NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF HIGHWAY SAFETY
WASHINGTON, D.C.

TECHNICAL RECONSTRUCTION GROUP CHAIRMAN'S FACTUAL REPORT

A. CRASH INFORMATION

Location:	Interstate 70/76 (I-70/76) Pennsylvania Turnpike at mile-post marker 86.1 westbound, Mount Pleasant Township, in Westmoreland County, Pennsylvania
Vehicle #1:	2005 Van Hool 57-passenger motorcoach C2045
Operator:	58-year-old male (fatally injured)
Occupants:	59 passengers (2 fatalities, 57 various injuries)
Carrier:	Z&D Tour Inc., Rockaway, NJ
Vehicle #2:	2018 Freightliner Cascadia truck-tractor towing a 2019 53-foot Hyundai Translead semitrailer
Operator:	35-year-old male (not injured)
Passenger:	35-year-old-male (minor injury)
Carrier:	Fed Ex Ground, Moon Township, PA
Vehicle #3:	2018 Freightliner Cascadia truck-tractor towing a 2018 53-foot Stoughton semitrailer
Operator:	53-year-old male (fatally injured)
Passenger:	48-year-old male (fatally injured)
Carrier:	United Parcel Service, Harrisburg, PA
Vehicle #4:	2007 Mercedes Benz C280 sedan
Operator:	46-year-old male (not injured)
Passenger:	20-year-old-male (not injured)
Passenger:	20-year-old-male (not injured)
Vehicle #5:	2018 Freightliner Cascadia truck-tractor towing a 2020 28.5-foot Stoughton semitrailer
Operator:	62-year-old male (not injured)
Passenger:	41-year-old male (not injured)
Carrier:	United Parcel Service, Willow Grove, PA

Date: January 5, 2020

Time: Approximately 3:30 a.m. local time

NTSB #: **HWY20MH002**

B. TECHNICAL RECONSTRUCTION GROUP

Robert Squire – Highway Crash Investigator, Group Chairman
NTSB Office of Highway Safety
490 L'Enfant Plaza East, S.W., Washington, DC 20594

Tfc Michael Laird
Pennsylvania State Police
New Stanton, PA 15672

C. CRASH SUMMARY

For a summary of the crash, refer to the *Crash Summary Report* in the docket for this investigation.

D. DETAILS OF THE TECHNICAL RECONSTRUCTION INVESTIGATION

The Technical Reconstruction Group for this investigation was convened for the purpose of providing on-scene documentation of the crash location and involved vehicles, and to assist in the analysis of collision events and causation factors. In support of these tasks the group reviewed documentation provided by the Pennsylvania State Police (PSP), Pennsylvania Turnpike Commission (PTC) and certain motor carrier-supplied information.

Factual reports prepared by other NTSB investigative groups should be consulted for information related to other aspects of the investigation, including information used within this report.

1. Introduction, Collision Site and Highway Description

The collision events involved a total of five (5) vehicles – four commercial (heavy) motor vehicles and a passenger car. The events included one single vehicle rollover event followed by subsequent collision events that occurred in quick succession within the westbound lanes of the Pennsylvania Turnpike (I-70/76).[1] At final rest, all five vehicles were clustered together. The location of the initial event, which involved the Van Hool motorcoach overturning, was identified by approximate geographic coordinates of 40.15535ºN (latitude) and -79.43650ºW (longitude).[2] This position was located less than 200 feet east of mile post marker 86.1. The collision events occurred within Mount Pleasant Township, as indicated in **Figure 1**.

[1] The turnpike is designated as Interstate-70/76 between the towns of New Stanton, PA and Breezewood, PA.
[2] Approximate position where the motorcoach had initially come to rest after overturning.

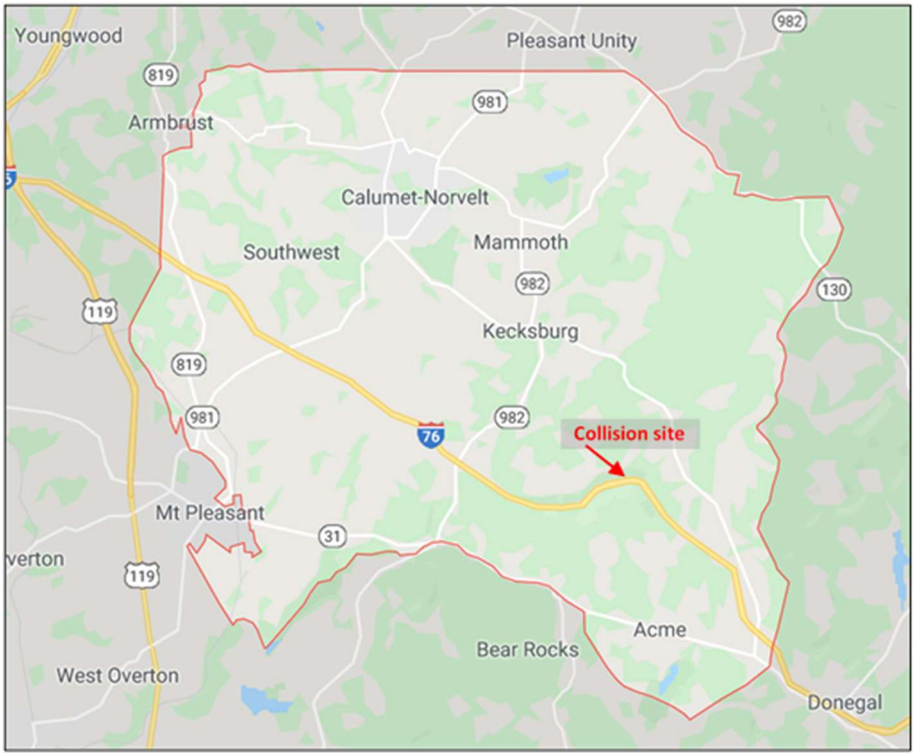


Figure 1: Area map of Mount Pleasant Township with approximate location of the crash indicated.

NTSB investigators examined and documented the site and other relevant features on January 9, 2020, four days after the collision using terrestrial photography and a small unmanned aircraft system (sUAS) platform.[3] Site documentation data acquired by PSP investigators before the scene was cleared included sUAS aerial photographs, three-dimensional laser scanning and total station mapping. Additional 3D laser scanning was conducted by a PTC contractor hired to corroborate the vertical grade and cross slope of the highway pavement and lower portion of the adjacent side slope.

The collision events occurred along a highway spiral segment westward of the end of a leftward 1296-foot radius curve between mile posts 86.2 and 86.1.[4] The westbound approach to this area exhibits a descending vertical grade of about 3% over a distance of about 1.9 miles. **Figures 2** and **3** depict the approximate locations of areas of interest overlaid atop Google Earth imagery.

[3] sUAS – "small unmanned aircraft system" as defined by 14 CFR Part 107.
[4] Directional descriptions are consistent with traveling westbound. Mile post marker values increase from west to east.

Figure 2: Modified Google Earth imagery depicting the section of I-70/76 on which the collision events occurred. The locations indicated approximate the positions of the motorcoach in the roadway before the subsequent collisions.

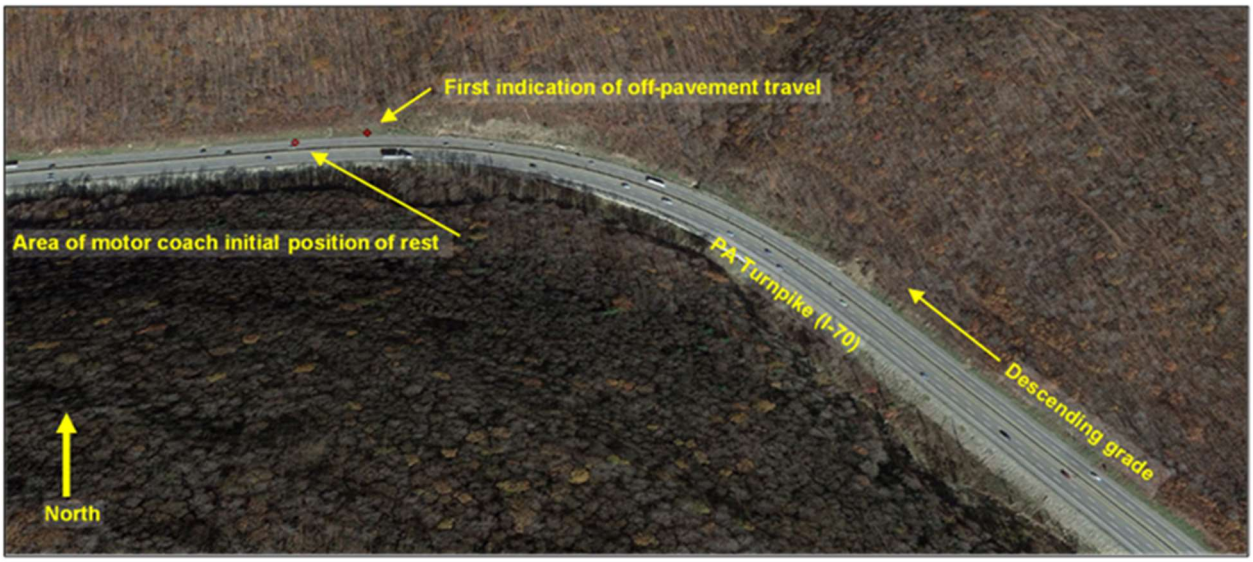


Figure 3: Modified Google Earth imagery depicting the section of I-70/76 on which the collision events occurred. The locations indicated approximate the positions of the motorcoach in the roadway before the subsequent collisions and approximate area of highway departure.

The events initiated after the westbound Van Hool motorcoach, while nearing the end of a leftward curve, departed the right side of the highway and impacted the embankment. After impacting the right roadside embankment, the motorcoach rotated clockwise approximately 240˚ and overturned onto its right (passenger) side. Following the overturning event, the motorcoach came to rest approximately perpendicular across the highway travel lanes and shoulders with the undercarriage facing east. After the motorcoach had stabilized it was then struck by the FedEx Cascadia-Hyundai combination. Within seconds of this impact event stabilizing, the rear of the FedEx combination was struck by the UPS-1 Cascadia-Stoughton combination. The Mercedes passenger vehicle apparently avoided striking these vehicles and stopped adjacent to the UPS-1 unit near the right roadside embankment. The UPS-2 Cascadia-Stoughton combination sideswiped the Mercedes, apparently also propelling it forward as the truck departed the highway onto the right roadside embankment. The UPS-2 combination also slid slightly down the embankment and pushed the Mercedes further beneath the right-side frame rail of the UPS-1 trailer. While most of the successive impacts could be considered individual collision events, the totality of all events will be addressed as a combined series for this report.

1.1. Collision Location and Basic Highway Description

The collision involved a sequence of events, both collision- and non-collision-related that occurred on the westbound roadway. The collision events occurred along a spiral segment that followed a leftward 1,296-foot radius curve (westbound direction) just east of mile post 86.1.[5] Following all the events, the involved vehicles were clustered in an area around MP 86.1 with the western-most vehicle about 44 feet west of the mile post marker. As referenced in the highway design plans and NTSB *Highway Factors Group Chairman's Factual Report*, the 1,296-foot radius curve had a length of 958.6 feet with 419.9-foot-long spiral segments at both ends for an overall combined length of about 1,798.5 feet, which essentially encompassed the segment of highway between mile posts 86.1 and 86.4.[6] The combined change in heading along the curve and spiral segments was about 60.9 degrees.[7] The design plans indicated a maximum superelevation or cross slope of eight percent on the curve. An advisory speed limit of 55 miles per hour was posted through the curve. The highway and off-highway areas were unlit.

All the involved vehicles had been traveling westbound. As indicated in the highway plans and NTSB *Highway Factors Group Factual Report*, the highway had an approximate 3% vertical downgrade through the collision area. Eastward from MP 86.1, highway plans illustrating the vertical and horizontal highway geometry were reviewed for a distance of 13,458 feet (~2.5 miles). Over the distance eastward from MP 86.1, the westbound highway plans indicate a vertical grade averaging about 2.4%.[8] The descending grade began in the area of a vertical crest just east of MP 88.0, or about 10,478 feet (1.98 miles) east of MP 86.1. The onset of the descending grade exhibits a slope of less than one percent over the initial 3,782 feet. Over the remaining 6,696 (~1.27 miles) the slope increases to between two and 3.2 percent. The vertical grade of the highway segment on

[5] Design plan data calculated the curve radius at 1,295.9 feet. The spiral segment terminated about 119 feet west of MP 86.1.
[6] Mile point marker values increase in the eastbound direction.
[7] The spiral segments exhibited a change in heading of about 9.3° each with the change in heading for the simple curve of about 42.3°.
[8] Vertical grades measurements ranged between -0.057% and -3.2% in the westbound direction.

which the collision events occurred was about three percent (3.008%), with that slope having increased from two percent about 346 feet before the motorcoach departed the highway pavement.

Prior to entering the leftward curve on which the collision events occurred, the westbound vehicles would traverse six additional horizontal curves while descending the grade between MP 88.0 and MP 86.1. Each of those curves are less significant, as referenced by length, radius and heading change, than the curve on which the collision events occurred. As the vehicles transitioned into the descending grade, they would have just entered a sweeping leftward curve (#6). Before entering the accident curve, the vehicles would traverse three (3) rightward curves and two (2) additional leftward curves. **Table 1** provides a description of the horizontal geometry (curves and tangents) that the vehicles navigated in the westbound direction. The distance of the beginning of these features relative to MP 86.1 and the motorcoach's initially roadway departure and position of rest (before being struck) are likewise provided. The motorcoach reference positions are discussed in later sections of this report.

Table 1: Horizontal Geometry

Horizontal alignment feature	Feature length[1] (feet)	Curve change in heading and direction[2]	Curve radius[3] (feet)	Distance east of MP 86.1 (feet)[4]	Distance east of initial POR (feet)[4]	Distance east of initial road departure (feet)[4]
Curve (6) and spiral near MP 88.0	2,137	51.7º - left	1,883	10,970	10,942	10,787
Tangent	791			8,832	8,805	8,650
Curve (5)	358	3.6º - right	5,732	8,042	8,015	7,860
Tangent	1,908			7,683	7,656	7,501
Curve (4) and spiral	887	15.4° - right	1,909	5,776	5,748	5,593
Tangent	9			4,889	4,862	4,707
Curve (3) and spiral	756	11.5º – left	1,909	4,880	4,853	4,698
Tangent	51			4,125	4,097	3,942
Curve (2) and spiral	1,012	23.9º - right	1,434	4,074	4,047	3,892
Tangent	174			3,062	3,035	2,880
Curve (1) and spiral	737	7.5º - left	2,864	2,888	2,861	2,706
Tangent	471			2,151	2,123	1,968
Accident curve	1,799	60.9º – left	1,296	1,679	1,652	1,497
End accident curve				-119	-147	-302

[1] Curve lengths include spiral segment lengths.

[2] Total change in angular heading, including spiral segments

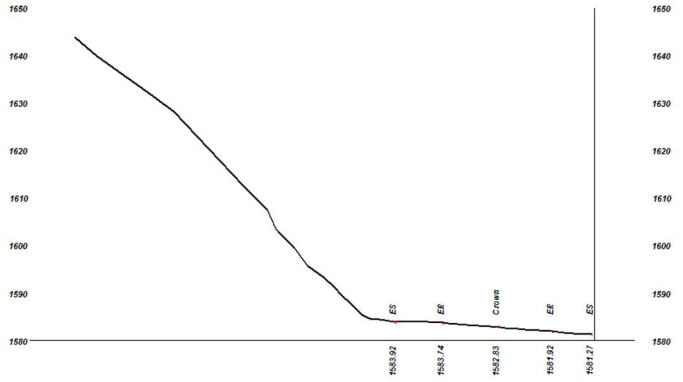
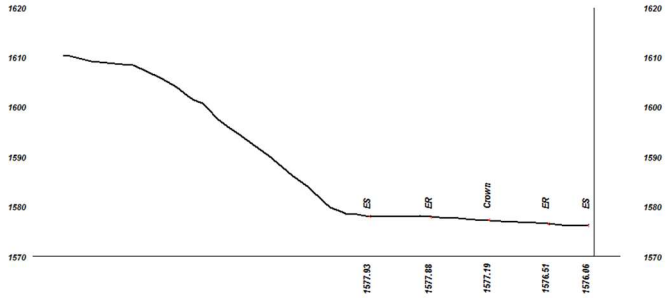
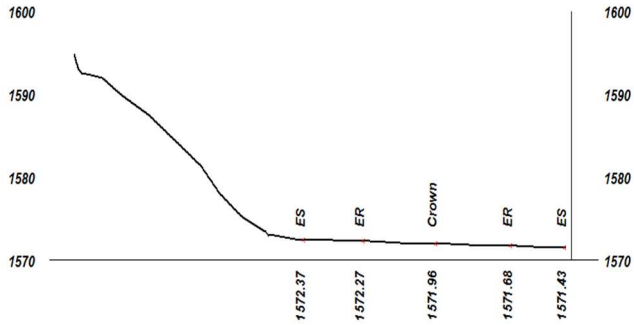
[3] Curve radii for simple curve only, spiral segments excluded.

[4] Distances in feet rounded to approximate whole number.

Following the collision, a PTC contractor conducted a survey of the westbound roadway leading into, and through the area of the collision events.[9] The contractor provided NTSB investigators with slope profile data that included the highway superelevation and right roadside embankment. Stationing references enabled an examination of the profiles at three locations of interest – the western terminus of the right roadside barrier, the area of roadway departure by the motorcoach, and the embankment area on which the motorcoach began to overturn. **Table 2** summarizes the profile data.

[9] Survey conducted on January 9, 2020, by Sucevic, Piccolomini & Kuchar Engineering, Inc. (SPK) as contracted by PTC.

Table 2: Cross Section Profile for Westbound Roadway and Right Roadside Embankment at Select Locations (data provided by SPK Engineering, Inc.)

Location	Highway cross slope (%)	Right roadside embankment slope (º)	Profile diagram (SPK Engineering)
Western terminus of right roadside barrier	4.3%	46º	
Area of initial highway departure by motorcoach	3.3%	38º	
Area of initial overturning by motorcoach	1.3%	37º	

Although the embankment slope angle was averaged for reporting, the overall characteristics were slightly irregular. While much of the roadside embankment surface on which the soil disruption (collision evidence) occurred was grass covered, below the surface the soil was a very rocky aggregate. A rocky subsurface and numerous large rocks were exposed or displaced

within areas scarred by the errant motorcoach. Further up the embankment from the collision evidence small trees and other vegetation were present. This gave way to larger trees as the embankment ascended.

2. Additional Investigative Resources

Data provided by the PSP to NTSB investigators included crash scene photographs, sUAS imagery, scene 3D scan data and total station data. The data provided by PSP was supplemented with sUAS imagery acquired by NTSB investigators with the Office of Aviation Safety (refer to the *NTSB Unmanned Aircraft System (UAS) Aerial Imagery Factual Report* for details). The sUAS images from both groups were rendered through the Pix4DMapper software to create three-dimensional point cloud projects for use in analysis.[10] The PSP total station data was combined with the Pix4D sUAS project for analysis and project scaling.

The PSP project captured images of the post-crash positions of the involved vehicles, collision debris and some roadway evidence. Certain roadway evidence unobscured by debris was visible in the aerial photos. Overall, the PSP project documented approximately 460 feet of the westbound roadway leading to vehicle positions of rest. **Figure 4** depicts a screen capture of the orthomosaic map rendered from the project point cloud. Certain features such as documented tire friction marks, significant road surface scars and other features have been highlighted (colorized) for emphasis. These features will be discussed in later sections of this report. Additional crash scene perspectives are provided in the NTSB UAS aerial imagery report.

Figure 4: Scaled orthomosaic image rendered from the PSP sUAS aerial images. Certain roadway evidence has been enhanced to improve its discernibility in the image.

[10] 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.

Figure 5 depicts a screen capture of an overhead perspective of the 3D point cloud rendered from the NTSB data. The NTSB project captured over 1,800 feet of westbound roadway leading to the vehicle positions of rest (approximated with the "x"). **Figure 6** provides another viewing perspective with the area of vehicle final rest approximated by the yellow arrow.

Figure 5: Image depicting 3D point cloud rendered from NTSB sUAS project. The vehicle final positions of rest are approximated by the "x".

Figure 6: Image depicting 3D point cloud rendered from NTSB sUAS project. The vehicle final positions of rest are approximated by the yellow arrow.

3. Roadway Evidence

The collision events initiated with a single vehicle rollover event followed by subsequent events that occurred in quick succession within the westbound lanes involving four additional vehicles.

The first event involved the Van Hool motorcoach which departed the westbound travel lanes and struck the right roadside embankment. The first area of contact was indicated by linear soil disruption and furrowing of the right roadside embankment that depicted an approximate 25-30-degree angular ascent along the embankment (relative to the roadway). This initial area of departure from the highway occurred along the spiral transition from the leftward curve about 195 feet west of the terminus of a concrete barrier that paralleled the right shoulder through the curve.[11] The initial area of soil furrowing ascended the embankment about 25-30 feet from the highway pavement edge. Subsequent areas of scarring to the right roadside embankment were observed approximately 68 and 145 feet westward of the initial area of pavement departure. The final area of scarring depicted a linear path oriented approximately 11-12 degrees to the pavement edge.

A few tire friction marks were visible in the scene photos with three subsequently documented by PSP investigators. In some areas, parallel marks indicative of a dual wheel

[11] The single-face concrete barrier that separated the westbound right road edge from the roadside embankment extended about 1,047.5 feet. In the westbound direction the barrier began about 254 feet into the spiral segment preceding the curve and terminated about 496 feet before end of spiral (beginning of tangent).

configuration were visible. Based on documentation, the overall lengths of those marks were about 99, 111, and 134 feet, respectively.

To reference the location of the tire marks to the collision, an initial position of rest for the motorcoach - after stabilizing from the overturning event but before being subsequently struck by the other vehicles - was established.[12] The 134-foot tire mark began in the left travel about 348 feet east of the Van Hool's initial position of rest. As the mark continued westward it remained in the left lane. The 111-foot tire friction mark originated about 172 feet east of the Van Hool position of rest. Onset of the tire mark was visible in the right travel lane adjacent to the broken-white lane line. As the mark continued westward it transitioned into the left travel lane and then became obscured by roadway debris. The 99-foot tire mark overlapped the 111-foot mark but remained mostly atop the lane line.

A significant arcing scrape mark that exhibited a white color was observed on the road surface adjacent to the eastern-most roadside embankment scarring. The scrape began just inside the left travel lane and progressed through the right travel in the westward direction. The arc exhibited an overall length of about 79 feet. The eastern origin for the scrape was about 50 feet into the roadway from the western end of the embankment scar.

Scene and sUAS photographs depict debris on the road surface that included roadside dirt and material as well as vehicle contents and cargo further to the west. Dirt and material displaced from the embankment (rocks and grass) angled across the roadway between the embankment scars and the Van Hool's initial position of rest. Some tire impressions leading toward other vehicle positions of final rest could be seen in the soil debris, which had become saturated (mud) by precipitation. Westward of the initial point of roadway departure, component debris followed by contents from the Van Hool motorcoach were observed. The motorcoach loading door and one of two windshield panels were located near the base of the embankment about 35 and 64 feet, respectively, westward from the vehicle's off-road departure point. While the first windshield panel was located at the pavement edge, the second was located about 21 feet further up the embankment. Closer to and extending further west of the Van Hool's initial position of rest, packages, luggage and other contents from the motorcoach and semi-trailers were visible.

Adjacent to the Van Hool's initial position of rest a 12-foot section of center median barrier had capsized (tipped) onto the left shoulder of the eastbound roadway. The breach in the barrier was located approximately 361 feet west of the right roadside barrier end. Video evidence indicated that a portion of Van Hool's front end had created the opening after capsizing the barrier segment.[13] As referenced in the NTSB *Highway Factors Group Factual Report*, the median barrier, or "glare screen" was comprised of interconnected pre-cast concrete segments measuring 52 inches high and 12 feet long. The segments were joined longitudinally using a slotted plate connection. The 24-inch-wide base of the barrier was set within a 2-inch-deep pavement channel making the effective barrier height about 50 inches above the road surface. A sealing compound was applied to at the base to restrict water intrusion between the barrier and pavement channel.

[12] Discernible roadway scrapes and video imagery from the forward-facing camera in the FedEx vehicle were used to approximate the Van Hool position across the roadway. For additional reference, this location was approximately 350 feet west of the right roadside barrier end. The approximated motorcoach center of gravity (CG) was referenced.
[13] Also see Video Study report prepared by the NTSB Office of Research and Engineering.

The Van Hool established an initial position of rest (POR) on the roadway about 162 feet westward from the point of initial roadway departure. Based on this initial position, it is estimated that the vehicle's center of gravity was redirected about 58 feet further west by the subsequent impacts, which also caused the vehicle to rotate clockwise an additional 90 degrees.

While obscured from Figure 4, the driver of the Van Hool had been ejected from the vehicle and was observed lying in the left shoulder of the eastbound roadway about 45 feet from the western end of the median barrier opening. Two motorcoach occupants were found beneath the FedEx trailer, against the median barrier about 22 feet west of the median barrier opening.

4. Vehicle Documentation

The Technical Reconstruction Group photographed, and 3D-laser scanned the exteriors of all the heavy vehicles involved in the collision events. The Mercedes passenger vehicle was photographed. The involved vehicles had been secured at a nearby vehicle towing and storage facility as directed by the PSP. A more detailed examination and documentation of the vehicles was undertaken by the NTSB Vehicle Factors Group. Additional information regarding the vehicles is available in the factual reports prepared by the NTSB Vehicle Factors and Survival Factors Groups.

4.1. 2005 Van Hool C2045, 57-passenger motorcoach

The motorcoach was identified as a 2005 Van Hool model c2045 having an occupancy capacity of 57 passengers plus the driver. Manufacturer dimensions, as conveyed in **Table 3**, indicate the vehicle had an overall length of about 45.5 feet. **Table 4** conveys post-crash axle end weights as measured by PSP investigators.

At its position of final rest following all collisions events, the motorcoach remained on its right side facing west and occupying both travel lanes. Overall, the vehicle exhibited impact evidence at the front, rear, and undercarriage. While a substantial portion of the frontal structure forward of the partition wall was displaced, the driver's seat remained attached at the base. The inner roof lining and roof support structure forward of the partition wall were bent downward. The loading steps had separated from the vehicle and the lower body structure forward of the right (curb) side front tire was displaced rearward. When oriented normally, the face of the front bumper cover displayed soil deposits, lateral scrapes, and vertical gouging, some of which superimposed the lateral marks.

It appears that the front overhanging structure had completely separated from the vehicle after its recovery – except for the driver's seat and left body side panel rearward of the front bumper. Collision scene photographs depict much of the vehicle's frontal structure as twisted and entangled with the front of the FedEx truck tractor. Separation of this structure was likely necessary for vehicle recovery. Post-collision, there was no discernible reduction in wheelbase length.

Regarding the left front lower sidewall panel, forward of the left front tire, dirt and grass deposits were observed embedded in trailing edges such that the debris were deposited in a rear to front direction.

At the left (driver) side rear corner, the structures below the bottom of the tail lamp assembly were displaced forward. When examined at the storage facility, the rear bumper had been separated from the vehicle. The lower, rearward facing engine components, such as the engine-mounted v-belt pulleys, engine crevices and tail pipe ends were embedded with soil, grass, and other debris. The placement and location of this debris indicate that the motor was not run after the debris became embedded.

While not easily accessible for viewing while the motorcoach was upright, an area of impact was observed to the undercarriage just rearward of the right front wheel. The impact forced a portion of the undercarriage sheeting upward toward passenger compartment and there was some tearing of the frame tubing. The damage appeared to affect a single undercarriage panel within the undercarriage framing and the displaced panel only intruded into the cargo bay. There appeared to be some scarring but no damage to axle positioning components. Some of the rearward front axle-positioning components on the right side also exhibited deposits of dirt and grass. The orientation of the debris deposits appeared to be front to rear.

The right exterior sidewall of the vehicle exhibited some scraping to the painted surfaces. The scrapes generally appeared light or superficial although some heavier scrapes were observed about the cargo bay doors. Overlapping scrapes oriented diagonally and vertically were noted.

Figures 7 and 8 depict images of the 3D point cloud as rendered from scans of the vehicle in the FARO Scene software.

Figure 7: Screen capture depicting the vehicle's right side and front as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software. An image of an undamaged c2045 motorcoach is depicted in the upper left corner.

Figure 8: Screen capture depicting the vehicle's left side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software.

Table 3: Vehicle Design Dimensions

	millimeters	inches	feet
Overall vehicle length	13895	547.05	45.59
Front body overhang	1890	74.41	6.20
Rear body overhang	2800	110.24	9.19
Distance axle 1 – Axle 2	7735	304.53	25.38
Distance axle 2 – axle 3	1300	51.18	4.27
Wheelbase axle 1 – midpoint A2-A3	8385	330.12	27.51
Overall height	3505	137.99	11.50

Table 4: Vehicle Post-Crash Wheel-end Weights - Empty

	Axle 1 – Steer axle	Axle 2 – Drive axle	Axle 3 – Tag axle
Driver side - Left	6050	5750	5150
Passenger side - Right	1650	7900	7250
Axle totals	**7700**	**13650**	**12400**
Total			**33750**

The operating weight of the motorcoach would likely have increased about 9,000 pounds with the occupants on board bringing the operating weight to approximately 42,750 pounds.[14]

4.2. 2018 Freightliner (New) Cascadia (model PRL-15K) truck-tractor towing a 2019 Hyundai Translead 53-foot semitrailer

The second heavy vehicle involved in the sequence of collisions was a combination unit identified as a 2018 Cascadia truck-tractor towing a 2019 Hyundai Translead, 53-foot van body trailer.[15] This unit was operated under contract with FedEx Ground and will generally be referenced as the FedEx combination.

Scene photographs depict that as a result of the collision the trailer had separated from the truck tractor and the two units were detached at final rest. At final rest, the forward portion of the trailer was resting atop the median barrier (glare screen) about 20 feet west of the breach in the barrier. The front end of the trailer overhung the barrier into the eastbound roadway by about three-fourth the trailer's width.

The truck-tractor was several feet westward of the trailer with the rear of the tractor's frame rails near the front of the trailer. The tractor occupied the left shoulder and left travel lane of the westbound roadway and was oriented clockwise about 46º relative to the trailer. The right front of the tractor was in contact with the undercarriage of the Van Hool near the front axle.

The truck-tractor exhibited frontal impact damage with greater damage observed to the hood and fender on the right side. The cab was no longer in line with the frame and appeared skewed toward the left at the rear. The fifth wheel coupler was a sliding type that allowed the coupler to be repositioned longitudinally along the tractor frame rails. Post collision, the entire coupler assembly had separated from the frame mounted rack and was displaced forward toward the rear of the cab. The coupler was observed wedged between the frame rails. Separation of the coupler from tractor frame appears to have released the trailer king pin, which remained intact, apparently undamaged, and securely attached to the trailer.

While the FedEx tractor shared the same basic 2018 Cascadia designation as the two UPS truck-tractors, this model was a 3rd generation model Cascadia, also known as the *New* Cascadia.[16]

Figure 9 depicts an image of the 3D point cloud as rendered from scans of the truck tractor in the FARO Scene software.

[14] For each of the 60 occupants a weight of 150 pounds was added as referenced in 49 CFR Part 567.4, *Requirements for manufacturers of motor vehicles* wherein each seating position is assigned this weight for purposes of establishing a gross vehicle weight rating.
[15] Manufacturer data indicates a PRL-15K model with a 227-inch wheelbase and 126-inch cab as measured from the front bumper to back of cab (BBC). The tractor was outfitted with a WABCO 6S/6M antilock brake system.
[16] Reported to have introduced in 2017 for 2018 model year.

Figure 9: Screen capture depicting the tractor's right side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software.

The semitrailer exhibited significant impact damage at the rear. When examined at the storage facility the steel structure that framed the trailer rear and included the roll-up door components and rear impact protection (underride guard) had been separated from the body. Scene photographs depicted this structure as having experienced significant impact deformation toward the right half causing most of the structure to separate from the trailer and hang precariously from the vehicle. The structure, which was likely removed for recovery transport, was examined while stored on a flatbed trailer at the storage facility.

Impact to the rear of the trailer was offset toward the right side. Additional contact damage that exhibited less deformation was observed at the right front corner edge of the trailer. Indentations to the corner edge appeared at numerous locations and covered the full height of the corner.

The trailer king pin was intact although the king pin (upper coupler) plate did exhibit some scarring toward the leading edge.

Figure 10 depicts an image of the 3D point cloud as rendered from scans of the trailer in the FARO Scene software.

Axle end weights for both units were acquired by PSP investigators and are presented in the NTSB *Vehicle Factors Group Factual Report*.

Figure 10: Screen capture depicting the trailer's right side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software.

4.3. 2018 Freightliner Cascadia (model PRL-44F) truck-tractor towing a 2018 Stoughton 53-foot semitrailer (UPS-1)

The third heavy vehicle involved in the sequence of collisions was a combination unit identified as a 2018 Cascadia truck-tractor towing a 2018 Stoughton, 53-foot van body trailer.[17] This unit was operated by UPS and will be referenced as the UPS-1 combination.

Scene photographs depict that at final rest the tractor was oriented southward primarily occupying the right travel lane and shoulder. The trailer was oriented northwesterly at an angle of about 124º relative to the tractor (i.e., depicting a significant jackknife). While not conclusive from the scene photographs, the two units appeared to have remained coupled. Post-collision the 5th wheel coupler on the tractor was intact. Scene photographs depict the right side of the tractor as being in contact with the rear of the motorcoach. The rear of the semitrailer extended past the rear of the FedEx trailer at an approximate 56º angle.

The truck-tractor exhibited catastrophic damage with evidence of having sustained an offset frontal impact at the left side that displaced the cab A-pillar. Impact damage extended along the left side fuel tank and wheel assemblies. The entire left side of the cab and sleeper berth had been torn open with the remaining cab shell skewed toward to the right. At final rest, the trailer had intruded into the tractor sleeper berth.

Figure 11 depicts an image of the 3D point cloud as rendered from scans of the truck tractor in the FARO Scene software.

[17] Manufacturer data indicates a PRL-44F model with a 235-inch wheelbase and 125-inch cab as measured from the front bumper to back of cab (BBC). The tractor was outfitted with a WABCO 4S/4M antilock brake system.

Figure 11: Screen capture depicting the trailer's left side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software.

The semitrailer exhibited impact damage to the left leading edge that included an opening having been torn in the sidewall. The opening extended vertically from the bottom frame rail to the roof and included the corner structure. The overall sidewall deformation extended about nine feet rearward from the front of the trailer. Two additional tears to the sidewall, measuring about two to three feet in length, were observed about 12 inches downward from the roof near the middle and further rearward on the trailer.

Figure 12 depicts an image of the 3D point cloud as rendered from scans of the trailer in the FARO Scene software.

Figure 12: Screen capture depicting the trailer's left side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software.

Wheel end weights for both units were acquired by PSP investigators and are presented in the NTSB *Vehicle Factors Group Factual Report*.

4.4. 2007 Mercedes Benz C280 4-door sedan

A Mercedes Benz C280, four-door sedan was the only passenger vehicle involved in the collision events. In general, the vehicle exhibited areas of impact to the right (passenger) side rear quarter panel, the roof and sideswipe contact along the left (driver) side. Some minor deformation was observed to the trailing edge of the left front fender in relation to the sideswipe evidence.

At final rest, the vehicle was observed oriented northwestward, parallel with and between the UPS-1 semitrailer and UPS-2 truck-tractor. As depicted in **Figure 13**, the forward driver's side roof area of the Mercedes had under-ridden the lower frame rail of the UPS-1 trailer. The right rear quarter panel was in contact with the UPS-2 left fuel tank and trailing corner of the cab.

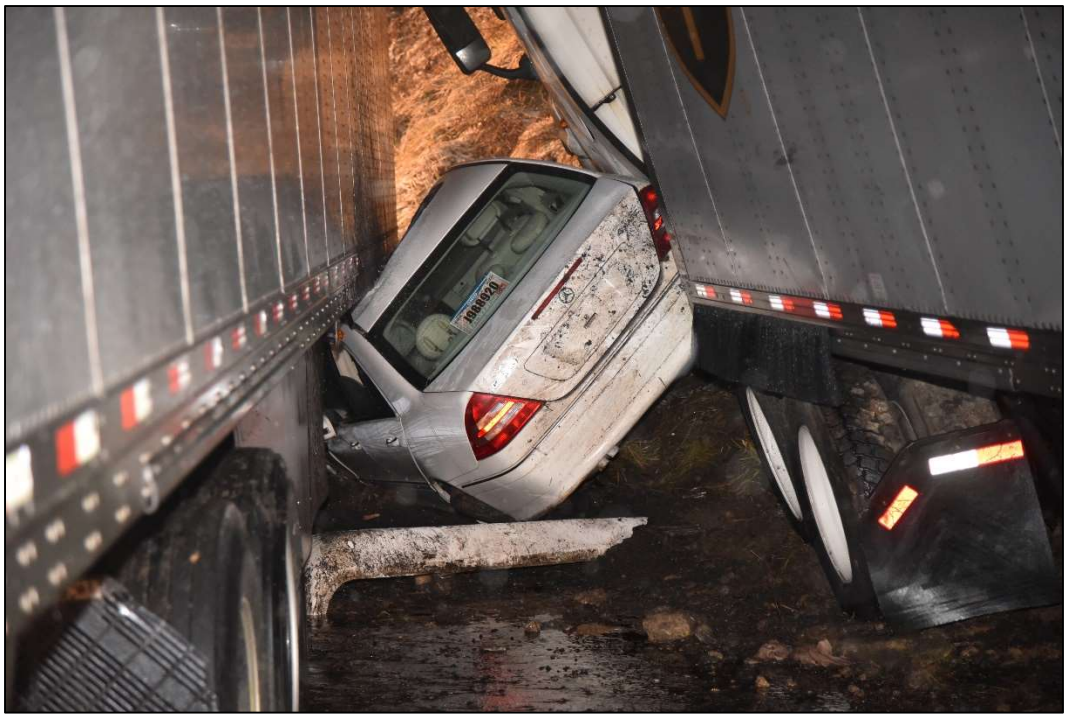


Figure 13: Photograph provided by PSP depicting the position of final for the Mercedes Benz between the UPS-2 tractor (right) and FedEx trailer (left) – PA State Police.

Figures 14 and 15 depict areas of damage sustained by the Mercedes.

Figure 14: Photograph depicting left front and left side of Mercedes Benz.

Figure 15: Photograph depicting right front and right side of Mercedes Benz.

Table 5 provides certain dimensional data for the vehicle.[18]

Table 5: Dimensional Data for 2007 Mercedes Benz C280

	inches	feet	
Overall length	178	14.83	
Wheelbase	107	8.92	
Front overhang	30	2.50	
Rear overhang	41	3.42	
Overall width	68	5.67	
Maximum height	55	4.58	
Curb weight			3460 lbs.

4.5. 2018 Freightliner Cascadia (model PRL-44F) truck-tractor towing a 2020 Stoughton 28.5-foot semitrailer (UPS-2)

The fourth heavy vehicle involved in the sequence of collisions was a combination unit identified as a 2018 Cascadia truck-tractor towing a 2020 Stoughton, 28.5-foot van body trailer.[19] This unit was operated by UPS and will generally be referenced as the UPS-2 combination.

Scene photographs depict that at final rest the tractor was oriented in a northwestward direction at about a 22º angle relative to the roadway and occupied the right shoulder and roadside embankment. The truck tractor and semitrailer remained coupled and were linearly oriented such that the tractor was off the pavement and had partially ascended the bottom portion of the embankment.

The truck-tractor exhibited evidence of contact damage on the left side beginning just below the driver's door and trailing rearward to the end of the saddle-mount fuel tank and cab. The front bumper cover was found detached when the vehicle was examined at the storage facility. Crash scene photographs depict the cover partially buried in the embankment as a result of the vehicle running off the pavement. Soil and grass were observed embedded about the steer axle wheels and suspension forward of the axle.

Figure 16 depicts an image of the 3D point cloud as rendered from scans of the truck tractor and trailer combination in the FARO Scene software.

Axle end weights for both units were acquired by PSP investigators and are presented in the NTSB *Vehicle Factors Group Factual Report*.

[18] Reference 4N6XPRT Systems Expert AutoStats v5.9.1.
[19] Manufacturer data indicates a PRL-44F model with a 235-inch wheelbase and 125-inch cab as measured from the front bumper to back of cab (BBC). The tractor was outfitted with a WABCO 4S/4M antilock brake system.

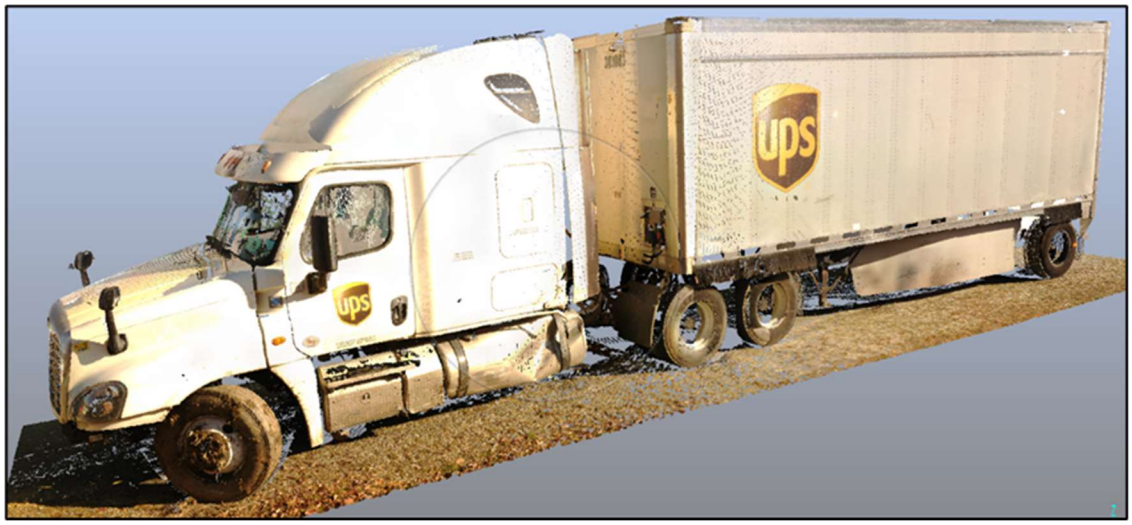


Figure 16: Screen capture depicting the tractor-trailer combination from the left side as viewed in the point cloud rendered from the three-dimensional scans through the FARO Scene software

5. Electronic Event Data

During their respective post-collision inspections, the involved vehicles were examined to identify potential sources of electronic data that could be useful for event or crash analysis. Various electronic systems in use on motor vehicles can have the capability to record certain parametric and/or event data that can be useful for analyzing a crash event or the vehicle's operating parameters preceding a crash.

Light duty vehicles, such as the Mercedes Benz, utilize an electronic control module to command the deployment of supplemental restraints (e.g., air bags, belt pretensioners). Many late model light vehicles will record certain vehicle and SRS activation parameters, including crash event accelerations, when the system commands or contemplates the deployment of a supplemental restraint. Regarding the Mercedes, no supplemental restraint deployment was observed and for this model year vehicle there was no supported commercially available equipment to access the system in search of other data potentially useful for the crash investigation.

Each of the four commercial vehicles involved in the crash were powered by diesel engines manufactured by Detroit Diesel Corporation. These engines are electronically managed with various controllers. Generically referred to as electronic control modules (ECMs), they may be capable of storing or recording certain engine and vehicle parametric and event data. Depending upon the vehicle and system, data may be stored in a single, or multiple modules. Data may be downloaded or imaged through commercially available software or require manufacturer assistance where the data is proprietary.

Each of the three truck-tractor semitrailer combinations were also found to have been equipped with one of two versions of the Detroit Assurance Safety System. This is a manufacturer installed suite of advanced safety features and driver assist technologies. This system was

identified as having the capability to store certain event data. This system's operation and any recovered data will be addressed by the NTSB Vehicle Factors Group.

The FedEx truck was also outfitted with a Lytx DriveCam fleet management video system. The carrier provided NTSB investigators with short video segments that depicted, in part, operation of the truck leading up to the impact with the overturned motorcoach and where the motorcoach passed the truck before the collision. Analysis and other details of these video segments are addressed in the *NTSB Video Study* prepared by the Office of Research and Engineering.

Lastly, the two UPS truck-tractors were outfitted with telemetry units described as *tractor telemetry units* (TTU) that transmitted, via cellular service, vehicle location (latitude and longitude), speed and ignition status data at certain intervals. The data was conveyed to NTSB investigators in a hard copy format.

5.1. Electronic Engine Control System Data - General

As noted, the four heavy vehicles involved in the crash events were powered by engines manufactured by Detroit Diesel Corporation. The Van Hool motorcoach was outfitted with a Series 60 engine, the FedEx Cascadia had a DD15 engine and the two UPS Cascadia trucks had DD13 engines. Various engine parametric and event data is accessible through two commercially available software packages authorized by Detroit Diesel – DDEC Reports and Diagnostic Link.[20] Most of the data imaged by the software is output in predefined report formats.

The DDEC Reports software images and reports data related to *last stop*, *hard braking*, and *fault code* events. Recorded time-series event data may include up to two hard brake events, one last stop event, and three most-recent fault code events.[21] Additionally, the DDEC Reports data will include certain daily engine use activity, histograms (engine load, engine speed, idle time, speed range, etc.), a three-month engine use summary and some limited configuration and life-to-date data.

Last stop and hard brake records are reported as time-series events. A last stop typically occurs when the vehicle speed decreases to 1.5 mph or less followed by an ignition "off" or the vehicle remaining stopped for at least 15 seconds.[22] The data is recorded in one-second intervals and covers 104 seconds before- and 15 seconds after the last stop event. A hard brake event typically triggers when a decrease in vehicle speed exceeds a programmed or configuration threshold. For these vehicles, the configuration information indicates the threshold was 7 mph per second. The time-series data is reported at one-second intervals over a period of 60 seconds before and 15 seconds after the trigger threshold. Fault codes are likewise reported as time-series events and are reported over a period of 55seconds before and 5 seconds after the event is triggered.

[20] DDEC – "Detroit Diesel Electronic Control". Diagnostic Link is synonymous with Detroit Diesel Diagnostic Link or DDDL.
[21] Event time and date is based upon an internal clock (typically formatted as EDT) which if not updated will lose accuracy (drift) over time. To adjust for drift, the event time/date are adjusted to that of the computer during the data imaging. Accuracy of the time/date stamp relies on both the internal system clock and the imaging computer.
[22] The DDEC-V ECM present in the Van Hool may require 20-25 seconds to write a last stop record.

The Diagnostic Link software will access data that includes ECM calibration, audit trail, ECM and engine configuration, additional fault code information and ECM clock details.[23]

5.2. Van Hool Motorcoach Data

The Van Hool's Detroit Diesel Series 60 engine was managed by DDEC V ECM that was recovered from the vehicle. As referenced in the NTSB *Vehicle Factors Group Factual Report*, NTSB investigators transported the module to Detroit Diesel for imaging on February 19, 2020. Detroit Diesel technicians provided NTSB investigators with data from the DDEC Reports and Diagnostic Link software imaging. Among the recorded data was a *last stop* event record. Sufficient configuration data was provided to validate the event as related to the crash. While two *hard brake* events were recorded, neither was associated with the collision.

Data reported with the *last stop* event included vehicle speed (mph), engine speed (revolutions per minute-RPM), brake (signal lamp switch activation), clutch (pedal switch activation), percent engine load, percent throttle, cruise control ("on"/"off") and fault code (present "yes"/"no"), all reported at one second intervals. **Figure 17** depicts a graph based on the DDEC Report data table – note that brake status was assigned an arbitrary value to be depicted as "on" or "off" ("off"=5, "on"=50). An image of the data table is presented in an appendix to this report. Also see the NTSB *Vehicle Factors Group Factual Report* for additional information regarding the recovered data report and inclusion of this data in the docket.

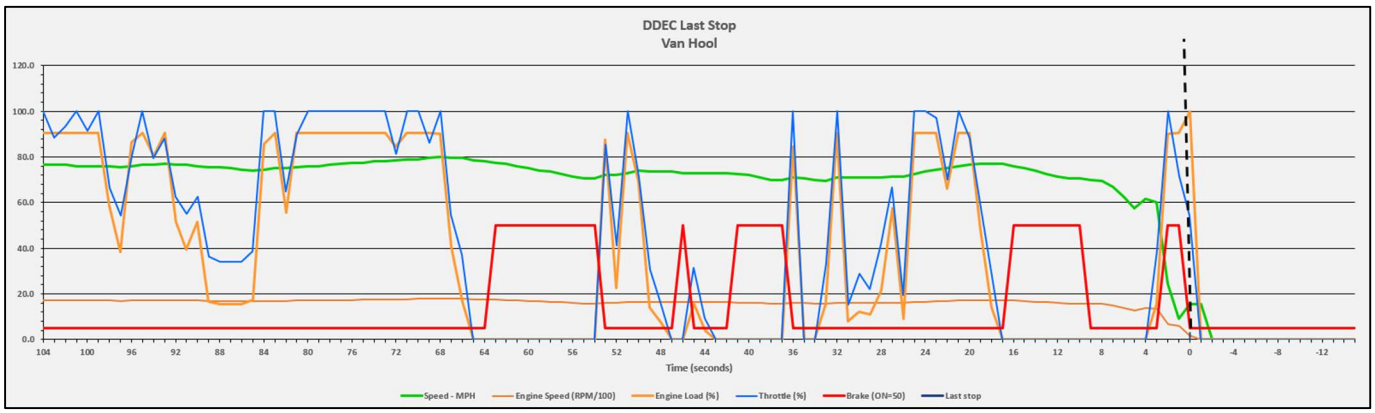


Figure 17: Graph depicting the Van Hool's last stop record acquired from the engine ECM through DDEC Reports software.

After adjusting for the ECM clock time drift (04h:12m:44s), the last stop record, as recorded, was triggered at 03:29:02 AM (EDT) on 01/05/2020.[24] While two hard brake events

[23] An exception to the ECM clock data existed in the FedEx model Cascadia. Instead of being located in CPC module as with the two UPS tractors, the real-time clock for this model Cascadia is located in the instrument cluster.
[24] Internal ECM clocks are known to lose accuracy over time ("drift"). Event times are adjusted using the download computer time to account for drift. Event time accuracy even after adjustment may be further influenced by irregular time drift and the accuracy of the initial setting.

were also recorded, the most recent occurred on 01/04/2020 at 05:06:15 AM and the one preceding that was reported on 01/02/2020.

Examining the data preceding the crash, the data indicate an overall average speed of 73.8 mph with a maximum speed of 80 mph. Just before entering the curve preceding the crash location (spiral segment included), the motorcoach attained a reported speed of 77 mph. The last stop data record covered about two miles of the motorcoach travel before the crash. Configuration data obtained through the Diagnostic Link software enabled validation of the reported vehicle speed.

The data download reported several fault or diagnostic codes. Diagnostic code data extracted as a snapshot through the Diagnostic Link software conveyed 11 active faults, however, nine (9) of those were initiated during the download as indicated by date but no time stamp.[25] This is a known occurrence during a bench-top or off-vehicle download where the ECM is powered outside the vehicle system. Two (2) diagnostic codes remained active at download but began earlier, those faults included "coolant level sensor – input voltage high" (initiated March 12) and missing other ECU information (initiated October 3). Two additional diagnostic codes were reported but ceased on the day of the crash. Those included "vehicle overspeed - absolute (March 31 – January 5, 2020) and "turbo speed sensor – input failure (June 6 – January 5, 2020).[26]

5.3. FedEx Cascadia Data

This truck-tractor as well as the two UPS units were imaged by PSP investigators on January 16, 2020.[27] The engine management ECMs were interrogated while still in the vehicles using only the DDEC Reports software. The DDEC Reports output conveyed two (2) *hard brake* records and a *last stop* record. One of the hard brake events and the last stop event were reported at 03:32:37 AM on 01/05/2020. It is important to note that the precision of this time cannot be validated as the ECM real time clock for this model is located in the instrument cluster and that data was not acquired.[28] The overall data appeared consisted with the crash events, but the time stamp lagged the event time recorded by the Lytx DriveCam video system by about 01m:20s.[29]

Data reported with the *last stop* and *hard brake* events include vehicle speed (mph), engine speed (revolutions per minute-RPM), brake (signal lamp switch activation), clutch (pedal switch activation), percent engine load, percent throttle, cruise control ("on"/"off") and fault code (present "yes"/"no"), all reported at one second intervals. **Figure 18** depicts a graph with the hard brake record overlaid atop the last stop record – note that brake status was assigned an arbitrary value to be depicted as "on" or "off" ("off"=10, "on"=30). An image of the data table is presented in an

[25] The three current diagnostic codes noted in the DDEC Reports printout include those set at the time of ECM download.
[26] The ECM calibration data indicated that the overspeed threshold was set at 82 mph.
[27] While the FedEx and two UPS tractors had different engines models (DD15 and DD13, respectively), all were managed by a DDEC 16 (EPA GHG 17) engine control module.
[28] The ECU (ECM) time displayed on the *Communications Manager* page during imaging displays a "default" time that is equivalent to midnight UTC in the time zone of the laptop clock. The vehicle real time clock must be viewed through the instrument cluster (ICU-C).
[29] The trigger event for this time stamp was not identified although the event time appears to approximate the cessation of the longitudinal acceleration associated with the impact.

appendix to this report. Also see the NTSB *Vehicle Factors Group Factual Report* for additional information regarding the recovered data report and inclusion of this data in the docket.

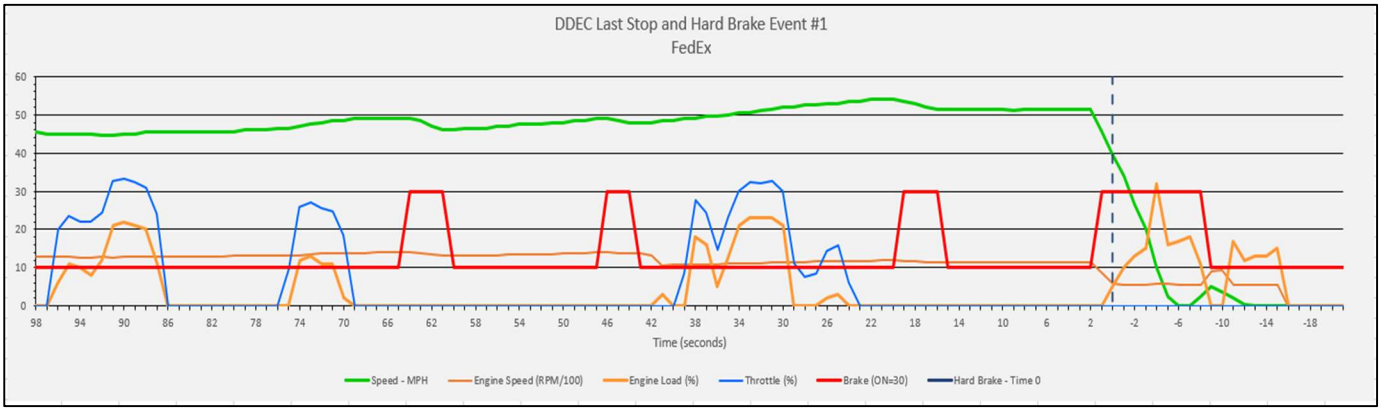


Figure 18: Graph depicting the combination of the FedEx unit's hard brake and last stop record acquired from the engine ECM through DDEC Reports software. The hard brake and last stop records have been combined.

Examining the data preceding the crash, the data indicate an overall average speed of 48.7 mph with a maximum speed of 54 mph. The combined last stop and hard brake data records covered about 1.36 miles of the truck's travel before the crash.

5.4. UPS Unit-1 Cascadia Data

Although PSP investigators were able to electronically connect with the truck-tractor's engine management ECMs using the DDEC software, no *hard brake* or *last stop* data related to the crash were recovered.[30] The two *hard brake* records contained in the DDEC report occurred during the preceding month. While the available *last stop* record indicated a time of 01:11:06 AM on 01/05/2020, the data fit with a stop that occurred about 01:12:55 AM, which was the last stop before the crash as indicated by other data. The ECM data indicated that the vehicle had traveled about 155 miles on 01/05/2020 with 02h:28m of drive time and 01h:01m of idle time.

Subsequently, UPS provided NTSB investigators with a hard copy printout of certain vehicle position and speed data received via an onboard tractor telemetry unit (TTU) manufactured by CalAmp Corporation.[i] In general, the data conveyed vehicle position via GNSS latitude and longitude geographic coordinates, a unit of speed in mph, a date/time (UTC) stamp and ignition status indication.[31] UPS representatives described the data as a means to identify near real-time vehicle routing and speed.

[30] A sudden or catastrophic engine shutdown or electrical failure resulting from the collision could preclude the writing of data to the ECM memory.
[31] GNSS-Global Navigation Satellite System. Global Positioning System (GPS) includes satellites within the GNSS.

The data presented covered approximately 28h:31m:36s between 8:53:13 AM on 01/04/2020 and 13:24:49 PM on 01/05/2020, as adjusted for the local time zone. Generally, the data was reported at ten second intervals (91% of the records) although some variance was observed – typically ranging between consecutive entries that totaled 10 seconds (e.g., 4/6 and 3/7) or at a 30-second interval. Seven sample intervals (0.12%) exceeded 30 seconds with at least two of those associated with a change in ignition status (i.e., ignition off).

UPS conveyed that the indicated times were likely generated as the data was created or transmitted (cellular signal).[32] The regular reporting interval for the data was identified as 10 seconds. Other time intervals represented either an upload of data across the cellular network or the triggering of an event.[33] Aside from a limited number of entries, consistency with time interval reporting was apparent.

The data provide an indication that the truck-tractor began moving at approximately 01:03:04 AM on 01/05/2020, an estimated 2h:28m before the crash events. The data indicate a continuous operation of the truck with constant highway speeds (55 mph+) being achieved about fifteen minutes after movement began. The average reported speed during this period was approximately 67 mph. While the recorded speed was conveyed as a sample taken during the time interval, the reported value was consistent with the calculated average speed over the distance between consecutive GNSS coordinates.[34] The vehicle travel distance was within one mile of that indicated by the ECM data and the drive/idle time was within about 2.5 minutes.

At an indicated time of 03:31:18 (local time) a noticeable change in the reported data was observed. This time sample was reported nine seconds after the previous and indicated a speed of 0 mph. One second later at 03:31:19, the reported speed was 56 mph – a decrease from the relatively consistent 69-71 mph speeds reported during the preceding 3.5 minutes of travel and lower than nearly all the samples recorded at highway speed.[35] While the precision of location coordinates is likely consistent with typical GNSS, the location coordinates at the 03:31:18 time stamp precede the area of the collision. The location coordinates that follow were proximate the area of impact and the vehicle's post-collision position of rest.

UPS representatives conveyed that the one second interval and zero speed value can be indicative of a *harsh brake event* which is defined as a minimum decrease in vehicle speed of 10 mph per second (~0.45g). No additional types of events were reported as having been configured to trigger a data record in this manner. Typically, the triggering of a *harsh brake* event would be

[32] CalAmp clarified that the time stamps are derived from the GPS signal and recorded at the time of the event. In the event of a loss in GPS signal, a time stamp may be acquired from the cellular transmission. The data reporting interval is user configurable.

[33] While UPS had configured the TTU to trigger harsh braking events, CalAmp conveyed that the device can be configured to implement 100 triggers and 60 conditions for event reporting related to telematics applications. Event triggers can be configured to use accelerations derived from GPS or accelerometer data.

[34] CalAmp conveyed that speed data can be derived from either GPS integration or transmitted to the TTU via the vehicle CAN (controller area network) bus depending upon user configuration. The value reported depends upon the unit installation and configuration.

[35] Only three instances of a one-second interval appeared in the data. The other two samples occurred with a change in ignition status where the vehicle was not moving and preceded much longer reporting intervals.

accompanied by the transmission of additional data that would include vehicle speed, position (GNSS) and brake indicator at one-second intervals. Such data was not received.

Figure 19 depicts the final, approximate 30 seconds of the data overlaid atop a Google Earth image. **Table 6** depicts data reported during the 3.5 minutes preceding the noticeable change in reported values.

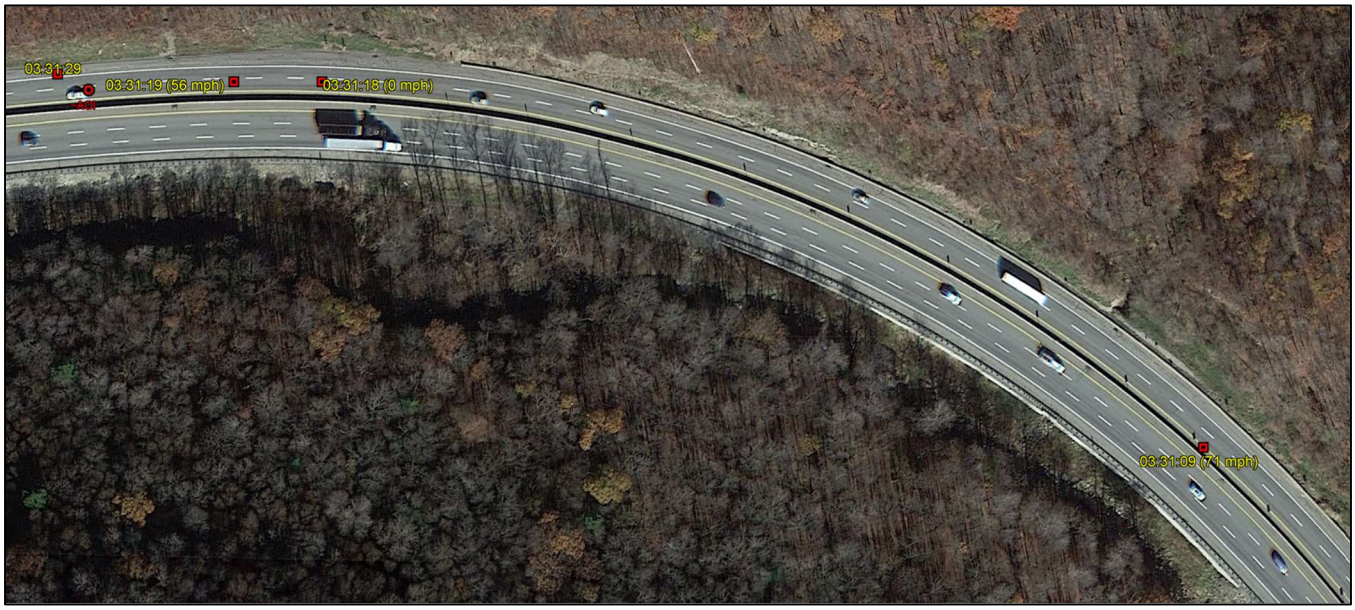


Figure 19: Depiction of relative TTU data position of UPS-1 combination preceding the area of the crash as overlaid on a Google Earth image.

Table 6: UPS-1 Position and Speed as Reported by Onboard Telemetry Unit (TTU)

Date / Time Stamp	Reporting Interval (sec)	Latitude	Longitude	Reported Speed (mph)
1/5/2020 3:27:39	10	40.111270	-79.385700	70
1/5/2020 3:27:49	10	40.112640	-79.388800	70
1/5/2020 3:27:59	10	40.114020	-79.392000	69
1/5/2020 3:28:09	10	40.115470	-79.395100	69
1/5/2020 3:28:19	10	40.117610	-79.397400	70
1/5/2020 3:28:29	10	40.120310	-79.398300	69
1/5/2020 3:28:39	10	40.122860	-79.399700	69
1/5/2020 3:28:49	10	40.124770	-79.402300	70
1/5/2020 3:28:59	10	40.126610	-79.405100	70
1/5/2020 3:29:09	10	40.128630	-79.407600	68
1/5/2020 3:29:19	10	40.131300	-79.408600	69
1/5/2020 3:29:29	10	40.134080	-79.409000	69
1/5/2020 3:29:39	10	40.136840	-79.409600	70
1/5/2020 3:29:49	10	40.139190	-79.411500	69
1/5/2020 3:29:59	10	40.140750	-79.414500	69
1/5/2020 3:30:29	30	40.145550	-79.423600	70
1/5/2020 3:30:39	10	40.147610	-79.426100	70
1/5/2020 3:30:49	10	40.149640	-79.428600	70
1/5/2020 3:30:59	10	40.152130	-79.430400	71
1/5/2020 3:31:09	10	40.154440	-79.432700	71
1/5/2020 3:31:18	9	40.155390	-79.435700	0
1/5/2020 3:31:19	1	40.155390	-79.436000	56
1/5/2020 3:31:29	10	40.155410	-79.436600	POR

5.5. UPS Unit-2 Cascadia Data

The engine management ECMs were interrogated while still in the vehicle using only the DDEC Reports software. The DDEC Reports output conveyed two (2) *hard brake* records and a *last stop* record. One of the hard brake events and the last stop event were reported on 01/05/2020 at 03:31:50 AM and 03:31:58 AM respectively after adjusting for the ECM clock drift (00h:01m:44s).

Data reported with the *last stop* and *hard brake* events included vehicle speed (mph), engine speed (revolutions per minute-RPM), brake (signal lamp switch activation), clutch (pedal

switch activation), percent engine load, percent throttle, cruise control ("on"/"off") and fault code (present "yes"/"no"), all reported at one second intervals. **Figure 20** depicts a graph based on the DDEC Report data table wherein the hard brake record has been overlaid atop the last stop record – note that brake status was assigned an arbitrary value to be depicted ("off"=10, "on"=40). An image of the data table is presented in an appendix to this report. Also see the NTSB *Vehicle Factors Group Factual Report* for additional information regarding the recovered data report and inclusion of this data in the docket.

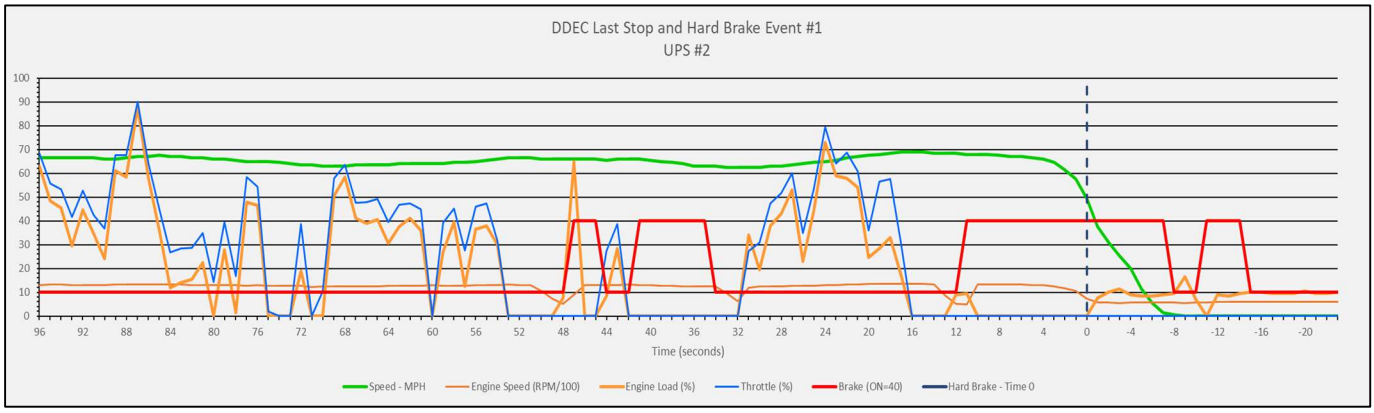


Figure 20: Graph depicting the combination of the UPS-2 unit's hard brake and last stop record acquired from the engine ECM through DDEC Reports software. The hard brake and last stop records have been combined.

Examination of the data preceding the crash indicated an overall average speed of approximately 65.5 mph with a maximum speed of 69 mph. The combined last stop and hard brake data records covered about 1.78 miles of the truck's travel before the crash.

As with the UPS-1 combination, the carrier also provided TTU data for the UPS-2 combination. The data covered approximately 6h:33m:41s between 9:02:21 PM on 01/04/2020 and 03:36:02 on 01/05/2020 AM EDT. The data set were presented in a format identical to the UPS-1 data and where reviewed, followed a similar 10-second reporting interval. The data indicate that the vehicle had been in motion beginning about 2h:37m:35s before reaching the crash location. The final three minutes of data, covering about 3.5 miles indicated an average speed of 65.6 mph.

The UPS-2 TTU data provided no indication of a *harsh braking* event and continued to log speed and positional information until an indicated time of 03:31:24 where the speed had decreased from 67 mph to 0 mph. The GNSS coordinate data at this sample placed the vehicle just under 1,000 feet from its position of rest. The subsequent data sample ten seconds later likewise reported zero mph and the GNSS position was proximate the vehicle's position of final rest on the embankment. This speed and location data persisted for remaining 04m:38s of the record. While the time stamps indicate some additional offset from the adjusted ECM clock for the *last stop* and *hard brake* event may be warranted, the available data provide insufficient precision to do so. Nonetheless, indicated speeds, time intervals and relative distances were consistent.

Figure 21 depicts the final, approximate 70 seconds of the data overlaid atop a Google Earth image. **Table 7** depicts data reported during the 3.5 minutes preceding the noticeable change in reported values.

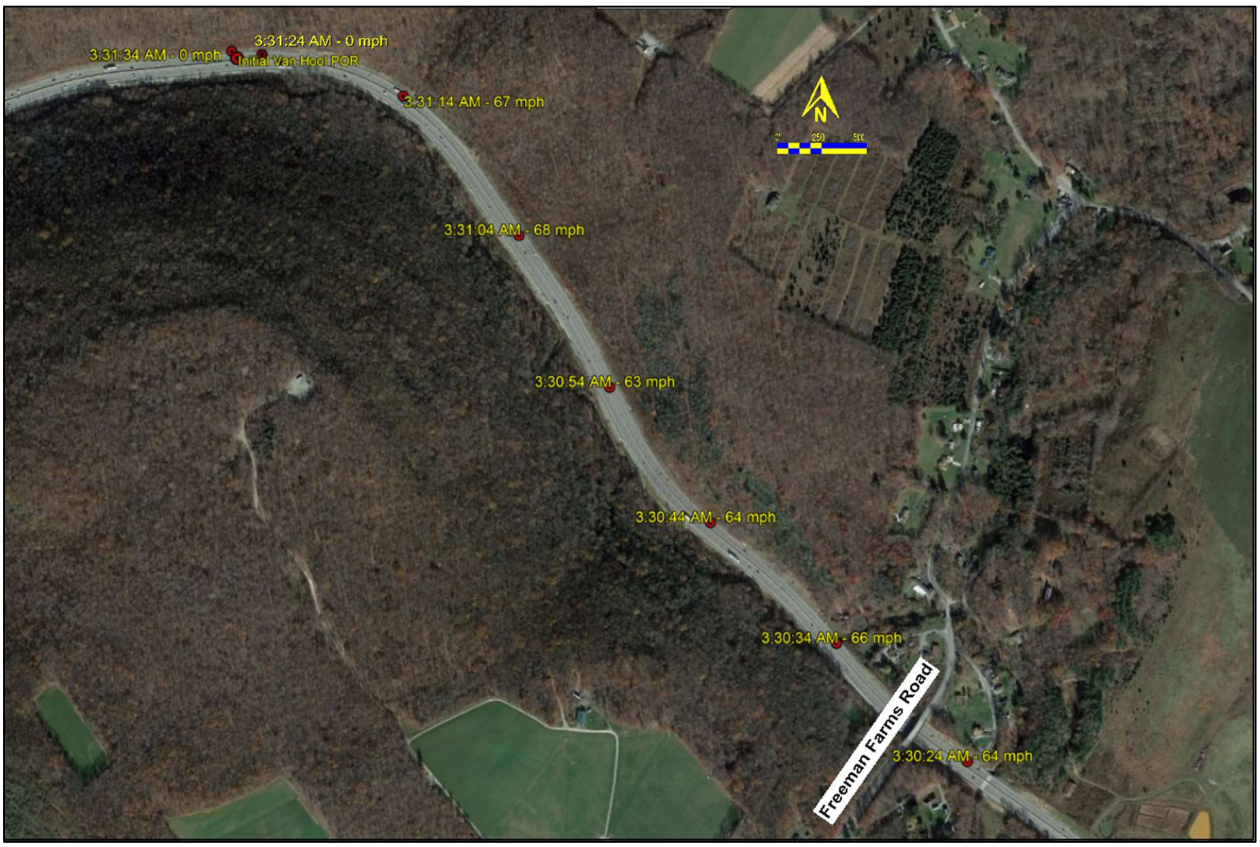


Figure 21: Depiction of TTU data relative position of UPS-2 combination preceding the area of the crash as overlaid on a Google Earth image.

Table 7: UPS-2 Position and Speed as Reported by Onboard Telemetry Unit (TTU)

Date / Time Stamp	Reporting Interval (sec)	Latitude	Longitude	Reported Speed (mph)
1/5/2020 3:28:14	10	40.11781	-79.3975	70
1/5/2020 3:28:24	10	40.12052	-79.3984	67
1/5/2020 3:28:34	10	40.12288	-79.3997	63
1/5/2020 3:28:44	10	40.12462	-79.4021	64
1/5/2020 3:28:54	10	40.12637	-79.4048	66
1/5/2020 3:29:04	10	40.12820	-79.4073	64
1/5/2020 3:29:14	10	40.13063	-79.4085	67
1/5/2020 3:29:24	10	40.13337	-79.409	68
1/5/2020 3:29:34	10	40.13610	-79.4094	67
1/5/2020 3:29:44	10	40.13855	-79.4108	66
1/5/2020 3:29:54	10	40.14026	-79.4135	66
1/5/2020 3:30:04	10	40.14172	-79.4165	65
1/5/2020 3:30:14	10	40.14321	-79.4193	63
1/5/2020 3:30:24	10	40.14471	-79.422	64
1/5/2020 3:30:34	10	40.14650	-79.4246	66
1/5/2020 3:30:44	10	40.14833	-79.4271	64
1/5/2020 3:30:54	10	40.15038	-79.4291	63
1/5/2020 3:31:04	10	40.15268	-79.4309	68
1/5/2020 3:31:14	10	40.15479	-79.4332	67
1/5/2020 3:31:24	10	40.15542	-79.436	0
1/5/2020 3:31:34	10	40.15547	-79.4366	POR

E. REFERENCES

- NTSB *Highway Factors Group Factual Report*
- NTSB *Vehicle Factors Group Factual Report*
- NTSB *Video Study*

F. DOCKET MATERIAL

The following attachments and photographs are included in the docket for this investigation: None

END OF REPORT

Robert J. Squire
Highway Accident Investigator

Appendix A: Vehicle DDEC Report Data Table:

Time (sec)	Speed (mph)	Engine Speed (rpm)	Brake	Clutch	Engine Load (%)	Throttle (%)	Cruise	DTC
104	76.5	1718	No	No	90.5	100	No	Yes
103	76.5	1715	No	No	90.5	88.4	No	Yes
102	76.5	1715	No	No	90.5	93.2	No	Yes
101	76.0	1713	No	No	90.5	100	No	Yes
100	76.0	1715	No	No	90.5	91.6	No	Yes
99	76.0	1713	No	No	90.5	100	No	Yes
98	76.0	1706	No	No	58.5	66.4	No	Yes
97	75.5	1700	No	No	38.5	54.4	No	Yes
96	76.0	1710	No	No	86.5	80.4	No	Yes
95	76.5	1714	No	No	90.5	100	No	Yes
94	76.5	1719	No	No	80.5	79.6	No	Yes
93	77.0	1729	No	No	90.5	88	No	Yes
92	76.5	1725	No	No	51.5	62.4	No	Yes
91	76.5	1714	No	No	39.5	55.2	No	Yes
90	76.0	1710	No	No	51.5	62.4	No	Yes
89	75.5	1695	No	No	16.5	36.4	No	Yes
88	75.5	1693	No	No	15.5	34	No	Yes
87	75.0	1679	No	No	15.5	34	No	Yes
86	74.5	1671	No	No	15.5	34	No	Yes
85	74.0	1666	No	No	17.5	38.4	No	No
84	74.5	1677	No	No	85.5	100	No	No
83	75.0	1687	No	No	90.5	100	No	Yes
82	75.0	1688	No	No	55.5	64.8	No	Yes
81	75.5	1703	No	No	90.5	90	No	Yes
80	76.0	1707	No	No	90.5	100	No	Yes
79	76.0	1714	No	No	90.5	100	No	Yes
78	76.5	1725	No	No	90.5	100	No	Yes
77	77.0	1732	No	No	90.5	100	No	Yes
76	77.5	1739	No	No	90.5	100	No	Yes
75	77.5	1748	No	No	90.5	100	No	Yes
74	78.0	1754	No	No	90.5	100	No	Yes
73	78.0	1759	No	No	90.5	100	No	Yes
72	78.5	1766	No	No	84.5	81.2	No	Yes
71	79.0	1772	No	No	90.5	100	No	Yes
70	79.0	1783	No	No	90.5	100	No	Yes
69	79.5	1788	No	No	90.5	86	No	Yes
68	80.0	1795	No	No	90	100	No	Yes
67	79.5	1788	No	No	40.5	54.8	No	Yes
66	79.5	1784	No	No	16.5	37.2	No	Yes
65	78.5	1775	No	No	0	0	No	Yes
64	78.0	1758	No	No	0	0	No	Yes
63	77.5	1745	Yes	No	0	0	No	Yes
62	77.0	1727	Yes	No	0	0	No	Yes
61	76.0	1714	Yes	No	0	0	No	Yes
60	75.0	1689	Yes	No	0	0	No	Yes
59	74.0	1667	Yes	No	0	0	No	Yes
58	73.5	1654	Yes	No	0	0	No	Yes
57	72.5	1628	Yes	No	0	0	No	Yes
56	71.5	1606	Yes	No	0	0	No	Yes
55	70.5	1582	Yes	No	0	0	No	Yes
54	70.5	1585	Yes	No	0	0	No	Yes
53	72.0	1617	No	No	87.5	85.6	No	Yes
52	72.0	1615	No	No	22.5	41.2	No	Yes
51	73.0	1645	No	No	90.5	100	No	Yes
50	74.0	1659	No	No	69	71.2	No	Yes
49	73.5	1650	No	No	14	30.8	No	Yes
48	73.5	1654	No	No	7.5	16.4	No	Yes
47	73.5	1649	No	No	0	0	No	Yes
46	73.0	1646	Yes	No	0	0	No	Yes
45	73.0	1632	No	No	15.5	31.6	No	Yes
44	73.0	1647	No	No	4	9.2	No	Yes
43	73.0	1642	No	No	0	0	No	No
42	73.0	1636	No	No	0	0	No	No
41	72.5	1626	Yes	No	0	0	No	No
40	72.0	1615	Yes	No	0	0	No	No
39	71.0	1593	Yes	No	0	0	No	No
38	70.0	1572	Yes	No	0	0	No	No
37	70.0	1572	Yes	No	0	0	No	No
36	71.0	1593	No	No	84.5	100	No	No
35	70.5	1590	No	No	0	0	No	Yes
34	70.0	1572	No	No	0	0	No	Yes
33	69.5	1572	No	No	15.5	33.2	No	Yes
32	71.0	1597	No	No	90.5	100	No	Yes
31	71.0	1591	No	No	8	15.2	No	Yes
30	71.0	1598	No	No	12	28.8	No	Yes
29	71.0	1603	No	No	11	22	No	Yes
28	71.0	1607	No	No	21.5	41.6	No	Yes
27	71.5	1610	No	No	57.5	66.8	No	Yes
26	71.5	1603	No	No	9	19.6	No	Yes
25	72.5	1636	No	No	90.5	100	No	Yes
24	73.5	1655	No	No	90.5	100	No	Yes
23	74.5	1674	No	No	90.5	97.2	No	Yes
22	75.0	1682	No	No	66	70	No	Yes
21	76.0	1707	No	No	90.5	100	No	Yes
20	76.5	1725	No	No	90.5	88	No	Yes
19	77.0	1731	No	No	48	60	No	Yes
18	77.0	1725	No	No	14	30	No	Yes
17	77.0	1728	No	No	0	0	No	Yes
16	76.0	1707	Yes	No	0	0	No	Yes
15	75.0	1685	Yes	No	0	0	No	Yes
14	74.0	1660	Yes	No	0	0	No	Yes
13	72.5	1631	Yes	No	0	0	No	Yes
12	71.5	1609	Yes	No	0	0	No	Yes
11	70.5	1589	Yes	No	0	0	No	Yes
10	70.5	1585	Yes	No	0	0	No	No
9	70.0	1578	No	No	0	0	No	No
8	69.5	1560	No	No	0	0	No	No
7	67.0	1508	No	No	0	0	No	No
6	62.5	1401	No	No	0	0	No	No
5	57.5	1284	No	No	0	0	No	No
4	61.5	1393	No	No	0	0	No	No
3	60.0	1342	No	No	15.5	38.8	No	No
2	24.5	687	Yes	No	90	100	No	Yes
1	9.0	607	Yes	No	90.5	71.6	No	Yes
0	15.5	188	No	No	100	54.4	No	No
-1	15.5	0	No	No	0	0	No	No
-2	0.0	0	No	No	0	0	No	No
-3	0.0	0	No	No	0	0	No	No
-4	0.0	0	No	No	0	0	No	No
-5	0.0	0	No	No	0	0	No	No
-6	0.0	0	No	No	0	0	No	No
-7	0.0	0	No	No	0	0	No	No
-8	0.0	0	No	No	0	0	No	No
-9	0.0	0	No	No	0	0	No	No
-10	0.0	0	No	No	0	0	No	No
-11	0.0	0	No	No	0	0	No	No
-12	0.0	0	No	No	0	0	No	No
-13	0.0	0	No	No	0	0	No	No
-14	0.0	0	No	No	0	0	No	No
-15	0.0	0	No	No	0	0	No	No

Figure 22: DDEC Reports last stop data table for the Van Hool motorcoach.

Time (sec)	Last stop	Speed (mph)	Engine Speed (rpm)	Brake	Clutch	Engine Load (%)	Throttle (%)	Cruise	DTC
98	1:44	45.5	1297	No	No	0	0	No	No
97	1:43	45	1287	No	No	0	0	No	No
96	1:42	45	1283	No	No	6	20	No	No
95	1:41	45	1284	No	No	11	23.6	No	No
94	1:40	45	1268	No	No	10	22	No	No
93	1:39	45	1275	No	No	8	22	No	No
92	1:38	44.5	1277	No	No	12	24.4	No	No
91	1:37	44.5	1275	No	No	21	32.8	No	No
90	1:36	45	1284	No	No	22	33.2	No	No
89	1:35	45	1284	No	No	21	32.4	No	No
88	1:34	45.5	1291	No	No	20	30.8	No	No
87	1:33	45.5	1291	No	No	11	24	No	No
86	1:32	45.5	1292	No	No	0	0	No	No
85	1:31	45.5	1295	No	No	0	0	No	No
84	1:30	45.5	1292	No	No	0	0	No	No
83	1:29	45.5	1295	No	No	0	0	No	No
82	1:28	45.5	1299	No	No	0	0	No	No
81	1:27	45.5	1300	No	No	0	0	No	No
80	1:26	45.5	1307	No	No	0	0	No	No
79	1:25	46	1309	No	No	0	0	No	No
78	1:24	46	1313	No	No	0	0	No	No
77	1:23	46	1314	No	No	0	0	No	No
76	1:22	46.5	1321	No	No	0	0	No	No
75	1:21	46.5	1328	No	No	0	9.6	No	No
74	1:20	47	1333	No	No	12	26	No	No
73	1:19	47.5	1355	No	No	13	27.2	No	No
72	1:18	48	1366	No	No	11	25.6	No	No
71	1:17	48.5	1380	No	No	11	24.8	No	No
70	1:16	48.5	1389	No	No	2	18.4	No	No
69	1:15	49	1391	No	No	0	0	No	No
68	1:14	49	1392	No	No	0	0	No	No
67	1:13	49	1395	No	No	0	0	No	No
66	1:12	49	1396	No	No	0	0	No	No
65	1:11	49	1396	No	No	0	0	No	No
64	1:10	49	1395	Yes	No	0	0	No	No
63	1:09	48.5	1375	Yes	No	0	0	No	No
62	1:08	47	1341	Yes	No	0	0	No	No
61	1:07	46	1317	Yes	No	0	0	No	No
60	1:06	46	1315	No	No	0	0	No	No
59	1:05	46.5	1320	No	No	0	0	No	No
58	1:04	46.5	1324	No	No	0	0	No	No
57	1:03	46.5	1328	No	No	0	0	No	No
56	1:02	47	1335	No	No	0	0	No	No
55	1:01	47	1338	No	No	0	0	No	No
54	1:00	47.5	1346	No	No	0	0	No	No
53	0:59	47.5	1355	No	No	0	0	No	No
52	0:58	47.5	1358	No	No	0	0	No	No
51	0:57	48	1364	No	No	0	0	No	No
50	0:56	48	1370	No	No	0	0	No	No
49	0:55	48.5	1379	No	No	0	0	No	No
48	0:54	48.5	1388	No	No	0	0	No	No
47	0:53	49	1395	No	No	0	0	No	No
46	0:52	49	1398	Yes	No	0	0	No	No
45	0:51	48.5	1383	Yes	No	0	0	No	No
44	0:50	48	1374	Yes	No	0	0	No	No
43	0:49	48	1372	No	No	0	0	No	No
42	0:48	48	1328	No	Yes	0	0	No	No
41	0:47	48.5	1049	No	Yes	3	0	No	No
40	0:46	48.5	1071	No	Yes	0	0	No	No
39	0:45	49	1076	No	No	0	8.4	No	No
38	0:44	49	1096	No	No	18	27.6	No	No
37	0:43	49.5	1088	No	No	16	24.4	No	No
36	0:42	49.5	1098	No	No	5	14.8	No	No
35	0:41	50	1115	No	No	13	23.2	No	No
34	0:40	50.5	1109	No	No	21	30	No	No
33	0:39	50.5	1117	No	No	23	32.4	No	No
32	0:38	51	1128	No	No	23	32	No	No
31	0:37	51.5	1134	No	No	23	32.8	No	No
30	0:36	52	1146	No	No	21	30	No	No
29	0:35	52	1152	No	No	0	11.2	No	No
28	0:34	52.5	1158	No	No	0	7.6	No	No
27	0:33	52.5	1162	No	No	0	8.4	No	No
26	0:32	53	1169	No	No	2	14.4	No	No
25	0:31	53	1171	No	No	3	16	No	No
24	0:30	53.5	1180	No	No	0	6	No	No
23	0:29	53.5	1182	No	No	0	0	No	No
22	0:28	54	1187	No	No	0	0	No	No
21	0:27	54	1192	No	No	0	0	No	No
20	0:26	54	1191	No	Yes	0	0	No	No
19	0:25	53.5	1186	Yes	No	0	0	No	No
18	0:24	53	1164	Yes	No	0	0	No	No
17	0:23	52	1145	Yes	No	0	0	No	No
16	0:22	51.5	1135	Yes	No	0	0	No	No
15	0:21	51.5	1134	No	No	0	0	No	No
14	0:20	51.5	1133	No	No	0	0	No	No
13	0:19	51.5	1133	No	No	0	0	No	No
12	0:18	51.5	1133	No	No	0	0	No	No
11	0:17	51.5	1133	No	No	0	0	No	No
10	0:16	51.5	1132	No	No	0	0	No	No
9	0:15	51	1131	No	No	0	0	No	No
8	0:14	51.5	1131	No	No	0	0	No	No
7	0:13	51.5	1132	No	No	0	0	No	No
6	0:12	51.5	1133	No	No	0	0	No	No
5	0:11	51.5	1132	No	No	0	0	No	No
4	0:10	51.5	1136	No	No	0	0	No	No
3	0:09	51.5	1139	No	No	0	0	No	No
2	0:08	51.5	1142	No	No	0	0	No	No
1	0:07	45.5	868	Yes	Yes	0	0	No	No
0	0:06	39.5	583	Yes	No	5	0	No	No
-1	0:05	34	557	Yes	No	10	0	No	No
-2	0:04	26.5	558	Yes	No	13	0	No	No
-3	0:03	20	558	Yes	No	15	0	No	No
-4	0:02	10	593	Yes	No	32	0	No	No
-5	0:01	2.5	574	Yes	No	16	0	No	No
-6	0:00	0	564	Yes	No	17	0	No	No
-7	0:01	0	557	Yes	No	18	0	No	No
-8	0:02	2.5	564	Yes	Yes	11	0	No	No
-9	0:03	5	900	No	Yes	0	0	No	No
-10	0:04	3.5	929	No	Yes	0	0	No	No
-11	0:05	2	566	No	Yes	17	0	No	No
-12	0:06	0.5	565	No	Yes	12	0	No	No
-13	0:07	0	566	No	No	13	0	No	No
-14	0:08	0	563	No	No	13	0	No	No
-15	0:09	0	559	No	No	15	0	No	No
-16	0:10	0	0	No	No	0	0	No	No
-17	0:11	0	0	No	No	0	0	No	No
-18	0:12	0	0	No	No	0	0	No	No
-19	0:13	0	0	No	No	0	0	No	No
-20	0:14	0	0	No	No	0	0	No	No
-21	0:15	0	0	No	No	0	0	No	No

Figure 23: Combined DDEC Reports combined last stop and hard brake data table for the FedEx truck-tractor.

Time (sec)	Last Stop	Speed (mph)	Engine Speed (rpm)	Brake	Clutch	Engine Load (%)	Throttle (%)	Cruise	DTC
96	1:44	66.5	1314	No	No	63	68.4	No	No
95	1:43	66.5	1315	No	No	48.5	55.6	No	No
94	1:42	66.5	1319	No	No	45.5	53.2	No	No
93	1:41	66.5	1313	No	No	29.5	41.6	No	No
92	1:40	66.5	1313	No	No	44.5	52.8	No	No
91	1:39	66.5	1311	No	No	34.5	42.4	No	No
90	1:38	66	1309	No	No	24	36.8	No	No
89	1:37	66	1315	No	No	61	67.6	No	No
88	1:36	66.5	1318	No	No	58.5	67.6	No	No
87	1:35	67	1328	No	No	87.5	90	No	No
86	1:34	67	1329	No	No	58	64	No	No
85	1:33	67.5	1328	No	No	36	44.8	No	No
84	1:32	67	1325	No	No	12	26.8	No	No
83	1:31	67	1318	No	No	14	28.4	No	No
82	1:30	66.5	1312	No	No	15.5	28.8	No	No
81	1:29	66.5	1309	No	No	22.5	34.8	No	No
80	1:28	66	1306	No	No	0	14.4	No	No
79	1:27	66	1301	No	No	28	39.6	No	No
78	1:26	65.5	1300	No	No	1.5	16.8	No	No
77	1:25	65	1287	No	No	48	58.4	No	No
76	1:24	65	1289	No	No	46.5	54.4	No	No
75	1:23	65	1267	No	No	0	2	No	No
74	1:22	64.5	1272	No	No	0	0	No	No
73	1:21	64	1261	No	No	0	0	No	No
72	1:20	63.5	1267	No	No	19	38.8	No	No
71	1:19	63.5	1231	No	No	0	0	No	No
70	1:18	63	1241	No	No	0	10.4	No	No
69	1:17	63	1243	No	No	50.5	58	No	No
68	1:16	63	1253	No	No	58.5	63.6	No	No
67	1:15	63.5	1256	No	No	41	47.6	No	No
66	1:14	63.5	1258	No	No	39	48	No	No
65	1:13	63.5	1260	No	No	40.5	49.2	No	No
64	1:12	63.5	1266	No	No	30.5	39.6	No	No
63	1:11	64	1265	No	No	37.5	46.8	No	No
62	1:10	64	1269	No	No	41	47.2	No	No
61	1:09	64	1269	No	No	36	44.8	No	No
60	1:08	64	1290	No	No	0	0	No	No
59	1:07	64	1285	No	No	27	39.2	No	No
58	1:06	64.5	1283	No	No	39.5	45.2	No	No
57	1:05	64.5	1279	No	No	12.5	27.6	No	No
56	1:04	65	1292	No	No	36.5	46	No	No
55	1:03	65.5	1302	No	No	38	47.2	No	No
54	1:02	66	1309	No	No	30	31.6	No	No
53	1:01	66.5	1325	No	No	0	0	No	No
52	1:00	66.5	1313	No	No	0	0	No	No
51	0:59	66.5	1311	No	No	0	0	No	No
50	0:58	66	1057	No	Yes	0	0	No	No
49	0:57	66	720	No	Yes	0	0	No	No
48	0:56	66	511	No	No	7.5	0	No	No
47	0:55	66	899	Yes	No	65	0	No	No
46	0:54	66	1303	Yes	No	0	0	No	No
45	0:53	66	1300	Yes	No	0	0	No	No
44	0:52	65.5	1299	No	No	8.5	27.2	No	No
43	0:51	66	1304	No	No	28.5	38.8	No	No
42	0:50	66	1325	No	No	0	0	No	No
41	0:49	66	1301	Yes	No	0	0	No	No
40	0:48	65.5	1294	Yes	No	0	0	No	No
39	0:47	65	1278	Yes	No	0	0	No	No
38	0:46	64.5	1264	Yes	No	0	0	No	No
37	0:45	64	1252	Yes	No	0	0	No	No
36	0:44	63	1245	Yes	No	0	0	No	No
35	0:43	63	1243	Yes	No	0	0	No	No
34	0:42	63	1240	No	No	0	0	No	No
33	0:41	62.5	937	No	Yes	0	0	No	No
32	0:40	62.5	618	No	Yes	0	0	No	No
31	0:39	62.5	1200	No	No	34	27.2	No	No
30	0:38	62.5	1240	No	No	19.5	30.8	No	No
29	0:37	63	1247	No	No	38	47.2	No	No
28	0:36	63	1255	No	No	43	51.6	No	No
27	0:35	63.5	1267	No	No	53	60	No	No
26	0:34	64	1270	No	No	23	34.8	No	No
25	0:33	64.5	1283	No	No	44	53.2	No	No
24	0:32	65	1295	No	No	73	79.6	No	No
23	0:31	65.5	1306	No	No	59	64	No	No
22	0:30	66.5	1321	No	No	58	68.8	No	No
21	0:29	67	1338	No	No	54	60.8	No	No
20	0:28	67.5	1344	No	No	24.5	36	No	No
19	0:27	68	1353	No	No	28.5	56.4	No	No
18	0:26	68.5	1360	No	No	33	57.6	No	No
17	0:25	69	1365	No	No	17	30.4	No	No
16	0:24	69	1363	No	No	0	0	No	No
15	0:23	69	1359	No	No	0	0	No	No
14	0:22	68.5	1315	No	No	0	0	No	No
13	0:21	68.5	864	No	Yes	0	0	No	No
12	0:20	68.5	530	No	No	9	0	No	No
11	0:19	68	500	Yes	No	9.5	0	No	No
10	0:18	68	1339	Yes	No	0	0	No	No
9	0:17	68	1337	Yes	No	0	0	No	No
8	0:16	67.5	1329	Yes	No	0	0	No	No
7	0:15	67	1324	Yes	No	0	0	No	No
6	0:14	67	1318	Yes	No	0	0	No	No
5	0:13	66.5	1312	Yes	No	0	0	No	No
4	0:12	66	1296	Yes	No	0	0	No	No
3	0:11	64.5	1241	Yes	No	0	0	No	No
2	0:10	61.5	1176	Yes	No	0	0	No	No
1	0:09	57.5	1068	Yes	No	0	0	No	No
0	0:08	49.5	734	Yes	Yes	0	0	No	No
-1	0:07	37.5	568	Yes	Yes	7.5	0	No	No
-2	0:06	31	559	Yes	Yes	10	0	No	No
-3	0:05	25.5	555	Yes	Yes	11.5	0	No	No
-4	0:04	20	563	Yes	Yes	9	0	No	No
-5	0:03	11.5	565	Yes	Yes	8.5	0	No	No
-6	0:02	5.5	566	Yes	Yes	8.5	0	No	No
-7	0:01	1.5	563	Yes	Yes	9	0	No	No
-8	0:00	0.5	560	No	Yes	9.5	0	No	No
-9	-0:01	0	547	No	Yes	16.5	0	No	No
-10	-0:02	0	568	No	Yes	7	0	No	No
-11	-0:03	0	576	Yes	Yes	0	0	No	No
-12	-0:04	0	595	Yes	Yes	9	0	No	No
-13	-0:05	0	599	Yes	No	8.5	0	No	No
-14	-0:06	0	597	Yes	No	9.5	0	No	No
-15	-0:07	0	597	No	No	10	0	No	No
-16	-0:08	0	598	No	No	10	0	No	No
-17	-0:09	0	600	No	No	9.5	0	No	No
-18	-0:10	0	599	No	No	9.5	0	No	No
-19	-0:11	0	600	No	No	9.5	0	No	No
-20	-0:12	0	598	No	No	10.5	0	No	No
-21	-0:13	0	600	No	No	9.5	0	No	No
-22	-0:14	0	600	No	No	9.5	0	No	No
-23	-0:15	0	600	No	No	10	0	No	No

Figure 24: Combined DDEC Reports combined last stop and hard brake data table for the UPS-2 truck-tractor.

Notes

[i] The tractor telemetry unit was identified as a CalAmp TTU-3640. CalAmp Corporation specializes in areas of telematics and tracking devices, vehicle connectivity, cloud services and fleet management applications. The company offers numerous devices for vehicle tracking with customizable data telematics. The TTU-3640 features a GNSS accuracy of ~2.0m CEP Open Sky, GPS SBAS 24 hours static with a location update rate of 4Hz, including SBAS - satellite-based augmentation system (WAAS - Wide Area Augmentation System in North America). The device features an internal tri-axial accelerometer that can be tied into numerous user-defined event triggers. Duration and sample rate in motion logs are configurable. Raw accelerometer data is gathered at 400Hz, but some features use lower sample rates, such as motion detection.