Motor Vehicle Defect Petition to Recall All Tesla Vehicles Due to Sudden Unintended Acceleration

Ann Carlson, Acting Administrator
National Highway Traffic Safety Administration
400 Seventh Street, S.W.
Washington, DC 20590

4 August 2023

Dear Acting Administrator Carlson,

This letter provides additional supporting information for petition DP 23-002 to reopen investigation DP 20-001 that NHTSA denied on January 8, 2021. To provide context for this new information, some previous information provided earlier will be included.

1. The following observations about Tesla's Model 3 inverter hardware have been made by R. Belt:
    a. Two analog accelerator pedal signals V_{sig}(analog) are digitized by two different ADC's.
    b. Digitization requires obtaining the unknown voltage values V_{sig}(digital) from the numerical outputs N_{sig} of the two ADC's. This requires calibration of the two ADC's.
    c. Calibration requires digitizing the same known calibration voltage V_{cal}(analog) by the two ADC's and then finding their actual numerical outputs N_{cal}. The ratio V_{cal} / N_{cal} is then stored in digital memory and used to multiply the measured ADC outputs N_{sig} to obtain the unknown voltage values V_{sig}(digital) using the equation $V_{sig}(\text{digital}) = N_{sig} (V_{cal} / N_{cal})$.
    d. The same calibration ratio V_{cal} / N_{cal} is used for both ADC's until a new calibration is performed minutes later.
    e. The known calibration voltage V_{cal}(analog) is a fixed fraction of the supply voltage for the two accelerator pedal sensors. This calibration voltage is used when the accelerator pedal sensors are ratiometric. Ratiometric sensors, when processed correctly, reduce errors caused by slow changes in the supply voltages due to thermal effects.
    f. If while digitizing the known calibration voltage V_{cal}(analog), the measured values of N_{cal} should decrease, then the calibration equation in paragraph c above shows that the digitized values of V_{sig}(digital) will increase even though the analog values V_{sig}(analog) do not change.
    g. When this happens, the digitized signals V_{sig}(digital) in both ADC's will increase by exactly the same ratio because both ADC's are calibrated using the same calibration voltage V_{cal}(analog).
    h. The two accelerator pedal sensor sensors have outputs A and B that differ by a fixed ratio of A = 2B.
    i. When the accelerator pedal is not pressed, the two accelerator pedal sensors have non-zero outputs of about a half a volt and a quarter of a volt.
    j. When these two non-zero digital outputs are multiplied by the same fixed ratio produced by a calibration error in the two ADC's, then the increased digital outputs fall higher on the same transfer curves as the original

accelerator pedal sensor outputs, giving the false impression that the accelerator pedal has been pressed even when it has not been pressed.

k. The result of the above observations is that both digital accelerator pedal sensor signals V_{sig}(digital) can increase up to the maximum value of 100% while the analog accelerator pedal sensor outputs V_{sig}(analog) remain at their lowest (un-pressed) values. The increased accelerator pedal sensor signals V_{sig}(digital) will mimic in every way the digital signals produced by the driver stepping on the accelerator pedal. This can happen without anyone even touching the accelerator pedal.

l. All the above observations are true and have been verified by analyzing the actual design of Tesla's Model 3 inverter. This verifies that the change in a single voltage value V_{cal} can increase both accelerator pedal signals V_{sig}(digital) from the two accelerator pedal sensors for a time period that lasts as long as the same calibration is stored in digital memory until a new calibration is performed minutes later. Experimental verification of these observations can be performed by operating the Tesla inverter using a lower calibration voltage V_{cal}. That all of the above is true is a strong indication that an error in the calibration voltage is a cause of sudden acceleration in Tesla vehicles. This establishes a strong need for an experimental investigation of how the calibration voltage V_{cal} can be changed.

(New Information). If one looks at Exponent's report entitled **"Analysis of Toyota ETCS-I System Hardware and Software"** dated 12 September 2012, it says on pages 125 and 126 that while testing a 2002 V6 Camry and a 2007 V6 Camry at idle, they found that "if the supply voltage for the circuit generating VTA1 and VTA2 [the analog outputs produced by the two APP sensors] drops due to a series resistance fault, then since the Hall effect sensors are ratiometric, a drop in the supply voltage to the sensors results in a drop in [the analog sensor outputs] VTA1 and VTA2. The algorithm in the ECM compensates by opening the throttle further." This implies that the algorithm in the ECM is acting like a calibration algorithm that increases the digitized accelerator pedal signals by the same amount that the analog accelerator pedal sensor supply voltage and outputs decrease, causing the throttle output to remain constant. This behavior is exactly what is discussed in R. Belt's papers as the normal behavior of a calibration algorithm acting on ratiometric sensor outputs during ADC digitization. If this is the normal behavior, then a few hundred microsecond dip in the +5V sensor supply voltage during its digitization for calibration purposes will cause an increase in the digitized APP sensor voltages that can cause sudden acceleration while the driver's foot is off the accelerator pedal, as discussed in Belt's papers. This Exponent reference discussing Toyota vehicles provides further evidence that R. Belt's explanation of the cause of sudden acceleration in Tesla vehicles is correct. It also implies that these two Toyota vehicles, and perhaps all Toyota vehicles with electronic throttles, may be susceptible to the same cause of sudden unintended acceleration as alleged in Tesla vehicles according to Belt's papers.

m. The only thing that has not been verified yet is a cause for why the calibration voltage V_{cal} might change. This cause has been hypothesized to be a voltage dip in the 12 volt supply voltage caused by the inrush current of the electronic power steering motor when it turns on while turning the front wheels. The following observations, some of which are new, support this hypothesis:

   i. Millions of GM vehicles have had transient voltage dips of less than eight volts produced by the power steering motor.
   ii. Most of these GM vehicles use column power steering with small motors that have static currents of about 70 amps.
   iii. Tesla vehicles are heavier and require larger power steering motors that have higher static currents of over 100 amps.
   iv. The maximum current provided by Tesla's 12V lead acid battery is only about 100 amps. This is marginal for supporting the static current requirement. But it is insufficient for supporting transient current requirements. Tesla's DC/DC converter cannot support transient current requirements because its output impedance limits currents for times as short as several hundred microseconds.
   v. The transient inrush currents of electric motors are three to five times higher than their maximum static currents, and generally last for several hundred microseconds.
   vi. The transient inrush currents of electric motors like an ICE starting motor can cause the 12V supply voltage to dip below 8 volts even with a fully charged battery.
   vii. Tesla's 12V batteries frequently operate with low SOC values that produce lower voltage dips on the 12V supply bus. The low SOC values mean there is less positive charge in the battery to negate a transient negative current that discharges the battery. This means that with low SOC values, transient voltage dips much lower than eight volts can be produced.
   viii. This hypothesis is compatible with the operation of the TLF35584 power management integrated circuit (PMIC) chip that supplies the supply voltages to the accelerator pedal sensors and the ADC's.
   ix. This hypothesis can be verified experimentally by measuring the amplitude and duration of the transient inrush currents produced by the power steering motor and by injecting transient currents having a similar amplitude and duration into the 12V supply line at known times to determine how the calibration voltage V_{cal} can be changed.

Another less likely possibility is that the drop in the calibration voltage V_{cal} is caused by a momentary failure of the connector contacts between the voltage regulator and the two accelerator pedal sensors in which the contacts become momentarily open. **In either case, because a momentary drop in the APP sensor supply voltage being used as a calibration voltage can cause sudden unintended acceleration, NHTSA must conduct an experimental investigation to determine how the calibration voltage can be changed.**

2. Tesla's incident rate for the driver stepping on the wrong pedal far exceeds the incident rates of other manufacturer's vehicles. If all sudden acceleration incidents are really caused by pedal confusion, then Tesla's incident rate should be the same as for all other vehicles. The pedal confusion hypothesis cannot explain why Tesla's incident rate is higher than for other vehicles. But Belt's theory can explain why Tesla's incident rate is higher than for other vehicles.

3. Tesla has one incident where the vehicle accelerated while the driver was outside the vehicle. The pedal confusion hypothesis cannot explain this incident. Belt's theory can.

4. Tesla has two more incidents where the vehicle accelerated in reverse while the vehicle was in self-park. In the first case the driver initiated vehicle motion by pushing a start button with her hand while not pushing on any foot pedals, so pedal confusion is impossible. After the acceleration began, the driver pressed on the brake pedal, but not in time to prevent a crash. Pedal confusion cannot explain this incident of sudden acceleration. Belt's theory can. Here is the first incident:

> "My Tesla Model 3 was so new that didn't even have the license plate yet. I've done self-park quite a few times, and even went to the sales center to confirm the way to engage self-park. When the vehicle senses the space and you go reverse, the blue start button will come on. So you can press it and let the auto self-park. Sadly, the self-park caused the accident on 11/30/18 when I was on Lyon Street in San Francisco. When I pressed on the reverse 'start' button, the car went uncontrollably (like a demon was in the car) and hit the rear parked car. I could barely hit the brake in time to stop the zoomed reverse. This accident not only damaged my new Model 3, it hit the bumper and headlight of another parked vehicle. The incident truly traumatized me on the Tesla car functions. Thankfully, there was not any upcoming rear traffic. With the self-reverse speed, the accident could be a lot worse. Tesla insisted that it is not an auto-pilot or self-park issue. They said we have to wait 4 weeks for the engineering review and report. After waiting for the Tesla report for 4 weeks, they claimed the vehicle was 'not' engaged in the 'self-park' function. --- Well, why would the blue 'start' button be available for me to believe that the self-park was ready????? They made the excuse the creep function was activated. That is ridiculous! If the blue 'start' button was available for self-park, driver would assume the vehicle is ready to be parked. Who would guess the vehicle would zoom back uncontrollably? Can you imagine how dangerous this is for all the self-park drivers and passengers? The accident could be much worse. NHTSA must initiate an investigation and provide a finding for this Tesla self-park issue!"
>
> [redacted]

And here is the second incident (new information):

> ***S-Car.Go:*** "Let me describe in a bit more detail how my near rear collision occurred while auto parking, and Tesla's analysis of my data log".
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> "I back into my parking spaces every morning in the parking structure at the hospital where I work. While backing up I use my foot on the brake, releasing it and pressing it as needed to allow my 2017 Model S to "creep" slowly backwards until I am close to the wall behind me. I use the rear camera, and direct visual observation to determine my position. If I am backing up between two cars, the Automatic Parking notice may come up, which is what it did last

week. I normally ignore it. But just out of curiosity I tried it when my incident occurred. As noted when I reported this incident, the first time I tried this it worked. But the next day when I tried it a second time, in order to initiate auto-park, I must keep my foot on the brake and either click the "start" button on the screen, or the "not this time" button on the screen. When I tried this, I clicked "start" on the screen, lifted my foot off the brake, and as soon as I did, I noticed the alarming speed at which the back-up was occurring. I quickly pressed down on the brake again, fortunately only gently hitting the back wall with no damage. Typical reaction time for something like this is between 300-500 milliseconds, which is probably about the total time for this entire event. I allowed the auto-park to begin when I was about 3-4 feet from the back wall of the garage. As quick as my reaction time is, it would have been physically impossible for me to lift my foot off the brake, push the accelerator and then return my foot to the brake without a full-force crash into the back wall within the time between hitting start and stopping the car. I reported this immediately to Tesla who downloaded the log".

"After a week, my local service center, (which I like a lot by the way), wrote to me saying that the log indicated the driver "pressed the accelerator." You be the judge: I believe the technician was accurately reporting what the log said. But I suggest that the reading from the log did not distinguish between the acceleration generated by its own algorithm, and me as the driver pressing the accelerator".

"For those of you on this forum who have been skeptical of these reports of unwarranted acceleration, I invite you to try this yourself. And even if the back-up speed seems to be working normally, see whether you would have the time to release, start the auto park, release the brake, depress the accelerator and hit the brake again without hitting a barrier 3-4 feet behind you and damaging your bumper". [redacted]

(New information) As one of the drivers in these incidents explains, Tesla's vehicle requires that the driver's foot be pressing on the brake pedal while the blue 'start" button is pressed manually in order to start the auto-park function. The vehicle then begins moving when the driver lifts his foot off the brake pedal. At this point the vehicles accelerated uncontrollably in reverse. Both drivers attempted to re-apply the brake pedal, but the short distance involved (3-4 feet) did not leave enough time (300-500 milliseconds) to bring the vehicle to a stop before a crash. In both cases, Tesla accused the driver of causing the incident by stepping on the accelerator pedal. This implies that the accelerator pedal sensor reading was increased during the incident when it should not have been. But this would have required the drivers to remove their foot from the brake pedal, depress the accelerator pedal, and then hit the brake pedal again without hitting the vehicle or wall behind – actions that both drivers maintain could not have been performed within the short time available. Instead, they maintain that they kept their foot over the brake pedal where it was originally. They then tried to press on the brake pedal to stop the vehicle, but the time was too short to avoid a crash. There was no pedal confusion in this case because the vehicle confirmed that the driver's foot was on the brake pedal to begin the auto-park function. And there was no reason for them to remove their foot from the brake pedal to step on the accelerator pedal while the vehicle was in the process of auto-parking.

Instead, they kept their foot over the brake pedal, which allowed them to immediately apply the brakes. But the time was too short. So, what could have caused the increase in the accelerator pedal reading? The only plausible answer is that the vehicle itself caused the increase in the accelerator pedal reading by the mechanism explained in R. Belt's papers. Claiming that the drivers stepped on the accelerator pedal to cause the increase in the accelerator pedal reading not only requires that one completely dismiss the testimony of both drivers, but leads to an implausible answer to the question of why a driver would apply the accelerator pedal when it is not needed, when there is no pedal confusion, and when it is even dangerous to do so. So, pedal confusion cannot explain these two incidents of sudden acceleration. Belt's theory can.

5. It just doesn't make any sense for a driver to suddenly jam on the brakes or to suddenly mash the accelerator pedal the floor while moving slowly in a confined space like a garage or a parking lot, or while pulling into a parking space in front of a store. Here is an example of a driver's explanation of the situation:

> [redacted]: *"I just had the same experience with a Tesla S. If it hasn't happened to you, you can easily think it is driver's error. But the actual experience is so shocking that there is no way a person could floor the accelerator and cause the car to suddenly go like gangbusters and not know--especially in a garage or stopped at a traffic light where you would be braking gently. It's like nothing you have ever experienced. But, as I said, it's easy to dismiss if you haven't experienced it. I wonder if the log can actually tell whether the accelerator was pressed or not [rather than just indicating a higher accelerator percent value]. Rather, it seems to be a malfunctioning linkage that is expressed, giving the impression that the accelerator pedal was pressed".*
>
> [redacted]

   This is a typical driver's story, with a non-typical insight about the accelerator pedal log data. This insight is developed further into a complete explanation for the cause of Tesla sudden acceleration in R. Belt's papers provided to NHTSA.

6. Some Tesla SUA incidents have occurred while the vehicle was stopped at a traffic light. In this case, no pedals were being suddenly pressed, so there should have been no pedal confusion.

7. Tesla's SUA incidents have a high correlation with the front wheels turning at low vehicle speed. But pedal confusion cannot explain this correlation. Pedal confusion should occur any time the driver suddenly steps on the brake pedal, regardless of whether the vehicle is turning or not during the incident. Therefore, pedal confusion should not cause a higher probability for sudden acceleration when the vehicle is in a turning situation. Belt's theory, on the other hand, explains this higher probability by the fact that that the electronically powered steering system causes a dip in the supply voltage when the front wheels are being turned, and that this dip leads to the sudden acceleration.

8. There is evidence that Tesla brake lights are defective, either not turning on at all or turning on only after a time delay. At least three videos of long-term sudden acceleration in Tesla vehicles, one in Paris, one in China, and one in Oslo, Norway, show that the brake lights never came on during the long incidents. Are

we to believe that the driver never pressed on the brake pedal to try to stop the sudden acceleration? If we believe that pedal confusion was the cause of these incidents, are we supposed to believe that the driver was so confused in these incidents that he never attempted to take his foot off the accelerator pedal to attempt to step on the brake pedal, which would have caused the brake lights to turn on? Or are we to believe that the driver was so confused in these incidents that he never took his foot off the accelerator pedal but didn't even attempt to let up on the accelerator pedal even slightly to allow regen braking to take effect, which would also have caused the brake lights to turn on? It would seem that the pedal confusion hypothesis forces us to believe that the drivers in these incidents were so confused that they pressed the accelerator pedal to the floor immediately and never let up on it for the entire duration of the incidents, which lasted nearly a minute in time. This does not sound reasonable. It is more reasonable to assume that drivers in these incidents were attempting to apply the brakes to stop the vehicles. But the brake lights never came on because they were either permanently defective or had a delay in coming on. And the reason that the brake lights have never found to be defective by Tesla or by most drivers is that most Tesla drivers prefer to use one-pedal driving, in which case the brake lights are turned on by the regen system and not by the brake light switch. If someone objects that the brake/throttle override function would have stopped the torque in these cases if the driver was stepping on the brake pedal – an event that obviously didn't happen – then the answer to this objection is that brake/throttle override is applied in response to the brake light switch turning on. So no brake lights illuminated means no brake/throttle override activated, allowing the torque from the SUA-caused high accelerator pedal values to continue while the brakes were being applied. It is possible that the electric motor in the brake booster was also de-activated in these incidents by the same voltage dip that caused the sudden acceleration in the first place, requiring the drivers to press 3 to 5 times harder on the accelerator pedal than normal. This can be explained further by the author upon request by NHTSA. The sudden acceleration scenario provided by R. Belt can explain these incidents while the pedal confusion hypothesis leads to an irrational conclusion.

9. Drivers in some Tesla SUA incidents have testified that the drive motor sped up while the driver was braking or beginning to brake. Yet, EDR logs have never shown the brake pedal to be applied <u>before</u> the accelerator pedal data increased. EDR data always shows that the brake pedal was applied 2 to 3 seconds <u>after</u> the accelerator pedal data began to increase. NHTSA has used this driver's testimony as evidence of pedal confusion. But an alternative explanation is that the brake pedal was actually applied earlier, with the brake light switch <u>signal</u> in the EDR being delayed by 2 to 3 seconds. This can happen if there is stiction in the brake light switch. Such stiction has been observed in at least one Tesla and in the brake light switches of other vehicles. It may not have been observed in Tesla vehicles to date because the brake pedal is not used much in Tesla vehicles because of one pedal driving. Can such a stiction-caused delay in the brake pedal EDR data be ruled out?

10. When citing evidence that sudden acceleration is caused by pedal confusion, NHTSA must remember that direct observation of the driver's feet during these sudden acceleration incidents was not performed. The EDR data can only tell that the digital accelerator pedal data has increased. It cannot tell us that this increase is caused by the driver stepping on the accelerator pedal because the driver's feet were not being observed. So this is an inference, and not a direct observation. Being an inference, there may be other reasons why the accelerator pedal data has increased. One of these other reasons is that sudden acceleration may have caused the increase in the accelerator pedal data as explained by R. Belt's two papers on sudden acceleration in Tesla vehicles. Therefore, as a result of these papers, it is no longer reasonable to conclude that the accelerator pedal data can increase by only one cause. Similarly, the EDR data can only tell us that the brake light switch has been turned on or not. It is an inference whether the driver failed to press on the brake pedal or not because there may be other reasons why the brake lights did not turn on even when the pedal was pressed; namely, a defective brake light switch or a delay in the brake lights turning on. The situation is similar with brake pressure data, which Tesla has sometimes reported after getting it directly from the brake hydraulic module. But low brake pressure does not imply the absence of stepping on the brake pedal or the absence of braking because there may be other reasons why the brake pressure did not increase in an incident; namely, that the brake booster was inoperable during the incident.
11. Have any incidents of SUA ever occurred in autopilot where the EDR data shows that the accelerator pedal was pressed down? Normally, this should not happen. But if it did if, it could be explained by the same cause of sudden acceleration as proposed by R. Belt.
12. If SUA is caused by the accelerator pedal digital signal increasing while the analog accelerator pedal signal does not change, then the brake pedal would normally be pressed after the accelerator pedal signal has begun to increase, because the driver either heard or felt the acceleration. In this case, the brake-over-throttle function should cause the engine torque to stop, but only after the brake pedal switch signal is received by the ECM. If the brake light signal is delayed by stiction in the brake pedal switch, then the engine torque may decrease while the brake light signal is delayed because the brake pedal has been applied. This could result in the vehicle slowing down somewhat <u>before</u> the brake light comes on while the accelerator pedal signal is still near its peak. The sudden decrease in the accelerator pedal percent signal that follows the peak value may then be caused by the brake light coming on after a delay, initiating the brake/throttle override.

It is requested that NHTSA consider the above information in its review of petition DP 23-002, and, if the petition is rejected, include specific responses to this information in the written rejection.

Sincerely yours,

[redacted]

Ronald A. Belt

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https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-552 Rules for NHTSA petitions.

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Ann Carlson, Acting Administrator
National Highway Traffic Safety Administration
400 Seventh Street, S.W.
Washington, DC 20590

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