Appendix D. Summary of Test Scenarios

Technical Support to the National Highway Traffic Safety Administration (NHTSA) on the Reported Toyota Motor Corporation (TMC) Unintended Acceleration (UA) Investigation

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This Appendix documents the test scenarios completed by NASA for the National Highway Traffic Safety Administration (NHTSA) Toyota Sudden Acceleration Study.

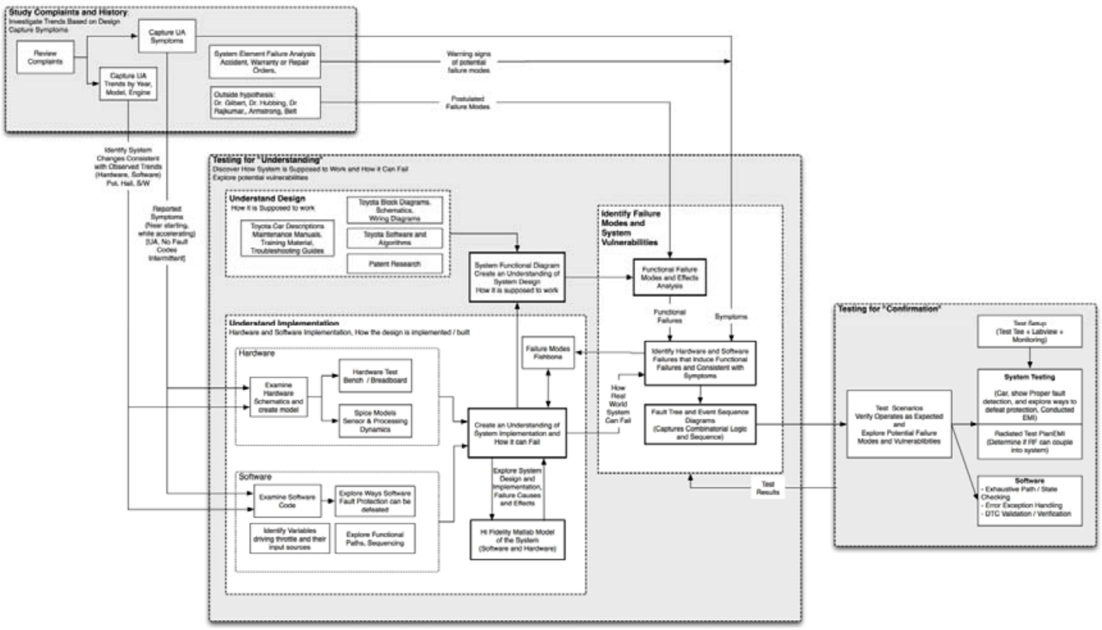

Figure D-1. Assessment Approach

Figure D-1 illustrates the flow the NESC followed in assessing potential design and implementation vulnerabilities in the TMC ETCS-i system that could possibly cause a UA. Exploratory analysis and testing looked at interactions of operational sequences and events along with one or multiple failure conditions. A significant amount of testing was completed to understand how the ETCS-i operates and what fail-safes exist. Once this "testing for understanding" was completed, more formal testing of test scenarios of operational sequences, and failure conditions was completed. For the purposes of this study, functional failures such as open circuit signal lines, short to ground, high resistance, shorts between signals and short to source voltage as well as potential design vulnerabilities in fault detection and mitigation were the primary focus. Monitoring of actual responses inside the ECM hardware was not possible; however, the software model and ASIC block diagrams did give a level of insight into system function. Model responses were compared to the hardware external responses. Likewise, potential faults related to timing margins were beyond the scope of this effort. Test scenarios were run on a range of vehicles to encompass major changes such as the potentiometer versus Hall Effect sensor changes and ECM evolution.

Test scenarios were developed based on analysis of software and hardware documentation. Table D-1 is a list of test scenarios, multiple individual tests grouped into themes, performed in the course of this study. Multiple tests were run for each Scenario with different failure conditions and on either a simulator or vehicle(s). Vehicle tests were performed at PARK or in idle, at speed or at both conditions. As noted earlier, testing was both for understanding and confirmation and the table indicates which were done for each scenario. Test for confirmation were more formal tests and included more thorough documentation than the tests for understanding.

Table D-1. List of Test Scenarios and Conditions

Function	*Scenario Title*	*Objective*	*Type of Test (Understanding or Confirmation)*	*Failure Condition*	*Test System/Condition (Simulator or Vehicle- PARK or at Speed)*
Throttle	Map the ECU response to throttle sensor inputs	Map ECU DTC response to throttle sensor signal range failures. Determine if there are dead zones and if they can be exploited an to force unintended acceleration	Understanding	Mapping	Simulator Vehicle - PARK/Idle
Throttle	Evaluate computer response to failures in the throttle sensors	Determine if series resistance in throttle sensor power, signal line (e.g. high resistance connector contact), or both together can result in erroneous throttle signals that cause the computer to open the throttle. Address the theory proposed by Rajkumar that a valid voltage bias on the throttle sensor signals might trick the feedback loop into opening the throttle further. Also, test for learning effects of sensor signal failures on the Idle Speed Control (ISC) system.	Understanding & Confirmation	Insert series resistance and noisy or failing resistance in the Vc (+5 V) supply line, sensor ground (5 Volt return) line, sensor output	Simulator Vehicle - PARK/idle, at Speed
Throttle	Evaluate throttle response to noise (AC, spikes, and DC variation) on the ECU power supply input (+12 volts) and/or output (+5 volts)	Determine if the ECU power supply is susceptible to noise.	Understanding	Conducted Susceptibility (CS) testing	Vehicle - PARK/idle, at Speed
Throttle	Evaluate throttle response to AC noise into the throttle sensor signal feedback loop on the PID controller	Determine if PID controller signal loop is sensitive to AC noise	Understanding	Phase/gain test set to produce Bode plot for the throttle control loop. AC sinusoidal variation to the VTA1 signal only, VTA2 signal only and VTA1 & VTA2 together and VPA1 signal only, VPA2 signal only, VPA2 signal only, and VPA1 & VPA2 signal together.	Simulator
Throttle	Evaluate motor/bridge failure detection logic (includes the motor, H-Bridge or Motor ASIC)	Test the effect of anomalous throttle motor drive on the electronic throttle system. Also investigate possibilities of throttle motor latch-up.	Understanding & Confirmation	Force the vehicle throttle to open using the simulator and the power (M+) line	Simulator Vehicle - PARK/Idle

Function	*Scenario Title*	*Objective*	*Type of Test (Understanding or Confirmation)*	*Failure Condition*	*Test System/Condition (Simulator or Vehicle- PARK or at Speed)*
Throttle	Evaluate effects of throttle angle on vehicle acceleration?	Collect data to measure the effect that throttle opening has on acceleration	Understanding	Release brake at throttle 3, 5, 10, & 18 % opening conditions & step throttle to 3, 5, 10, & 18% throttle opening at 30 mph	Vehicle - Idle & 30 mph
Throttle	Throttle angle air flow test	Understand air flow from different engine conditions	Understanding	Measure mass airflow at different engine conditions	Vehicle –Park and from 0 to ~60mph
Pedal	Map the ECU response to the pedal sensor inputs	Map engine ECU DTC response to pedal sensor signal range failures. Verify dead zones where faults may not be detected per software model results	Understanding	Mapping	Simulator Vehicle - PARK/Idle
Pedal	Evaluate throttle response to failures in the pedal sensors	Determine if anomalies in pedal sensor power, signal line or both together can result in erroneous pedal signals that cause the computer to open the throttle more than desired and test for learning effects of sensor signal failures on the Idle Speed Control (ISC) system.	Understanding & Confirmation	Step VPA1 signal from 0 to 5 volts in increments while the VPA2 signal is normal idle VPA1& VPA2 signal fail open circuit, short to (with resistance) +12 Volts, and short to ground Partially paired VPA1 and VPA2 signal with resistance and with added resistance & opens to the individual pedal signals	Simulator Vehicle - PARK/idle, at Speed
Pedal	Evaluate the pedal to throttle control loop stability and transient response	Test to characterize the pedal to throttle control loop phase and gain margin and transient response.	Understanding	Use phase/gain test set to inject signal across the 100 ohm resistor and produce Bode plot for the pedal to throttle control loop. Also characterize step response.	Simulator

Function	*Scenario Title*	*Objective*	*Type of Test (Understanding or Confirmation)*	*Failure Condition*	*Test System/Condition (Simulator or Vehicle- PARK or at Speed)*
Pedal	Characterization of defective pedal	Characterize a defective pedal mechanically, electrically and its 's performance	Understanding	Examine the defective pedal to determine its failure mode, cause, and effects on the vehicle under different conditions	Simulator Vehicle - PARK/idle, at Speed
Idle Speed Control	Evaluate throttle response to failures in electrical load sensors	Test effect of electrical load switch signal failures on the electronic throttle system.	Understanding	Fail the sensing signals from the Air Conditioning, Headlamp, and Radiator Fan electrical load on/off signals	Vehicle - PARK/Idle
Idle Speed Control	Evaluate throttle response to failures in mechanically load sensors	Test effect of mechanical load switch signal failures on the electronic throttle system.	Understanding & Confirmation	Fail the sensing signals from the engine coolant temperature, temperature of air flow, timing, Crankshaft and camshaft signals (timing, crankshaft & camshaft to noise also)	Vehicle - PARK/idle, at Speed)
Cruise Control Vehicle	Evaluate cruise control switch failures for increased acceleration	Test warning signs that switches may get stuck on and/or be susceptible to noise inducing unintended set speed	Understanding & Confirmation	Fail the signal by short to +12 Volts, short to Ground, and resistive shorts to Ground.	Vehicle at Speed
Cruise Control Vehicle	Evaluate cruise control switch failures for increased acceleration	Test warning signs that switches may get stuck on and/or be susceptible to noise inducing unintended set speed	Understanding & Confirmation	Fail the switch to set state and accelerate, attempt to “CANCEL” or “OFF” using the Cruise Control switch	Vehicle at Speed
Cruise Control Vehicle	Evaluate the effects of noise introduced into the cruise control line on unintended increased throttle angle	Determine if the Cruise Control system is susceptible to noise inducing unintended set speed.	Understanding & Confirmation	Conducted Susceptibility testing	Vehicle at Speed

Function	*Scenario Title*	*Objective*	*Type of Test (Understanding or Confirmation)*	*Failure Condition*	*Test System/Condition (Simulator or Vehicle- PARK or at Speed)*
Cruise Control Vehicle	Evaluate brake switch failures effects on preventing the cancelling of cruise control	Test effect of failed brake switch and its effect on cruise control enable/cancel and determine if DTC is set	Understanding & Confirmation	Fail the normally open & closed signal, and apply brakes when engaged and engaging enable/cancel switch. Enable Cruise control and restrain the brake plunger and verify vehicle maintains speed when brake is pressed. Press the brake as if to cancel the cruise control.	Vehicle at Speed
Trans-mission Shifting	Evaluate torque converter lock up on speed increase	Test to determine whether the vehicle reaches a steady state under load with a given accelerator position and if it continues to demand an increase in throttle	Understanding & Confirmation	Dynamometer - 150 ft-lb. load - increase speed past torque convertor lock–up of ~34 mph	Vehicle at Speed
Fuel Cutoff	Fuel cutoff test	Evaluate conditions for Fuel Cutoff	Understanding & Confirmation	Record conditions that cause each of the Fuel Cutoff modes to engage and disengage	Vehicle - PARK/idle, at Speed
Inspection and evaluation of complaint cars	Inspection and evaluation of complaint cars	Characterize available suspect vehicles in an attempt to replicate the initial complaint, including possible fault traces.	Understanding	Measure voltages, resistances, DTC's and inspect for anomalies	Vehicle - PARK/idle, at Speed