[78] Electronic Throttle Control Investigation Preliminary Report; David Gilbert and Omar Trinidad; Feb. 21, 2010
[79] Appendix B: Cruise Control related VOQs

was driving the family to a concert on November 10, 2010, on Highway I-80, with the cruise control on, set at 70-75 miles per hour. As the Camry headed down the ramp, Paul's wife and son, Shirlene Van Alfen and Cameron Van Alfen, both said that they admonished Paul to slow down. The driver responded that the cruise control would not disengage, and his brakes had stopped working. Cameron observed his father attempting to put all of his considerable weight on the brake pedal, but to no avail and he "had heard him tell us five or six times that nothing was working."[80]

(Van Alfen's vehicle had the floor mat and pedal shim recalls performed, but had not had the accelerator pedal shortened, nor does it appear that the brake override software update was done, according to Recall 90L.)

The NESC team identified "functional failures of the cruise control can result in 0.06 g's acceleration or 2.12 kph/s, and may not generate a DTC."[81]

Among the functional failures:

"*With the cruise control engaged, a 240 Ohm resistive short of the cruise control signal wire to ground caused the cruise control to remain engaged and the vehicle accelerated to the maximum speed threshold of the system*. This test simulated the ACCEL button in a failed closed position. If the brake pedal was applied with the short present, the system canceled. After releasing the brake pedal, if the short is recycled, the system would resume to the previously set speed, and be canceled again by pressing the brake."[82]

"The brake switch consists of one normally-open switch and one normally-closed switch. Both are mechanically connected with a switch plunger. With the cruise control enabled and the brake switch plunger disabled, the cruise control remained activated and functioning even when brake pedal applications were induced. The system maintained the set speed until enough brake force was applied to decrease vehicle speed by approximately 9 mph or below the 25 mph threshold of operation causing the system to fully disengage. *No DTC was generated*."[83]

The NESC team later dismisses the significance of this finding: "however, there are multiple methods for cancelling or turning off cruise control." How many is difficult to

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[80] State of Utah Investigating Officer's Report of Traffic Crash; 081000600; November 12, 2010

[81] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 172 Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[82] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 136; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[83] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 136; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

ascertain from the report. The NESC team variously reports that there are five ways to disengage the cruise control;[84] four ways;[85] and three ways via auto-cancel.[86]

One method that is not available, apparently, is a fuel cut-off feature:

"When the pedal position sensors indicate the driver foot is off the pedal, a fuel cut function is used to limit maximum engine speed. An exception is when cruise control is engaged. When cruise control is engaged, this fuel cut function is disabled."[87]

NESC AND NHTSA Ignore That Which Cannot Be Explained

NHTSA has achieved the appearance of arriving at a scientifically based conclusion by editing the incidents and facts that don't fit its conclusions and downplaying the importance of those that do. This strategy was never more evident than in the agency's decision to deny a 2009 defect petition by Jeffrey Pepski, a Minnesota Lexus ES350 owner who experienced a UA event on the highway in February 2009. In *Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems*, NHTSA characterized the termination of the petition thus:

"ODI denied the 2009 petition on the basis of Toyota's announcement of Safety Recall 09V-388 to address pedal entrapment issues, which in ODI's assessment addressed the issue reported by the petitioner."[88]

This is incorrect. First, there is no evidence to support the agency's contention that Pepski's event was caused by floor mat entrapment. He experienced a UA event, while driving at high speed, in which the vehicle accelerated to 80 mph. Pepski reported that he tried pumping and pulling up the accelerator with his foot – to no avail. Pepski's Lexus was equipped with a standard carpet mat, not the all-weather variety said to trap accelerator pedals. If NHTSA had any evidence to suggest that the carpeted floor mats caused pedal entrapment, why has the agency not pressed Toyota to recall?

Second, Pepski specifically asked the agency in April 2009 to re-open its investigation into Lexus SUAs and *look beyond floor-mat related causes* for long-duration high speed

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[84] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 72; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[85] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 134; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[86] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 135; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[87] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 146; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2010

[88] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 6; National Highway Traffic Safety Administration (NHTSA); Feb. 2011

events. This, according to Toyota officials, put the agency in a bind. On May 5, 2009 about a week before Toyota would send a response to Pepski's petition, one of Toyota's Washington staffers, Chris Santucci sent an e-mail to colleague Takeharu Nishida discussing his negotiations with the agency:

> "I have discussed our rebuttal with them, and they are welcoming of such a letter, They are struggling with sending an IR letter, because they shouldn't ask us about floormat issues because the petitioner contends that NHTSA did not investigate throttle issues other than floormat-related. So they should ask us for non-floormat related reports, right? *But they are concerned that if they ask for these other reports, they will have many reports that just cannot be explained, and since they do not think that they can explain them, they don't really want them.* Does that make sense? I think it is good news for Toyota."[89]

Instead of trying to investigate Pepski's complaint as requested, the agency attempted to make his incident a floor mat-related event. In the May 5 e-mail, Santucci described the agency's position:

> "For background, NHTSA did inspect the petitioner's vehicle. While they did not see clearly the witness marks of the carpeted floor mat on the carpet in the forward, unhooked position, they do suspect that the floor mat was responsible for the petitioner's issue."[90]

Jeff Pepski continues to reject NHTSA's assessment:

> "My incident occurred on February 3, 2009. My petition to NHTSA was dated March 13, 2009 and I met with the NHTSA reps [Bill Collins and Stephen McHenry with the DOT] and Toyota rep [Mike Zarnecki, the Field Technical Specialist from the Lexus Central Area Office] on May 1, 2009. Since no chain of evidence existed, the possibility of any observable witness marks as of May 1 would be remote and the level of reliability would be non-existent. All three parties were present when I asked Mike Zarnecki to demonstrate how the floor mats could have possibly caused the accelerator pedal to become entrapped. After much manual manipulation of the floor mat, he was able to show how it may occur. At my request he pulled up and pushed down on the gas pedal; the floor mat immediately became free. I explained that the SUA that I experienced did not cease after I had done the same while driving on February 3. If the floor mat had entrapped the accelerator pedal as all three claimed, the vehicle would have stopped accelerating after dislodging the floor mat. The SUA I experienced continued as the floor mat was not the cause."[91]

In gathering examples from NHTSA's own Vehicle Owner Questionnaire database, Pepski identified consumer complaints in which the vehicle that accelerated in

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[89] Re: Defect Petition; Christopher Santucci; E-mail; Toyota; May 5, 2009
[90] Re: Defect Petition; Christopher Santucci; E-mail; Toyota; May 5, 2009
[91] Re: Sending Along an E-mail You Might Find Interesting; Jeffrey Pepski; E-mail; Sep. 23, 2010

contradiction to the driver's commands had no floor mat, or mats that were properly installed and secured.

From VOQ 10230560:

> "On June 10, 2008 about 11:00pm, I was on my way from Indianapolis, In to Columbus, OH. I was using cruise control and went to reduce my cruise speed with the switch on the steering column. My 2007 ES350 immediately began to accelerate under full power. I switched my cruise control off, but it would not disengage. My speed was increasing still. I hit my brakes as hard as possible, but they would barely keep the car at it's speed above 80 as I was dodging traffic on I-70 eastbound. After 2 miles of trying to gain control of the car, full brakes and much less brake pad for the experience, I was able to get the car to stop and the cruise control did finally disengage once the vehicle was stopped but not before. All mats were locked in place with clips. No vehicle errors to report. This is a deadly situation. I am 6'4", 250 lbs and it took everything I had to stop the car. Had this been in a more congested area, the results could have been far worse." [92]

From VOQ 10199857:

> "I purchased 2007 Lexus ES 350 in December of 2006. Sometime in last month, when I was driving the vehicle on a highway, its brake stopped working all of a sudden, and started accelerating by itself. I looked at my foot wondering if my foot was on gas pedal, instead of brake pedal, but it was on brake pedal. I was in a total panic, but managed to drove [sic] the car away to the shoulder of the highway by putting the car in park mode. I thought I was dead at that moment. I am trying to sue the Lexus. I honestly believe that car will kill someone. Before starting a legal proceeding, my attorney sent a letter to Lexus headquarter, and was told that the vehicle had no problem, and that the cause was the floor mat. But, it was not. As I said earlier, I looked at my foot when the vehicle did not stop, and after I stopped the car, I carefully looked at both gas pedal and brake again. I am not blind. Have you seen any other complaints for similar problems? Please let me know. It will be really helpful for me to win the case. I am not trying to make money by suing Lexus, but trying to have Lexus recall all of its ES350 since it will kill someone."[93]

From VOQ 10203221:

> "On two prior occasions the vehicle accelerated from speeds between 20-30 mph, to speeds up to 50-60 mph. On 9/11/07, the vehicle accelerated at speeds up to 80-90 mph. We are aware of the Lexus notification of floor mat interference, so we removed the mats after the first two times, but the last and most frightening, occurrence happened without the mat in the vehicle. The car had to be forced into

[92] ODI Number 10230560; National Highway Traffic Safety Administration (NHTSA); June 10, 2008
[93] ODI Number 10199857; National Highway Traffic Safety Administration (NHTSA); July 3, 2007

> park in order to slow it down to a halt. My wife was driving the vehicle at the time and she states she almost had several multiple car accidents while trying to stop the vehicle. I had the vehicle towed to the dealer and they said it's the floor mat, before even driving the car. We won't drive the car again until someone other than Lexus determines what the problem is."[94]

NHTSA has offered no evidence that these complaints were investigated, let alone that the circumstances of the incident were in contradiction to the complainant's description. NHTSA did mischaracterize those VOQs as floor mat-related incidents in denying DP09001. The agency has never explained this discrepancy. In essence, NHTSA's explanation is: These are floor-mat incidents because we say they are.

Again, if, as the agency has claimed, only mechanical interference from a floor mat can cause a long-duration, high-speed event, and if Pepski's SUA incident was caused by a carpeted floor mat, why haven't these floor mats been recalled?

Brakes Always Overcome Throttle

Toyota has also defended its system by alleging that the brakes can always overcome the throttle. NHTSA has validated this claim: "Three general factors are identified that may affect brake effectiveness during a UA event: (1) brake malfunction; (2) brake fade; or (3) reduced vacuum assist not related to a malfunction. Brake malfunction is the only one of these factors that could affect brake effectiveness on the initial brake application in a UA event. No evidence of such malfunctions has been found in post-incident inspections and service of vehicles involved in UA events."[95]

Yet many VOQ scenarios describe UA events that occurred when the driver was braking, and the NHTSA-NESC reports acknowledge this sequence. For example, Table 6.8-1 of the NESC report describes six incidents, four of which state that the sudden acceleration started while the driver's foot was on the brake.[96] The NHTSA report repeatedly observes that a significant number of complaints involve drivers who complain that they were braking when the UA event occurred:

"Further review of the stationary and low speed incidents (combined) found that parking lot entry and exit accounted for the largest share of these incidents (40% of VOQs 64% of crashes. Many of the parking maneuver narratives reported incidents characterized by

[94] ODI Number 10203221; National Highway Traffic Safety Administration (NHTSA); September 11, 2007

[95] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 31; National Highway Traffic Safety Administration (NHTSA); Feb. 2011

[96] Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation; Pg. 154; Michael T. Kirsch; NASA Engineering and Safety Center; Jan. 18, 2011

high engine power either after the driver applied the brake or immediately after shifting the transmission."[97]

Yet, neither report describes any tests performed while the service brakes were applied, based on NHTSA's belief that if the driver's foot was really on the brake, then the vehicle would not have accelerated because the brakes can always overcome engine torque. Therefore, if permanent brake malfunction cannot be proven, then the brakes must be effective in stopping UA.

However, NHTSA's assumption the only three factors affect brake effectiveness on the initial brake application in a UA event is incorrect. Not all Toyota vehicles use vacuum assist to provide power brakes. Many Toyota vehicles today, including all hybrid vehicles, use an electric pump instead of vacuum assist to provide the pressure for power brakes. The electric pump pumps nitrogen gas into an accumulator. The pump turns on when the ignition is turned on, and runs for about 15 seconds. It also runs intermittently any time that the accumulator pressure is low, due to brake use. The accumulator allows about 6 to 7 pumps of the brake before all the pressure is depleted.

Because the pump is a DC electric motor, it can become overheated due to too much torque or to overuse. If it does, the pump will shut down to prevent damage to it. This means that it is possible for the accumulator to become depleted, causing the hydraulic brakes to operate in a non-power assisted fashion. This loss of power assist could be interpreted by a driver as loss of brakes. Failure of the electrical power to the electric pump can also cause the loss of pump operation, leading to loss of braking effectiveness.

Further, regardless of the type of braking power assist, a malfunction of the ABS brakes could produce a similar result. The electronic control unit for the ABS brake system reads the wheel speed sensors, calculates whether they indicate that a wheel is beginning to lock up, and then switches valves that pulse the brakes at about 50 times per second. In other words, the ABS brake system temporarily reduces and then re-applies the brake pressure to the wheels created by the hydraulic brakes. It may be possible for some malfunction in the electronics to reduce the brake pressure to all wheels, leaving the driver with only power un-assisted hydraulic brakes. There are at least two possible connections between the ETCS-i throttle system and the ABS brake system that can fail: the stop light switch; the power supply system; and the CAN bus system. If ABS brakes malfunction, this could reduce the brake effectiveness by about 25 percent, which many drivers might interpret as the brakes not working.

NHTSA and NESC's belief that there is no connection between the ETCS-i and the ABS is based on an assumption that does not apply to all models: that all Toyota vehicles have only simple hydraulic brakes with vacuum power assist, and not with electric pump power assist, or with ABS as an option. This simple view of braking operation may have been true in the 1980s, but it does not reflect today's fleet. Nonetheless, this view has

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[97] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 36; National Highway Traffic Safety Administration (NHTSA); Feb. 2011

biased NHTSA and NESC's investigations into sudden acceleration by eliminating possible causes of brake loss that should be experimentally investigated.

Sticky Accelerator Pedals

NHTSA's most recent report states: "NHTSA identified two types of vehicle-based mechanical defects as causes of UA. Those were related to pedal entrapment and 'sticky pedal.' While this problem generally involves occurrences at lower power levels where the car continues to accelerate because the pedal does not return fully, or returns slowly, when the driver lessens pressure on the pedal." In other words, sticking accelerator pedals is not a cause of high-speed UAs.

As described by Toyota, the so-called sticky pedals, manufactured by supplier CTS, were slow to return to idle and could become stuck in a partially depressed position. While this problem is clearly a safety defect, by Toyota's own account (and NHTSA's previous account) it doesn't lead to the type of unintended acceleration incidents reported by drivers. But NHTSA and Toyota have always enjoyed conflating the two, without offering any evidence that sticky pedals cause unintended acceleration events.

The President of Toyota Motor Sales, James Lentz, confirmed this in an exchange with the Oversight and Investigations Subcommittee of the House Energy and Commerce Committee:

"REP STUPAK: Do you have any analysis, any evidence that sticky pedals can cause a sudden, unintended acceleration?

MR. LENTZ: It depends on the definition of "sudden." If it means that you can be depressing a pedal, take your foot off the pedal and the car continues its speed, it does cause that.

REP. STUPAK: Quoting your counsel, "typically does not translate into a sudden high-speed acceleration event" — sticky pedals. So sticky pedals really isn't doing anything about sudden high-speed –

MR. LENTZ: Not for high speed."[98]

Despite this, NHTSA officials have publicly concluded that one high-profile SUA event at high speed was the result of a sticky pedal. Kevin Haggerty, an Avalon owner from New Jersey, also testified before Congress about his incident. Haggerty reported five SUA events. Several times, the vehicle accelerated without his foot on the gas pedal. The engine would return to idle after driving a few miles or after the Avalon shut down and restarted or was stopped and put into park. Haggerty's vehicle was checked at the dealership, but they could find nothing wrong. According to his NHTSA complaint:

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[98] Panel II: Hearing of the Oversight and Investigations Subcommittee of the House Energy and Commerce Committee; Subject: Response By Toyota And The National Highway Traffic Safety Administration To Incidents Of Sudden Unintended Acceleration; Feb. 24, 2010

> "Then on 12/28/09 I was driving to work on a major highway. The car began to accelerate without my foot on the gas pedal. As I pushed on the brake, the car continued to accelerate. At that time I was not able to stop my vehicle by pressing hard on the brake. The only way I was able to slow the car down was to put the car into neutral. I took the next exit, which was the exit for the Toyota dealership. I called the dealership and told the service manager to meet me outside because I was experiencing acceleration problems. I drove approximately 5 miles by alternating from neutral to drive and pressing very firmly on the brakes. As I pulled into the front of the dealership I put the car into neutral and exited the car. With the brakes smoking from the excessive braking and the car's rpm's racing the manager entered my car. He confirmed that the mats were properly in place and confirmed the rpm's were very high."[99]

The Haggerty incident is particularly notable because Toyota technicians witnessed the vehicle engine racing at full-throttle, in neutral, and no mechanical causes of the incident were found. Subsequent interviews with Mr. Haggerty revealed that the Toyota dealer contacted Toyota's regional representative in Caldwell, NJ, who later inspected the vehicle. The details of this inspection were not provided to the owner. However, Toyota Motor Sales authorized replacement of the throttle body and accelerator pedal assemblies and sensors and paid for the $1700 repair and rental car costs. The owner was told by the Toyota dealer that the vehicle's computer had stored no error codes, and they were unsure whether the repairs would fix the vehicle.

After Haggerty had his last UA experience, ABC News spoke with the service manager at Muller Toyota in Clinton, New Jersey. ABC News confirmed for SRS that the service manager stated that the pedal on Kevin Haggerty's vehicle was examined and was not stuck or out of position. The service manager also affirmed that he provided that information to NHTSA.

Toyota Has Replicated SUA with No DTCs

Among the many thousands of pages of documents Toyota has submitted to NHTSA are Field Technical Reports. These are records of inspections made by dealership or Toyota corporate technicians to investigate customer complaints. As part of the complaint filed in the multi-litigation district lawsuit, Toyota technicians have duplicated UA incidents without mechanical interference,

For example, a customer with a 2009 Tacoma with 2,387 miles complained that he was driving at 60 mph on a highway with the cruise control engaged, when he attempted to pass a slower vehicle on a slight incline.[100] The driver applied the accelerator and increased his speed to 75 mph to pass and then returned to his original lane and released

[99] ODI Number 10300210; National Highway Traffic Safety Administration (NHTSA); Dec. 28, 2009
[100] Amended Economic Loss Master Consolidated Complaint; Pg .117; United States District Court; Central District of California; Oct. 27, 2010

the accelerator. The vehicle, however, continued to accelerate and application of the brakes did not stop it. The driver cycled the key to the off position, and was able to slow the vehicle to a stop.

The dealership found the floor mats in place and properly secured, engine connections sound, but no DTCs stored in the engine computer. The dealership's service manager took the vehicle for a test drive on the highway, with the cruise control engaged at a 70 mph target speed on flat terrain. After slightly depressing the accelerator pedal, the vehicle "downshifted abruptly and accelerated at what was perceived as a high throttle angle."[101] "..The Service Manager removed his foot from the accelerator immediately upon the downshift and moved it completely away from the pedal area. The vehicle continued to accelerate at what felt like an estimated 70% throttle input with no pedal contact from the driver. Within 300 feet of the initial acceleration, the vehicle had reached 95 MPH. The estimated time to reach this speed from 71 MPH was 'between 5 and 10 Seconds.' The driver then applied the brake pedal and the acceleration stopped.'"[102]

In a second report, the dealership investigated a customer complaint that while at a stop, the engine started to "rev" and tried to "take off." The driver cycled the ignition three times before the revving stopped and the vehicle resumed normal operations. During a technical inspection: "Technician who was inspecting the vehicle had driven it approximately 10-12 minutes. 7-8 minutes into the drive the technician was sitting at a stop light. When the stop light changed the tech started to lightly accelerate. After traveling 20-30 feet the vehicle exhibited a slight hesitation then began to accelerate on its own. Engine speed was estimated to have gone from 1500 rpm to 5500 rpm at the time of the occurrence. Vehicle traveling 9-10 mph at time of occurrence. Approximate maximum speed reached was 20 mph prior to accelerator pedal release / brake application. Estimated throttle position at the time of the occurrence was 15-20 percent."[103]

These incidents, and others, can not be attributed to floor mats, sticking pedals or driver error – unless Toyota is willing to concede that its own technicians can't operate their products properly. What explains these unintended acceleration events?

Impact and Future Implications

The NHTSA's "exacting" study of Toyota's electronic throttle control system merely re-asserted what the agency has concluded since 2004 – that the causes of unintended

[101] Amended Economic Loss Master Consolidated Complaint; Pg .117; United States District Court; Central District of California; Oct. 27, 2010
[102] Amended Economic Loss Master Consolidated Complaint; Pg .110; United States District Court; Central District of California; Oct. 27, 2010
[103] Amended Economic Loss Master Consolidated Complaint; Pg .111; United States District Court; Central District of California; Oct. 27, 2010

acceleration are mechanical – via an errant floor mat or a sticking accelerator pedal – or due to driver error. Twenty-two years have passed since the agency commissioned the so-called "Silver Book," titled *An Examination of Sudden Unintended Acceleration*. Those decades have seen the advent new engine control modules, complex algorithms of code governing safety-critical tasks and transformation of essential, and formerly mechanical components, to sensors and signals. And yet, the agency's thinking about this issue remains mired in an era that has been virtually nonexistent for years.

It is some consolation, perhaps, that NHTSA has conceded that it is possible, under some conditions, that an electronic malfunction could cause an uncommanded open throttle without setting a diagnostic trouble code:

> "Failures that mimic valid accelerator pedal signals can be induced to produce large throttle openings. However, no single failure can produce such a condition. Two failures in the precise resistance range necessary to create the exact circuit configuration in the correct time phase are necessary for this functional failure to occur. As NHTSA understands the situation, the likelihood of two such specific failures occurring in a consumer's use of a vehicle in the precise resistance range and in the required sequence necessary to produce the UA condition is remote. Moreover, the occurrence of such failures outside of these very narrow conditions will always set a diagnostic trouble code (DTC)"[104]

However, the agency's use of qualifiers to bookend its conclusions ought to give the public pause. NHTSA narrowed its focus to "large throttle openings." This ignores many incidents, in which the degree of throttle opening may not exceed 25 percent, but the torque is sufficient to cause significant acceleration that can result in property damage, injury and death. Further, the NESC team uncovered circumstances in which Toyota's accelerator pedals produced an inconsistent response. Far from being a drivability concern, an accelerator pedal that does not deliver the degree of opening requested by the driver, is a safety hazard. More troubling, is that NHTSA has rested its case on the notion that electronically induced UA is a "remote likelihood." This implicitly brings into question the application of due diligence. A clearer definition of remote is in order. Highly critical components and systems require special attention. Such is the case with ETC systems.

The agency is already decades behind in regulating accelerator controls.

FMVSS 124 Accelerator Controls

In *Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems*, NHTSA describes its education in Toyota electronic engine controls as part of Preliminary Evaluation (PE) 04021: "During the course of the investigation NHTSA gained detailed knowledge of the Toyota ETC system's functionality through technical meetings held with Toyota's system engineers and from additional information obtained from Toyota,

[104] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 62; National Highway Traffic Safety Administration (NHTSA); Feb. 2011

much of which is proprietary or otherwise confidential in nature and, therefore, pursuant to Federal law and regulation, could not be released."[105]

At the time of this investigation, NHTSA was contemplating an upgrade to Federal Motor Vehicle Safety Standard (FMVSS) 124 Accelerator Controls. Rather than applying this newfound knowledge to the much-belated effort to amend a long-neglected safety standard, the agency walked away from the rulemaking. Just four months after it closed the PE with no finding of an electronic problem in Toyota and Lexus vehicles, the agency withdrew the rulemaking.

Although automakers began transitioning to electronic systems 16 years ago, today's systems are governed by a standard that was put into place in 1972 – when aviation fly-by-wire was born, but automotive systems were purely mechanical.[106] FMVSS 124 specifies the requirements for the return of a vehicle's throttle to the idle position when the driver removes the actuating force from the accelerator control or in the event of a severance or disconnection in the accelerator control system: 1 second for passenger vehicles and 2 seconds for light trucks. "The purpose of FMVSS 124 is to reduce deaths and injuries resulting from engine overspeed caused by malfunctions in the accelerator control system. The standard applies to passenger cars, multipurpose passenger vehicles (MPVs), trucks and buses."[107]

In the late 1980s, the agency began to field inquiries from automakers developing electronic throttle control systems. In a 1988 letter to Isuzu, for example, the agency noted that FMVSS 124 would apply to the new electronically based systems. [108]

In 1995, after seven years of issuing interpretations relating electronic systems to the mechanically-based standard, the agency asked for comments with the aim of revising the standard.[109] NHTSA asked automakers to respond to a variety of critical technical questions, such as, "Are there other predictable points of failure of an electronic control system?"[110] The agency also sought information about the fail-safes and redundancies of electronic throttle control systems.

In recounting the responses to this query, the agency noted: "In general, the comments of vehicle and engine manufacturers did not address the specific questions in the notice. Instead, they voiced a preference for rescinding the standard altogether, suggesting that

[105] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems; Pg. 5; National Highway Traffic Safety Administration (NHTSA); Feb. 2011
[106] Docket 69-20; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; 34 FR 15420; National Highway Traffic Safety Administration (NHTSA); Apr. l 8, 1972
[107] Laboratory Test Procedure for FMVSS 124 Accelerator Control Systems; National Highway Traffic Safety Administration (NHTSA); Apr. 20, 2000
[108] Interpretation letter to Koji Tokunaga, Isuzu; Erika Z. Jones; National Highway Traffic Safety Administration (NHTSA); Aug. 8, 1988
[109] Docket 95-93; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; 60 FR 62061; National Highway Traffic Safety Administration (NHTSA); Dec. 4, 1995
[110] Docket 95-93; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; 60 FR 62061; National Highway Traffic Safety Administration (NHTSA); Dec. 4, 1995

market forces and litigation pressure are sufficient to assure fail-safe performance without a Federal Motor Vehicle Safety Standard."[111]

The agency held a workshop in 1997 with the Truck Manufacturers Association (TMA) and the Alliance of Automobile Manufacturers' predecessor organization, the American Automobile Manufacturers Association (AAMA). Both reiterated that there was no need for a safety standard. Seven years after it first requested comments, NHTSA finally published a proposed rule.

The July 2002 NPRM proposed to explicitly state its applicability to new types of engines and throttle controls and added new test procedures to address different types of powertrain technology, including one to the measurement of engine speed under realistic powertrain load conditions on a chassis dynamometer. The agency considered this test ''technology neutral." The new standard would not expand in scope, nor become more stringent. For example, the original requirement covered single point failures – or disconnections at one end of the throttle cable. The proposed amendments did not seek to add multiple-point failures.

Despite the agency's attempt to establish fail-safe criteria that were performance rather than design-based, The Alliance and Toyota led the effort to push back the rule. The Alliance argued that FMVSS No. 124 should include a direct measurement of powertrain output to the drive wheels – this would better address the agency's desire for a technology neutral test. The advantage, the Alliance maintained, would be that the test could be used on hybrid powertrains in which engine RPM might not indicate drive torque. The Alliance suggested that the powertrain output test should measure speed creep – vehicle driving speed, instead of output horsepower or torque.[112] Toyota also argued for a speed creep test. It met with the agency to explain the potential difficulties with the proposed rule and show what Toyota would do under different fault conditions.[113]

Instead of forging ahead, in November 2004, NHTSA withdrew the rulemaking, saying it would do further research on issues relating to chassis dynamometer-based test procedures for accelerator controls. [114]

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[111] Docket 2002-12845-001; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; 67 FR 48117; National Highway Traffic Safety Administration (NHTSA); July 23, 2002

[112] Docket 2002-12845-001; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; Comment 14; Memo of meeting with Toyota; National Highway Traffic Safety Administration (NHTSA); Apr. 2, 2003

[113] Docket 2002-12845-001; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; Comment 13; National Highway Traffic Safety Administration (NHTSA); Mar. 4, 2003

[114] Docket 2002-12845-001; Federal Motor Vehicle Safety Standards; Accelerator Control Systems; Comment 16; Withdrawal of Rulemaking; National Highway Traffic Safety Administration (NHTSA); Nov. 10, 2004

Conclusion

Based on the evidence produced in the NHTSA and NESC reports, it is difficult to invest the same confidence in the Toyota electronic throttle control system as does Transportation Secretary Ray LaHood. The NESC team has described a safety net riddled with holes – of various sizes – into which undetected errors can be introduced. Many of these same holes have been verified by independent experts who were interviewed by Safety Research & Strategies. The NESC study showed that there are a variety of circumstances in which the Toyota system can fail without the ECU taking note and setting a Diagnostic Trouble Code – in direct contradiction to the heart of Toyota's defense against UA allegations in eight past investigations.

Tin whiskers, for example, are a well-known problem in electronics reliability. The safety-critical problems these tiny filaments can create are serious enough to merit a special section on NASA's website. The NESC team found the byproducts of tin solder in circuit boards – in 80-100 percent of its potentiometer pedal sample (depending on the sample size). How would the NESC team extrapolate that percentage to occurrences in the field, among the millions of Toyota vehicles so equipped? Is the NESC team satisfied, based on what is known generally about the formation of tin whiskers, and what the team found specifically in three out of three or four out of five potentiometer pedals, that it has uncovered all of the places tin whiskers might form, at what rate, under what environmental conditions and the full variety of resistive shorts they might produce? Is it "realistic" to claim that tin whiskers can not form resistive shorts at a critical circuit in the accelerator pedal position sensor based on the examination of three pedals? Is the possibility "remote" when the sample size is multiplied to the number of vehicles in the field? Would the NESC team stand before their peers and claim that testing of three components was enough, that the sample was scientifically defensible?

Further, the NESC team did not benchmark Toyota's system to its peers and the state of the art for automotive electronics. Its declaration that Toyota's safety system is robust is another claim without context. Rather, the NESC team documented aspects of a system that likely *would not* pass muster among other automakers. And the language used by NESC team leader Michael Kirsch in his briefings sounded more like marketing than a dispassionate scientific evaluation of, by all accounts, an electronic control system that lagged other systems even when it was introduced.

In conclusion, our analysis of the NHTSA-NESC partnership, as expressed in the contents of these twin reports finds:

- We continue to see a mismatch between the official statements about the NESC report and its actual contents. The NESC report did not exonerate Toyota's electronics. Rather, it concluded that, due to the complexity of the system, that "no reasonable amount of analysis or testing can prove electronics and software have no errors."
- The NESC report is not a definitive study of unintended acceleration in Toyota vehicles. It is a narrowly construed study of what might produce throttle openings

large enough to overcome braking. It ignores the role of torque in producing abrupt increases in speed that can result in a UA event.

- Toyota's safety system is not robust – the net designed to catch errors is riddled with holes of various dimensions.
- The NESC report is a collection of observations about these pivotal weaknesses in Toyota's electronic architecture that can, and in some cases, did, lead to an Unintended Acceleration.
- The NESC team's most significant findings were not pursued, or dismissed as "unlikely," with scant support or poor data analysis to buttress those conclusions.
- NHTSA and NESC failed to make credible use of either warranty or VOQ data to support their conclusions. In analyses of both data sets, researchers failed to use standard statistical methods and practices.
- NHTSA and NESC dismissed consumers' UA complaints as unreliable, because they were the result of publicity about the problem. This is a testable hypothesis, however, the researchers did not perform such a test. They treated it as a fact. An independent statistical analysis shows that owners of Camry vehicles equipped with ETCS-i reported UA at greater statistically significant rates than owners of Camry vehicles without ETCS-i, prior to publicity.
- The NESC team's conclusions regarding tin whiskers are troubling. Tin whiskers are a serious and ongoing problem in the manufacture of electronics. The discovery of tin whiskers growing in the circuitry of the accelerator pedal position sensor deserves much more weight than the NESC team gave it – The APP sensor circuit is a safety-critical component that can never be compromised. This area warrants further study.
- NHTSA's and NESC's contention that inconsistent pedal response is not a safety concern is inaccurate and sets a damaging precedent. A pedal that does not consistently respond to the driver requests when requested is a safety hazard – even if this is restricted to low-speed conditions. Drivers should not be responsible for mitigating a system that does not operate consistently.
- NHTSA, in failing to keep pace with automotive technology, has abnegated its responsibility to regulate and investigate sophisticated electronics. It has acceded to industry's wishes to allow the marketplace and litigation to serve as the regulators in this area.
- This was not an independent inquiry and it cannot be replicated or validated. It was commissioned by NHTSA officials who guided past investigations. Toyota was shoulder to shoulder with the NESC team, guiding its examination of its electronics system. The significant redactions throughout the report make it impossible to perform a thorough, independent analysis of the NESC findings.
- The warranty analysis used to undercut the significance of the tin whiskers discovery is not credible. NHTSA allowed Exponent, a science-for-hire firm employed by Toyota's counsel, to defend the automaker in a class-action suit to perform this analysis. The agency did not disclose this conflict of interest.

More damaging to public safety is how these reports have been conveyed to the general public. The Secretary of Transportation announced that these reports prove that there is nothing wrong with Toyota's electronic throttle control system, and the press gave these statements wide play. In ridding itself of the troublesome UA issue, NHTSA dismissed the validity of complaints from Toyota owners as the product of publicity. In an unrelated defect investigation regarding fuel spit-back in 2007-2008 Jeep vehicles, NHTSA Administrator David Strickland suggested that complaints to the agency, filed after Jeep owners found they shared a common problem on an Internet forum, may not represent "actual occurrences." The message to consumers is clear: *Stop complaining. We don't believe you.*

NHTSA's not-so-subtle discouragement to the contributors of one of the agency's most important surveillance tools, its willingness, as a defect investigator, to look past data that shows problems with Toyota electronics and the sluggish regulatory response does not bode well for the agency's relevance going forward. Further, these decisions carry important implications for the safety culture surrounding these verification systems.

What the NESC report actually shows is that there are gaps in the safety net, and that some of Toyota's manufacturing processes allow at least one critical circuit to become contaminated and develop short circuits. NHTSA adds these together and comes up with zero causes of a UA event. We believe that this report – even with its omissions and deficiencies – is an excellent starting point for further investigation. We urge the scientific community to pick up the issue where these reports leave off and make good use of this valuable information.