National Transportation Safety Board
Office of Highway Safety
Washington, DC 20594

HWY24MH013

TECHNICAL RECONSTRUCTION

Group Chair's Factual Report

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A. CRASH INFORMATION

Location: Swanton, Lucas County, Ohio
Date: August 15, 2024
Time: 5:29 am EDT

B. TECHNICAL RECONSTRUCTION GROUP

Group Chair Eric Gregson
National Transportation Safety Board

C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Information and Summary Report,* which can be found in the NTSB docket for this investigation.

D. DETAILS OF THE INVESTIGATION

The Technical Reconstruction Group was convened for this two-vehicle collision involving a Toyota sport utility vehicle (Toyota) and a Mack truck-tractor in combination with a Great Dane semitrailer (combination), to assist NTSB investigators with determining certain dynamics throughout the crash event; and to facilitate an evaluation of certain collision events and causation factor. In support of these tasks the group relied upon information, data and documentation provided by the Ohio State Highway Patrol (OSHP). Factual reports prepared by other NTSB investigative groups should be consulted for information related to other aspects of the investigation, including information referenced within this report.

E. FACTUAL INFORMATION

1.0 Crash Location

The crash event occurred in the eastbound lanes of Interstate 80/90 (also known as the Ohio Turnpike) (I-80), at the Global Positioning System (GPS) coordinates of 41.599778° latitude and -83.876903° longitude. Where the crash event began, I-80 consisted of two through high-speed travel lanes and two toll booth access lanes. The high-speed lanes and toll booth lanes were separated by a painted gore area that transitioned to a concrete barrier. Figure 1 is an area map depicting the approximate start of the crash event.

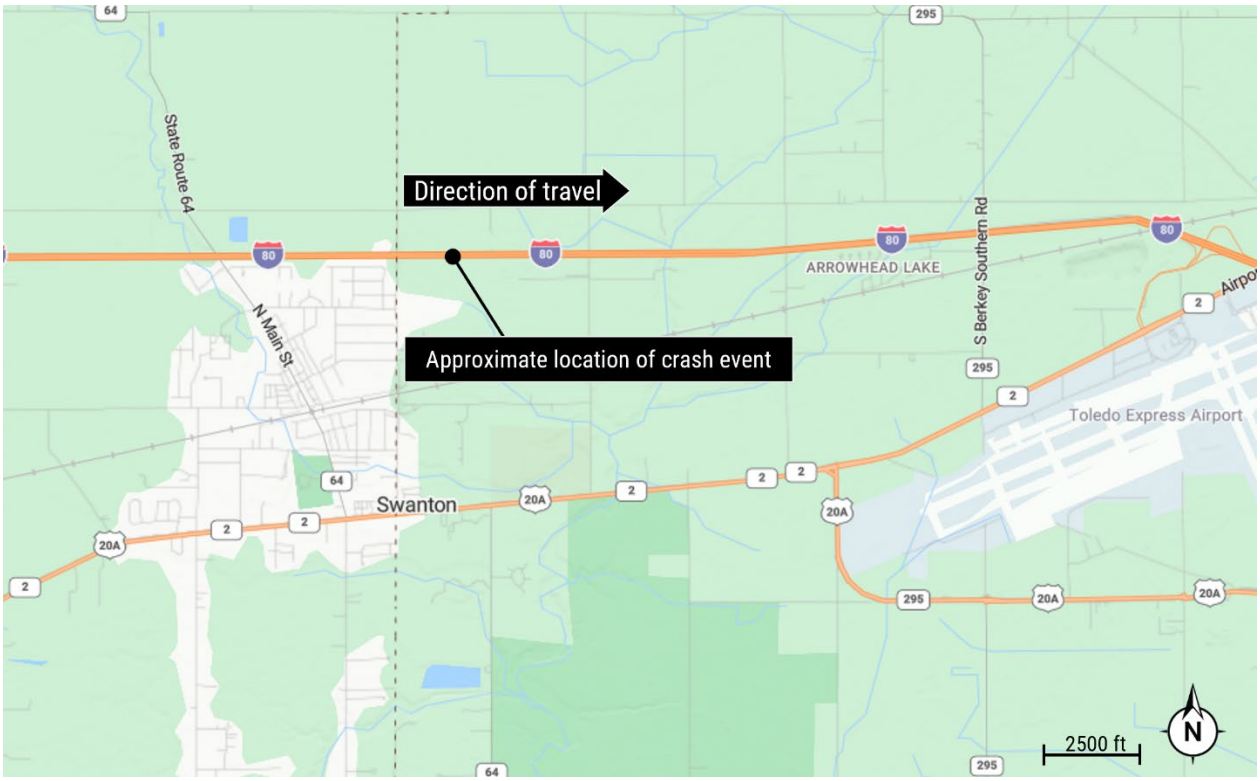

Figure 1. Area map depicting the approximate start of the crash event. (Source: Bing Maps revised)

The area of I-80 where the crash occurred was straight on a downhill grade of about (-) 0.34%.[1] The speed limit for the high-speed toll lanes on I-80 was 70 mph.

1.1 Post Collision Site Documentation and Roadway Evidence

The crash site was documented by OSHP investigators using terrestrial and aerial photography. OSHP investigators also established and marked ground control points (GCPs) which were collected utilizing their electronic total station.[2] NTSB investigators processed the sUAS photographs using Pix4DMapper photogrammetry software from which three-dimensional point clouds and two-dimensional orthomosaic images were generated for use in the analysis.[3]

[1] See the Highway Factors Group Chair Report for additional details.
[2] Ground control points – points on the surface that have known coordinates. The points are then utilized to geo-reference the points with the rendered three-dimensional point cloud.
[3] Pix4DMapper is a photogrammetry software package designed to use overlapping photographic images to generate 3D point clouds. Additional outputs from the generated point cloud include 3D models (textured mesh), digital surface and terrain models, and 2D orthomosaic maps. An orthomosaic is an image with high detail and resolution made by combining many smaller images and is corrected for lens distortion, camera tilt, perspective, and topographic relief.

OSHP identified and marked with orange spray paint a circular tire friction mark (TFM) in the right eastbound high-speed lane. The circular TFM (A) was located about 1,151 ft. west of the Swanton Township toll facility, and was about 3.5 ft. north of the white edge line. Contained within TFM (A) were scrape marks. TFM (A) transitioned from circular to a straight mark extending about 3.5 ft. eastward. Continuing eastward about 25 ft. a second circular mark was identified, TFM (B), and marked with orange spray paint by OHSP. Like TFM (A), TFM (B) was circular and contained scrape marks. A single mark, TFM (C), began about 6 ft. southeast of TFM (B) and continued southeasterly for about 56 ft. TFM (C) was straight with diagonal striations visible within the mark. Additional TFM's and roadway scars continued southeast at about a 17° angle, as compared to the direction of travel, concluding at the Toyota's position of final rest. Figure 2 is an image from the generated orthomosaic depicting the discussed roadway evidence which was consistent with post-impact travel of the Toyota.

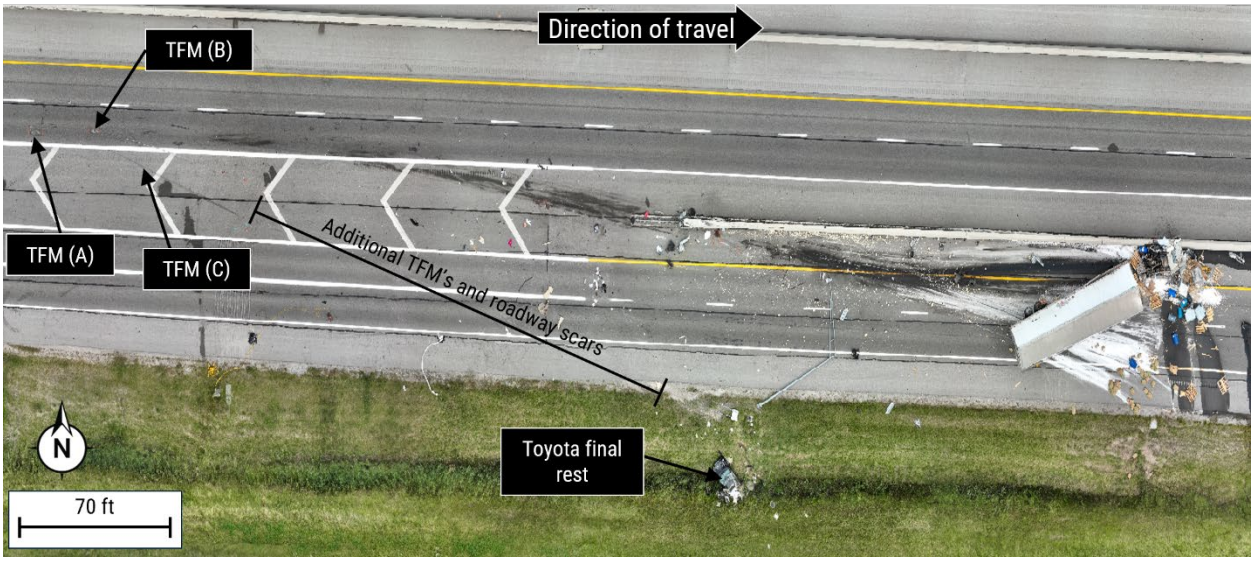

Figure 2. A selection of the orthomosaic image depicting roadway evidence and trajectory of TFM's and roadway scars from the Toyota – Annotated by the NTSB.

An additional series of evidence consistent with the post-impact travel of the combination was identified along eastbound I-80. Two TFM's began about 56 ft. east of TFM (A). The first of the two, identified as TFM (D), was about 4.3 ft. long and positioned about 2.3 ft. north of the white lane line delineating the gore area from the right high-speed toll lane. The second mark, TFM (E), measured about 6.8 ft. long and was positioned about 6.3 ft. north of the white line. Continuing east about 10 ft. from the end of TFM's (D) and (E) was a dark area consistent with engine fluids on the asphalt surface. The first area of fluid extended for about 26 ft. followed by a second area of fluid that continued southeast for about 123 ft. terminating at the beginning of the concrete barrier. Friction marks and scrapes were observed along the top of the concrete barrier at an angle from northwest to southeast. On the shoulder along the south side of the concrete barrier several friction marks, scrape marks, and fluid

continued to the combinations position of final rest. Figure 3 is a portion of the generated orthomosaic image depicting the discussed roadway evidence which was consistent with post-impact travel of the combination.

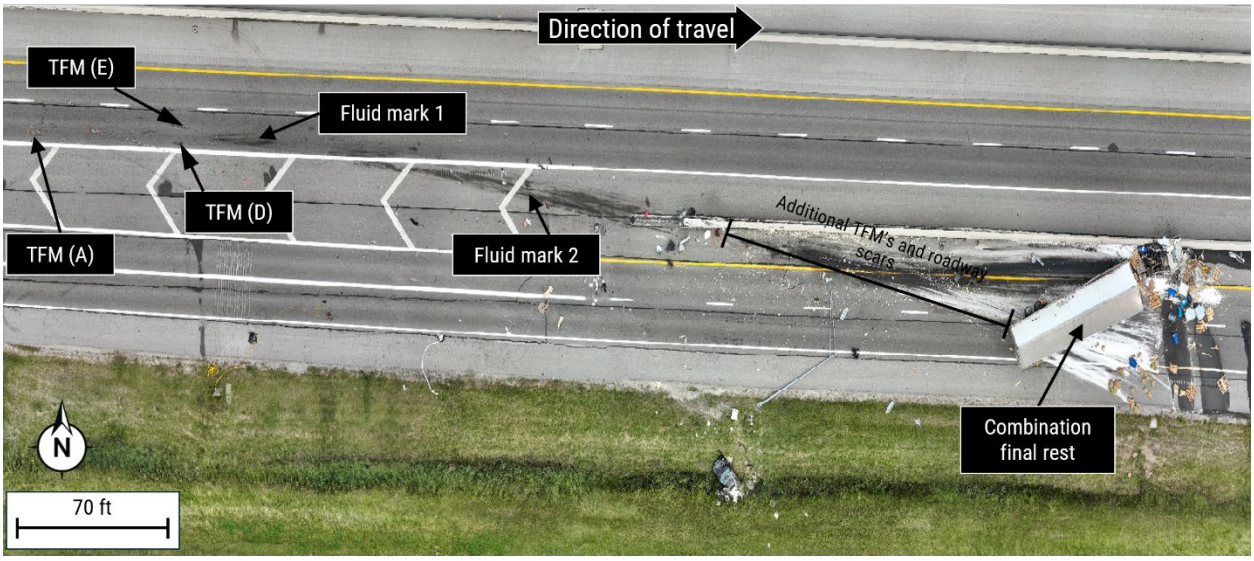

Figure 3. A selection from the orthomosaic image depicting additional roadway evidence and trajectory of TFM's and roadway scars from the Combination.

Table 1. Evidentiary marks and lengths.

Friction/Fluid mark	Length (ft)
A	3.5
B	N/A
C	56
D	4.3
E	6.8
Fluid mark 1	26
Fluid mark 2	123

2.0 Vehicles

One passenger vehicle (Toyota) and one commercial motor vehicle (Combination) was involved in the crash event. At its position of final rest, the Toyota was about 24 ft. off the south side of the roadway facing northwest and about 301 ft. from the area of impact. The combination was at its position of final rest facing northeast across the low-speed toll lanes about 446 ft. from the area of impact.

2.1 2019 Mack Truck-Tractor in combination with 2009 Great Dane Semitrailer

The unladen weight of the tractor were listed between 18,000 and 21,000 pounds. The semitrailer was listed between 13,000 and 15,000 pounds.[4] The semitrailer was loaded with hazardous materials. The bill of lading itemized the load along with the weight which was reported as 41,687 pounds.[5] The combination's weight at the time of the collision was between 72,687 and 77,687 pounds.
The cab portion of the tractor was torn from the frame mounts. All glass was shattered and missing. The roof line above the windshield was displaced rearward near the midline. The left saddle tank and left side step were displaced downward. The third axle was completely torn from the frame.

2.2 2015 Toyota Highlander

As manufactured, the Toyota had a published length and width of 15.9 and 6.3 ft., respectively, a wheelbase of 9.2 ft., and curb weight of 4,457 pounds.[6] Figure 4 is an image of an exemplar Toyota Highlander displaying certain dimensions.[7]

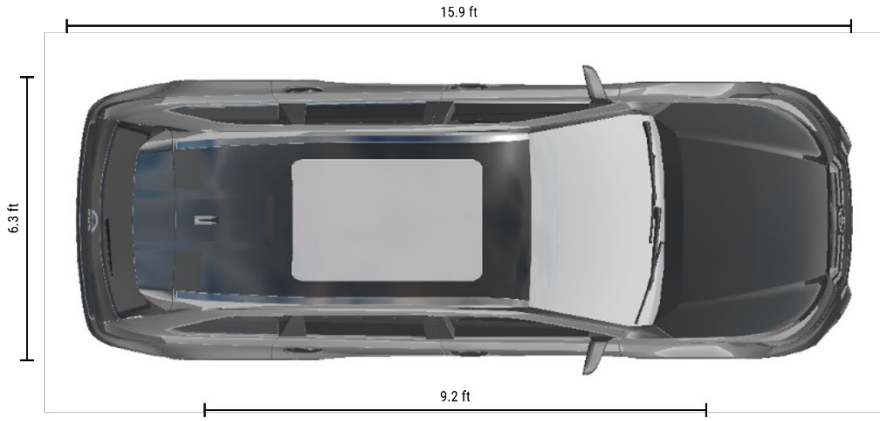

Figure 4. Top view of an exemplar model Toyota Highlander depicting certain measurements.

There were two areas on the Toyota that exhibited contact damage. The rear of the vehicle sustained severe damage. The rear hatch, left quarter-panel, left side passenger door and roof were torn, pushed forward and to the rear of the driver's door. The right rear corner, at the roof, was displaced inward towards the midline of the vehicle. The rear bumper, about the midline, was displaced inward with the left side corner pulled away from the vehicle. The second row left rear passenger seat back was collapsed forward into the back of the driver's seat. The second area of contact was along the front right fender above the wheel. The fender was pushed inward with the

[4] See the NTSB Vehicle Factors Group Chair Report for additional details.
[5] See the NTSB Hazardous Materials Group Chair Report for additional details.
[6] See the NTSB Vehicle Factors Group Chair Report for additional details.
[7] AutoStats

top being pushed downward. The right edge of the hood was pushed inward toward the center causing the top right corner to displace upward. The center of the hood was dented, in line with the fender damage, causing the top of the hood to buckle upwards. Additionally, multidirectional scratch marks were observed on the left fender, left "A" pillar, across the hood and roofline between the top of the windshield and front edge of the sunroof, and the left "A" pillar. Figure 5 shows two photographs of the damage the Toyota sustained. The left image shows the damage to the rear and the right image shows the damage to the front.

Figure 5. Two photographs depicting the damage to the Toyota.

3.0 Electronic Data

3.1 2015 Toyota Highlander

Light duty vehicles (GVWR of 3,855 kg/8,500 lbs. or less) manufactured on or after September 1, 2012, if equipped with an event data recorder must comply with rules enacted under 49 Code of Federal Regulation Part 563. As defined by Part 563, an event data recorder (EDR) means a device or function in a vehicle that records the vehicle's dynamic time-series data during the period just prior to a crash event (e.g. vehicle speed vs. time) or during a crash event (e.g. delta-v vs. time). The regulation further describes the data elements, sample rate, range, accuracy, and resolution. The EDR is generally contained within the electronic control unit (ECU) module – typically referred to as airbag control module (ACM). The ACM processes information from peripheral and internal sensors. When an acceleration or rollover threshold is met and deployment commands are issued, the EDR is triggered to record the associated event subsequently "locking" the data so not to be overwritten. Events not reaching a deployment threshold can still be recorded however, the data can be overwritten by subsequent events of greater magnitude.

3.1.1 Toyota Electronic Control Unit

The imaged airbag ECU reported a total of six trigger events providing data for all six records – two front/rear, two side, and two rollover events.[8] The first trigger event for this crash was a combination of a front/rear and side impact occurring 1 msec apart resulting in the deployment commanded of the side curtain airbag.[9] The maximum reported longitudinal change in velocity was 47.3 mph at 284 msec.

The next recorded event was classified as a rollover followed by an additional side crash. It was reported that the side crash event commanded the deployment of side curtain airbags as well as driver and front passenger pyrotechnic pretensioners.

Regarding occupant seat belt status, the records indicated a "On" status for the driver seat occupant and an "Off" status for the front passenger.

Pre-crash data were reported for 4.75 seconds leading up to time zero capturing multiple vehicle performance parameters.[10] The first data point was recorded 250 msec before the trigger (time zero), with subsequent data recorded at 500 msec intervals. All recorded events reported the same data during the recording period. At 4.75 seconds before impact, the vehicle was traveling about 43.5 mph. By time zero, the reported speed had decreased to 14.9 mph. Throughout the recording period, the accelerator pedal remained at 0% and the service brake remained "on". The steering input increased from -1.5° to -12.0° at time zero, indicating right steering input. Figure 6 is a graph depicting certain pre-crash data.

[8] The airbag ECU has two recording pages (memory maps) to store pre-crash data. Additionally, to store post-crash data, the airbag ECU has two recording pages for each accident type: two pages for frontal and rear crash, two pages for a side crash, and two pages for a rollover event.
[9] a) In airbag ECUs that record side crash events, both front/rear and side algorithms will wake up in an angular crash and record data separately with sequence times close together.
[10] "Time zero" is defined as "beginning of the crash event" and is the time at which the ECU algorithm is activated, a specific Delta-V is exceeded, or a non-reversible restrain device is deployed. Time zero may be defined differently for front, side, rear, and rollover events. All the pre-crash, event, cumulative change in velocity data, and deployment times are relative to "time zero".

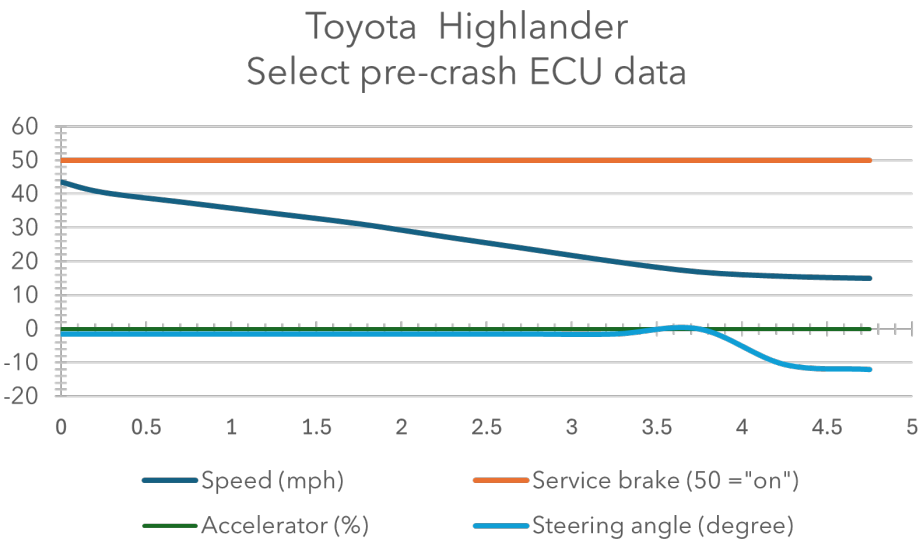

Figure 6. Graph depicting select pre-crash data from the Toyota ECU.

3.2 2019 Mack Truck Tractor

Electronic data recorded in heavy vehicles is not standardized across various engine manufacturers and if event or vehicle performance is recorded it can be in a proprietary format. A typical source of data is from the engine electronic control unit (EECU) associated with heavy duty diesel engines. Event data typically refers to acceleration events (hard braking), last stop records, and fault codes. When an event threshold is triggered data such as vehicle speed, accelerator pedal position, engine RPM, service brake status, etc. may be recorded in a time series format associated with the event.

The Mack was also equipped with the Bendix antilock brake system (ABS) and electronic stability program (ESP). Bendix ESP mitigates loss of control by monitoring sensors which detect steering angle, yaw rate, and acceleration, to prevent rollovers and oversteer/understeer situations. ESP can apply braking to certain wheels and reduce engine power when necessary.

OSHP investigators removed the EECU along with the Bendix ABS/ESP module. The modules were provided to NTSB investigators where they were then transported to the NTSB headquarters. On October 7th, 2024, both modules were transported to Delta V Forensic Engineering to be downloaded.

Recovered event data related to the crash included an acceleration triggered event and a last stop event. The recorded last stop event preceded the crash by about 3 hours and 185 miles. According to the parameters the hard braking threshold was set at -7.95 mph/s. The record contained 60 seconds of data preceding the

acceleration trigger reported at 0.25 second intervals. For the first 37 seconds prior to the trigger, the vehicle traveled at a consistent speed of 69.6 mph, with engine RPM ranging between 1500 and 1520 RPM, and the cruise control switch was reported as "on". For the remainder of the recorded 23 seconds, 38 to 60 seconds before the trigger, the speed varied between 69.0, 69.6, and 70.2 mph. Engine RPM was consistent and cruise control switch was "on". The service brake switch was "off" until 0.75 seconds before trigger when it reported as "on". Figure 7 is three charts depicting select pre-crash data

from the recorded acceleration triggered event of the Mack truck.

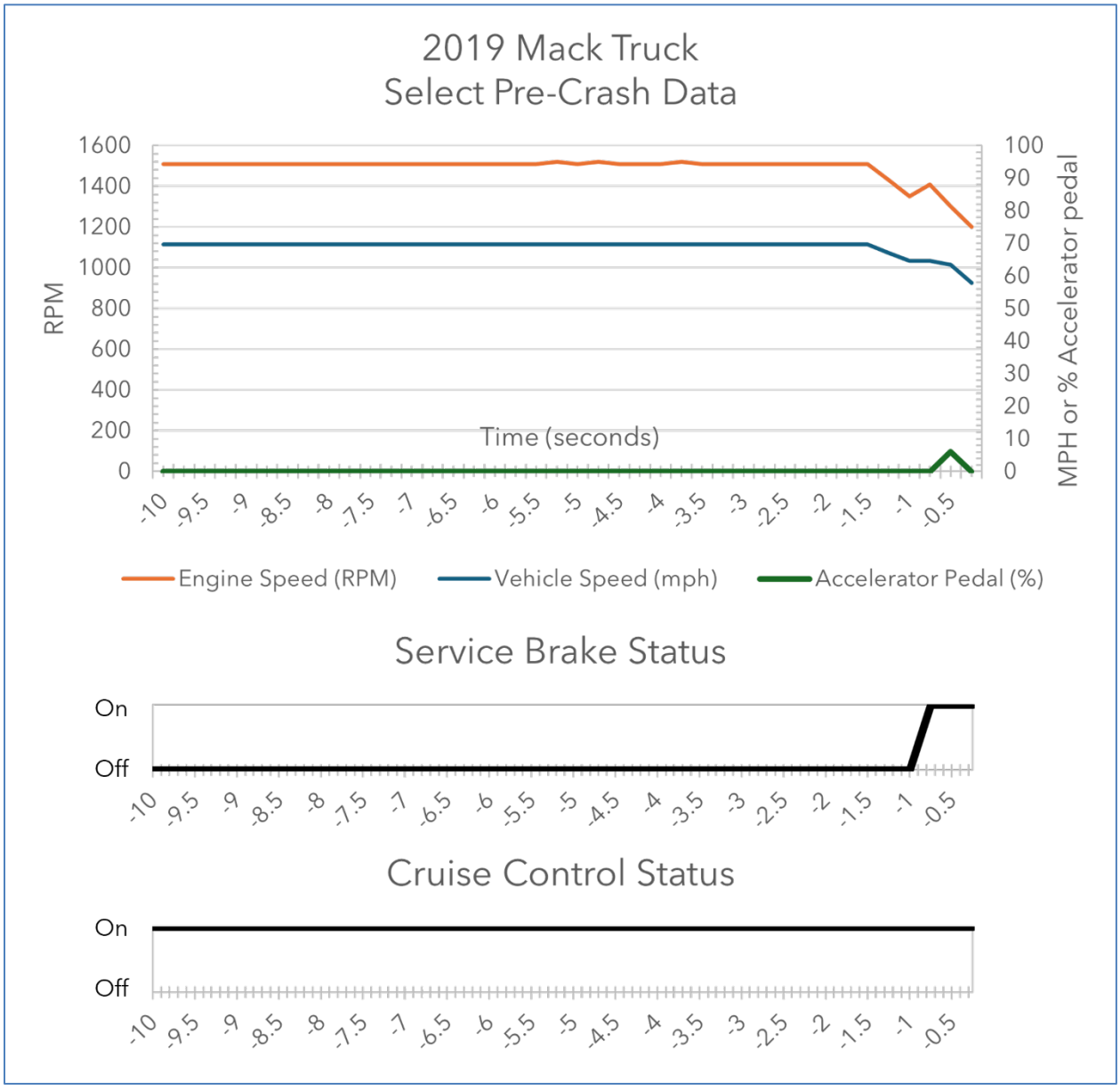

Figure 7. Chart depicting select data from the Mack acceleration event.

F. REFERENCES

NTSB Highway Factors Group Chair Factual Report
NTSB Vehicle Factors Group Chair Factual Report

G. LIST OF ATTACHMENTS

The following attachments are included in the docket for this investigation:

Technical Reconstruction Attachment-	Toyota EDR Report
Technical Reconstruction Attachment-	Mack ECU Report
Technical Reconstruction Attachment-	Mack Bendix Report

Submitted by:

Eric Gregson
Technical Reconstructionist