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

VEHICLE FACTORS GROUP CHAIRMAN'S FACTUAL REPORT

A. CRASH INFORMATION

Location:	Interstate 70/76 (I-70/76), Pennsylvania Turnpike at mile-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 New 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:	FedEx 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. VEHICLE FACTORS GROUP

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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 VEHICLE FACTORS INVESTIGATION

This document is a collection of factual information obtained during the detailed examinations of the 2005 Van Hool motorcoach, hereinafter referred to as the motorcoach, the 2018 Freightliner New Cascadia truck-tractor in combination with a 2019 Hyundai Translead semitrailer, hereinafter referred to as combination unit #1, and the 2018 Freightliner Cascadia truck-tractor in combination with a 2018 Stoughton semitrailer, hereinafter referred to as combination unit #2. Between January 6, 2020, and January 16, 2020, the Pennsylvania State Police (PSP) completed detailed inspections and the NTSB completed thorough examinations of the motorcoach, combination unit #1, and combination unit #2 at J.E. Herring Motor Co., located in Somerset, PA.

All primary vehicle mechanical and operational systems were examined, including the steering, braking, suspension, powertrain, and electrical systems. All available data recording devices were examined as well. Overall vehicle crash damage, along with any damage or anomalies discovered within the primary vehicle and operational systems were documented. Supporting photographs, vehicle specifications, maintenance records, and prior annual and roadside inspections were collected and reviewed.

The steering gearbox was removed from the motorcoach for further examination and analysis by the manufacturer. The Detroit Diesel Electronic Control (DDEC) module was removed from the motorcoach by the PSP and transferred to the NTSB for transport to Detroit Diesel headquarters in Detroit, MI, for further examination and analysis. The DDEC module from the motorcoach was examined and downloaded at Detroit Diesel on February 19, 2020. The data from the DDEC modules, installed on the two combination units, were downloaded by the PSP on January 16, 2020. The PSP provided the NTSB with copies of the downloaded data.

Combination unit #1, combination unit #2, and the 2018 Freightliner Cascadia truck-tractor in combination with a 2020, 28.5-foot Stoughton semitrailer, hereinafter referred to as combination unit #3, were equipped with Automatic Emergency Braking (AEB). AEB is a performance category of Advanced Driver Assist Systems (ADAS).[1] System components were removed from the three combination units and transported to Daimler Trucks North America (DTNA) headquarters in Portland, Oregon, for further examination and analysis. Components were examined and downloaded by the DTNA active safety team on February 20, 2020. On June 4, 2020, at the NTSB's request, components from combination unit #2 were removed by Penske Truck Leasing and shipped to the NTSB headquarters for further examination and analysis. The data from the DDEC and AEB system were analyzed from combination unit #3, but no mechanical or operational tests were performed. Post-crash examination was limited in scope to overall crash damage and photographic documentation. (These inspections were in addition to the post-crash inspections conducted by the PSP.)

For the 2007 Mercedes Benz C280 sedan (herein referred to as sedan), post-crash examination was limited in scope to overall crash damage and photographic documentation and

[1] The AEB is a function of Daimler's Detroit Assurance system. AEB is considered a component of ADAS as described by the Federal Motor Carrier Safety Administration in the Tech-Celerate Now Program, see www.tech-celeratenow.org.

no mechanical or operational tests were performed. (These inspections were in addition to the post-crash inspections conducted by the PSP.)

E. VEHICLE INSPECTIONS:

1. Vehicle #1: - 2005 Van Hool Motorcoach (Motorcoach)

1.1. General Information:[2]

Make:	Van Hool
Model:	C2045
Passengers:	57 - Passengers
VIN:[3]	YE2CC16BX52046617
Model Year:	2005
Date of Manufacture:	March 2005
Placed into Service: [4]	May 2005
Mileage:[5]	751,637 miles
Company Unit #:	1002
GVWR:[6]:	50,700 lbs
GAWR[7] (Axle 1):	16,500 lbs.
GAWR (Axle 2):	24,250 lbs.
GAWR (Axle 3):	15,000 lbs.
Engine:	Detroit, Series 60, 14.0L. SN:06RE149505
Transmission:	Allison, B500RM Automatic, SN:9430008551
Steering Gear:	ZF (Bosch), SN: 1838, Type: 8098955508, Manufactured 10/04
Brake Type:	Wabco, 6S/6M, Six-wheel, air-operated, antilock disc brakes

1.2. Damage Description:

For uniform description, "left" will refer to the driver's side, and "right" will refer to the motorcoach's boarding door side. The motorcoach was removed from the crash scene and transported to J.E Herring Motor Co., in Somerset, PA. before NTSB's arrival.

Front:

The front of the motorcoach had been sheared off and was no longer attached to the vehicle. The front bumper was located inside the front cargo bay. The bumper cover sustained numerous

[2] See Vehicle Attachment – *Motorcoach Build Sheets*.

[3] Vehicle Identification Number.

[4] Obtained from Van Hool vehicle records.

[5] Mileage was obtained from the DDEC report.

[6] Gross Vehicle Weight Rating (GVWR) is the total maximum weight that a vehicle is designed to carry when loaded, including the weight of the vehicle itself, plus fuel, passengers, and cargo.

[7] Gross Axle Weight Rating (GAWR) is the maximum distributed weight that a given axle is designed to support.

scratches and gouges. The left side of the bumper cover was broken with some pieces missing. The right side of the bumper cover sustained more damage than the left side. The driver's seat was still mounted in place along with the seatbelt assembly. The entry door and boarding steps were missing. The complete dash structure and instrument panel were missing. The steering wheel and column along with the driver foot pedals were missing as well. The frame tubes that supported the roof were bent, twisted, displaced to the right, and in a downward direction. The plastic headliner, which had been above the entry door and driver, was no longer attached to the frame tubes and was hanging down towards the back of the driver's seat. The electrical and air systems at the front of the motorcoach were compromised.

Right Side:

The right side of the motorcoach sustained numerous abrasions and gouges. The striations from the abrasions went in multiple directions. They appeared to be concentrated mostly at the right-rear corner where the paint had been stripped away. All seven-passenger windows sustained damage. Window frame locations 1,4, and 6 (from the front) still contained a single glass pane.[8] Window frame locations 2,3, 5, and 7 were missing all glass panes. The single glass pane in the sixth frame location sustained multiple abrasions. The fuel tank access door was damaged, and the fuel cap was broken at the pivot pin attachment. The fuel cap was found in the tray below the fill neck. The first cargo bay door was missing, and the cargo bay floor and supporting frame tubes were displaced upward. The electrical panel inside the first cargo bay was damaged.

Rear:

The most considerable amount of damage occurred to the lower-left corner from the left chassis frame horn outward. The lower-left corner was displaced forward into the battery compartment. The engine bay door sustained contact damage to the left of the license plate. The engine bay door was eventually removed to facilitate the vehicle examination. The rear bumper was missing. The fiberglass shell, which covered the rear of the motorcoach, sustained crash damage on the right side and from the top of the engine compartment to the roofline.

Left Side:

The battery compartment door, located at the left-rear corner of the motorcoach, was damaged and partially torn away. The battery compartment had been compromised from the forward displacement of the radiator. The last five-passenger window frame locations and glass panes were still intact. The third-passenger window frame location, from the front, was missing both the internal and external glass panes. The second-passenger window frame location, from the front (directly behind the driver), was missing the external glass pane. The driver's side-glass panes were missing along with part of the window frame. The left-side tires and wheels were covered with dirt and debris. The access door to the rear of the fuel tank was damaged. The access door below the driver's seating location was damaged with dirt and debris compacted into the trailing edge grooves.

[8] The passenger windows were comprised of two glass panes.

1.3. Weights and Measurements:[9]

The PSP weighed the motorcoach and provided the NTSB with the following information, see **Table 1**:

Table 1: Motorcoach weights without passengers and luggage.

Axle Number	Weight
AXLE 1	7,700 LBS.
AXLE 2	13,650 LBS.
AXLE 3	12,400 LBS.
TOTAL	33,750 LBS.

The entire motorcoach was scanned using a 3-diminsional (3D) laser scanner to allow for the creation of a 3D model, from which scaled measurements can be taken.

1.4. Driver Controls:

The dash, instrument panel, accelerator, and brake pedals along with the steering wheel and steering column were missing from the motorcoach. The missing driver controls were recovered from the crash debris pile, but all the switches and gauges were either broken or missing.

The accelerator and brake pedals remained attached to the floor plate at the bottom of the steering column. Although the pedals were not connected to any air or electrical systems, they were inspected and operated by hand for looseness, pedal alignments, and sticking or operational issues. There were no defects or discrepancies identified during these tests.

There driver's seat remained mounted on top of the pedestal and the pedestal remained securely mounted to what remained of the floorboard. The seatback was displaced forward onto the seat cushion, and the headrest was displaced forward into an approximate 90-degee angle to the seatback. An inspection of the seat mounting hardware did not reveal any defects.[10]

1.5. Steering System:

The motorcoach was equipped with a hydraulic power-assisted steering gear, a power steering pump, a drag link, a pitman arm, a remotely mounted power steering reservoir, a left tie rod with ball joints, a center tie rod with ball joints, a right tie rod with ball joints, and steering knuckles attached to each axle end.

Due to the extensive crash damage sustained at the front of the motorcoach, a functional check of the complete steering system was not performed. The steering wheel and column were located with the crash debris and retrieved for inspection. The retrieved steering components

[9] These weights represent only the motorcoach and cargo at the time of inspection.

[10] For additional information refer to the *Survival Factors Group Factual Report.*

included the steering wheel, upper and lower steering shafts, and the bevel gear. The steering components were still attached to the floorboard and frame tubes. The steering wheel ring was damaged and bent into a half-moon shape. The steering wheel ring cover was cut and torn in multiple locations.

An inspection of the tie rods, ball joint connections, and steering knuckles did not indicate any apparent defects with the steering system. The NTSB had the steering gearbox removed for further examination and analysis by the manufacturer. To check the left-to-right movement of the steering knuckles, the tie rods, and ball joints were left connected.

The steering knuckles were capable of being rotated from stop-to-stop by hand. No binding or roughness was observed during the rotation of the steering knuckles and remaining steering gear.

Bosch Automotive Steering conducted the steering gearbox examination and analysis. No abnormalities were discovered during the operational tests.[11] During the examination of the internal components, impact marks were discovered on the piston, worm shaft, and upper bearing and washer. The locations of the impact marks indicated the steering gear was in a 21-degree turn to the left at the time the impact marks were created.

1.6. Suspension:

The suspension for each side of the steering axle (axle 1) consisted of an independent system which consisted of multiple connecting links, air springs, and shock absorbers.

The suspension for each side of the drive axle (axle 2) consisted of a non-independent, solid axle system which consisted of shock absorbers, air springs, leaf spring packs, and a non-adjustable torque arm. There was a transversal torque arm attached to the drive-gear housing of the drive axle.

The suspension for each side of the tag axle (axle 3) consisted of a solid axle, shock absorbers, air springs, and non-adjustable torque arms.

Although there was no visible damage sustained to the suspension on the motorcoach, the damage to the vehicle's air system prevented application of air to the air springs to determine if any were defective.

1.7. Powertrain:

The powertrain of the motorcoach consisted of a six-cylinder diesel engine, an automatic transmission, a drive shaft, and a rear drive axle assembly (axle 2).

The engine was mounted at the rear of the motorcoach with the front of the engine facing rearward. The engine compartment was covered with oil and dirt.

[11] See Vehicle Attachment – *Motorcoach Steering Gear Inspection Report*.

Dirt and debris were found compacted onto the crankshaft pulley, the flywheel, the left frame horn, into the exhaust pipe ends, and between the engine mounts and engine cradle.

Damage to the vehicle's engine and engine components included the forward displacement of the air compressor, one of two accessory drive belts attached to the engine cooling fan was broken, and the second drive belt had come off the crankshaft pully. The radiator had been displaced forward into the battery compartment, and the engine cooling fan blades where broken. The left rubber engine mount was broken, the left bumper mount was displaced to the left, and the right side of the engine cradle was displaced upward.

As with the engine, the transmission was mounted at the rear of the motorcoach. The transmission was still intact and securely mounted to the rear of the engine and to the frame of motorcoach. The output shaft of the transmission was connected to a short driveline via a yoke and universal joint assembly. The opposite end of the driveline was connected to the pinion gear shaft of the drive axle also via a yoke and universal joint assembly. A visual inspection of the transmission revealed no damage or signs of an internal malfunction.

The drive axle housing was mounted to the motorcoach at the axle 2 location. Within the axle housing, the pinion gear transfers the rotational (longitudinal) movement transmitted from the transmission, via the driveline, to the ring gear. The ring gear then transfers rotational (transverse) movement to the two axle shafts which are connected to tires and wheels at their respective outboard ends. An inspection of the drive axle housing revealed no damage or signs of an internal malfunction.

1.8. Tires and Wheels:

The manufacturer's specification label for the motorcoach remained mounted to the stepwell section which had been retrieved from the crash debris. The manufacturer's label contained information specific to the vehicle identification number assigned to this vehicle, which included specified tire and wheel information.

Per the manufacturer's label, the motorcoach was specified to be equipped with 315/80R22.5 tires, mounted on 22.5 x 9.00 rims.[12] The tires were specified to be inflated to 120 psi for axle 1, 95 psi for axle 2, and 110 psi for axle 3.

General information about each of the tires on the motorcoach at the time of the inspection is included in **Table 2.** All the wheels were inspected for cracks, welds, and elongated lug nut holes. There were no non-crash related defects discovered on any of the wheels. An average rolling radius of 20-inches was measured for all axles.

Table 2: Motorcoach Tire and Wheel Information.

Axle 1	Left	Right
Make/Model	MICHELIN X Line Energy	MICHELIN X Line Energy

[12] Hereafter referenced as wheel.

Tire Size	315/80R22.5 (L)		315/80R22.5 (L)	
Pressure	95 psi		95 psi	
Tread Depth[13]	9/32 inch		10/32 inch	
DOT #[14]	N/A		N/A	
MLR[15]	9,090 lbs @ 130 psi (single)		9,090 lbs @ 130 psi (single)	
Tire Plies	Tread 4-Steel Sidewall 1-Steel		Tread 4-Steel Sidewall 1-Steel	
Wheel Size & Type	22.5 X 9.0 - Steel		22.5 X 9.0-Steel	
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Make/Model	MICHELIN X Line Energy	FIRESTONE FS 400	FIRESTONE FS 400	FIRESTONE FS 400
Tire Size	315/80R22.5 (L)	315/80R22.5 (L)	315/80R22.5 (L)	315/80R22.5 (L)
Pressure	92 psi	110 psi	96 psi	102 psi
Tread Depth	4/32 inch	6/32 inch	5/32 inch	10/32 inch
DOT #	N/A	4D4D 35K 0119	4D4D 35K 3018	4D4D 35K 3018
MLR	8,270 lbs @ 130 psi (dual)	8,820 lbs @ 130 psi (dual)	8,820 lbs @ 130 psi (Dual)	8,820 lbs @ 130 psi (Dual)
Tire Plies	Tread 4-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel
Wheel Size & Type	22.5 X 9.0-Steel	22.5 X 9.0-Steel	22.5 X 9.0-Steel	22.5 X 9.0-Steel
Axle 3	**Left**		**Right**	
Make/Model	FIRESTONE FS 400		FIRESTONE FS 400	
Tire Size	315/80R22.5 (L)		315/80R22.5 (L)	
Pressure	115 psi		88 psi	
Tread Depth	16/32 inch		10/32 inch	
DOT #	4D4D 35K 3018		4D4D 35K 3018	
MLR	9,370 lbs @ 130 psi (single)		9,370 lbs @ 130 psi (single)	
Tire Plies	Tread 5-steel Sidewall 1-Steel		Tread 5-Steel Sidewall 1-Steel	
Wheel Size & Type	22.5 X 9.0-Steel		22.5 X 9.0-Steel	

[13] This measurement reflects the smallest major tread depth measurement recorded.

[14] The DOT numbers had been ground off sometime before the crash.

[15] Maximum Load Rating is the maximum weight the tire has been manufactured to transport.

The tire damage observed during the tire and wheel examination:

- Axle 1 right-side tire had some minor abrasions on the outboard shoulder.
- Axle 1 left-side tire had minor abrasions on the outboard shoulder.
- Axle 2 right-side outside tire sustained abrasions on the outboard sidewall which extended from the tire bead to the shoulder.

1.9. Brake System:

The motorcoach was equipped with a dual air-operated, Antilock Brake System (ABS) with disc brakes on all axles. The dual air brake system allows for separation between the front and rear brakes. Each brake system contains an air reservoir with a one-way check valve installed on the inlet side of the reservoir. The one-way check valves will open if the air pressure entering the reservoir is greater than the air pressure inside the reservoir. Once the air pressure inside the reservoir becomes greater than the air pressure being supplied, the check valve will close to prevent air loss from that side of the brake system. The dual air brake system was designed so that if one of the two brake systems were to fail, the motorcoach would still have one brake system available for emergency braking.

Due to the crash damage, testing of check valves, low pressure warning, brake pedal application, air compressor operation, and air leakage could not be completed. The brake pedal and treadle valve assemblies, which were still in their original mounting positions, and were in the debris pile along with the steering wheel column. An examination of those components did not reveal any pre-crash defects.

The brake chambers were bolted directly to the brake calipers, so there were no exposed pushrods to obtain a pushrod stroke measurement. The disc brake components were examined, and the brake rotors were measured.[16] The brake component information along with the measurements taken of the brake rotors can be found in **Table 3**.

Table 3: Motorcoach Brake Information.[17]

Brake Location	Axle 1		Axle 2		Axle 3	
	Left	Right	Left	Right	Left	Right
Brake Type	Meritor Disc	Meritor Disc	Meritor Disc	Meritor Disc	Meritor Disc	Meritor Disc
Pushrod Stroke	N/A	N/A	N/A	N/A	N/A	N/A
Measured Rotor Thickness	1.814	1.761	1.662	1.765	1.698	1.749
Manufacturer's Specification – Minimum	1.457	1.457	1.457	1.457	1.457	1.457

[16] Title 49 CFR 393.47(d)(1)(2) 1/8-inch (0.125) minimum thickness allowed for air disc type brakes.

[17] A visual inspection of the brake linings was conducted, but no measurements were taken.

Rotor Thickness						

1.9.1. Anti-lock Braking Systems (ABS):

All air braked truck-tractors manufactured after March 1997, and all other commercial vehicles (such as single-unit trucks, trailers, and buses) manufactured after March 1998, are required to be equipped with anti-lock braking systems (ABS).[18] ABSs are designed to assist with keeping a vehicle steerable and stable during heavy braking moments by preventing wheel lock, maintaining the maximum friction possible between the tire and roadway, and making the vehicle stop in the shortest distance possible. In addition to the vehicle's physical brakes, ABSs are comprised of wheel speed sensors, electronic control units (ECU), and modulator units.

The 2005 Van Hool motorcoach involved in this collision was equipped with a Wabco 6S/6M[19] ABS. The ABS sensors, modulators, and wiring were in place and intact at all wheel locations. The ABS light function could not be verified due to the crash damage sustained by the instrument panel and electrical wiring. The ABS light was contained in the same instrument panel as the air gauges and was not located during the inspection.

1.9.2. Engine Compression Brake:

In 1960, the diesel engine compression brake was designed by Clessie Cummins, and has been produced by Jacobs Manufacturing Company since 1961. The compression engine brake, more commonly known today as the "Jake Brake®", was introduced to the trucking industry as a braking aid and has contributed significantly to highway safety. The Jake Brake is a hydro-mechanical device and only operates when the engine is in a no-fuel mode (accelerator pedal is not depressed).

The function of the Jake Brake is to basically change the role of a diesel engine from power producing to power absorbing. This power absorbing function is accomplished by opening the cylinder exhaust valve near the top of the compression stroke, which releases the combustion gases out through the exhaust instead of driving the piston back down to the bottom of the cylinder. This downward stroke of the piston is called the power stroke, and this is when the engine would receive the power needed to propel the vehicle. With the power stroke removed from a complete engine cycle, the engine acts like an air compressor by drawing air in and pushing air out with the cylinders being powered by the forward momentum of the vehicle via the drivetrain. This operation increases the drag on the vehicle allowing the vehicle to slow down in a controlled manner with minimal to no use of the braking system. **Figure 1** illustrates the internal operation of a 4-stroke diesel engine with the Jake Brake engaged.

[18] 49 CFR Part 393.55(c).

[19] 6S/6M means there were 6-sensors and 6-modulators.

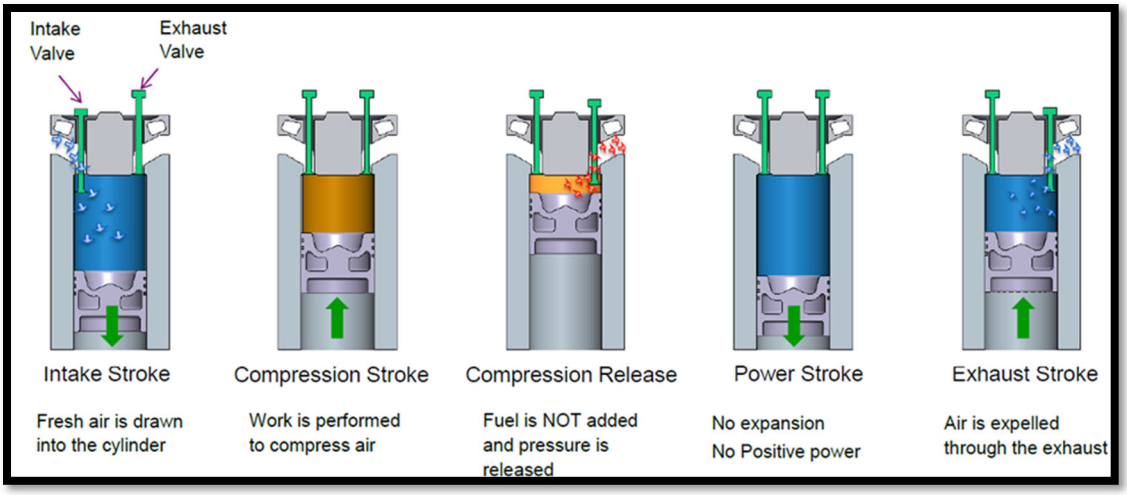

Figure 1: Operation of a 4-stroke engine with Jake Brake engaged. (Source: Eaton.com)

The motorcoach was equipped with a six-cylinder Detroit Diesel engine which contained a Jake Brake to aid with vehicle braking. To activate the Jake Brake, the driver had to manipulate a 3-position switch from the off position to either the 50% or 100% position (50% and 100% refer to the amount of engine braking the driver wanted to use at that specific time). Due to the substantial amount of damage sustained to the instrument panel, there were no switches available to indicate what position the Jake Brake switch was in at the time of the crash. Also, the lack of roadway evidence and event data recorders (EDR)s to capture switch positions make it complicated to determine if the Jake Brake contributed to this crash.

1.10. Electrical:

Due to the extensive crash damage, the electrical system, it was not possible to check the functionality or integrity of the electrical system. The bulbs from the taillamp assemblies were removed and inspected. The bulbs for the taillights had signs of hot shock and the bulbs for the brake lights showed no signs of damage. [20]

1.11. Vehicle Logged Data:[21]

The Detroit Diesel engine was controlled by a Detroit Diesel Electronic Control (DDEC) V Engine Control Module (ECM). The primary function of the ECM is to control the engine's performance, fuel efficiency, and emissions based on various engine and sensor inputs. The ECM is also capable of recording diagnostics associated with engine and/or sensor faults, which may then activate warnings on the dash, as well as record vehicle speed, engine speed, and other parameters during triggered events. This module was removed from the engine compartment of the motorcoach by the PSP and transferred to the NTSB for further analysis.

[20] Hot shock is the result of a hot bulb filament stretching and distorting from a sudden impact.

[21] See Vehicle Attachment – *Motorcoach DDEC Data* for additional information.

On February 19, 2020, the DDEC V ECM was transported by NTSB investigators to the Detroit Diesel headquarters in Detroit, MI. Under the direction of NTSB investigators, the ECM was connected to a bench test and the data was downloaded and saved.

The data retrieved from the DDEC contained a "last stop"[22] log, but no "hard brake" [23] event. A review of the data indicated an overall speed of 73.8 mph with a maximum speed of 80 mph. Prior to entering the curve proceeding the crash location, the motorcoach had a reported speed of 77 mph. The data did not reveal any operational abnormalities prior to the crash.

1.12. Maintenance History/Recalls

Driver vehicle inspection reports (DVIRs) from December 1, 2019, through January 2020 and maintenance records from June 2019 through November 2019 were obtained from Z&D Tour Inc. Of the 45 DVIRs reviewed, no defects were listed. The maintenance records were reviewed in detail along with as-needed repairs made to the motorcoach. No structural or major deficiencies were noted.[24] The maintenance records showed the following excerpts of work done:

- June 2, 2019, left-side drive axle tires replaced, brake rotor, caliper, pad sensor, ABS sensor, and brake pads.
- June 3, 2019, drive axle ABS valve, valve harness, and brake hose.
- June 17, 2019, right-side drive axle brake rotor, caliper, pad sensor, and brake pads. Replaced the brake chambers on both axle ends of the tag axle, 1-set of brake pads, 2 brake pads sensors, and the drive shaft.
- July16, 2019, replaced a right-side drive axle tire and rim.
- August 22, 2019, replaced a right-side drive axle tire.
- October2019, replaced the air compressor safety valve.
- October 10, 2019, replaced the left-side tag axle tire.
- October 13, 2019, replaced the air dryer.
- November 3, 2019, replaced a right-side drive axle tire, wheel bolt and lug nut.

The following are New Jersey State inspections conducted on this motorcoach:

- August 30, 2018, 2019 NJ State Inspection BIT000038201820857986 – OOS[25] for Failed build-up time, water in left-rear taillight, rear right taillight lens crack, missing rear body panel by right bumper, right side marker out. Retest inspection conducted on 9/4/2018 – passed.

[22] "Last Stop" log is created when the vehicle comes to a stop for longer than 15 seconds.

[23] "Hard Brake" log is created when the vehicle experiences a rapid deceleration exceeding the set threshold. Default threshold is 7 mph/s.

[24] For additional information refer to the *Motor Carrier Factors Group Chairman's Factual Report*.

[25] Out-of-Service.

- June 20, 2019, NJ State Inspection BIT000048201914720601- OOS for tire condition and exhaust system mounting. Retest conducted on the same day – passed.

2. Vehicle #2 - 2018 Freightliner New Cascadia truck-tractor in combination with a 2019, 53-foot Hyundai Translead semitrailer (combination unit #1)

2.1. General Information:

TRUCK TRACTOR:[26]

Make:	Freightliner
Model:	New Cascadia
VIN:	3AKJHHDR2JSKB7773
Model Year:	2018
Date of Manufacture:	December 2017
Mileage:[27]	461,175 miles
Company Unit #:	141747
GVWR:	52,350 lbs
GAWR (Axle 1):	12,500 lbs
GAWR (Axle 2):	20,000 lbs
GAWR (Axle 3):	20,000 lbs
Engine:	Detroit DD15, 14.8-liter, 455 HP.
Fuel Capacity:	240 Gallons (Two 120-gallon saddle tanks)
DEF Capacity:	23 Gallons
Transmission:	DT12-1650-OH1 HD, 12-Speed Overdrive,
Steering Gear:	TRW, THP-60
Brake Type:	Wabco, 6S/6M, Air-Operated, Antilock Drum Brakes

SEMITRAILER:

Make:	Hyundai Translead
Model:	VC2530132-JRS
VIN:	3H3V532C9KT818836
Model Year:	2019
Date of Manufacture:	October 2018
Company Unit #:	FEDZ551934
GVWR:	68,000 lbs
GAWR (per axle):	20,000 lbs
Brake Type:	Bendix, Air-Operated, Antilock Drum Brakes

[26] See Vehicle Attachment – *FedEx Freightliner Build Sheets* for additional Information.

[27] Obtained from the downloaded information from the Detroit Diesel Electronic Control module.

2.2. Damage Description:

For uniform description, "left" will refer to the driver's side, and "right" will refer to the curb side of the vehicle. Combination unit #1 had been removed from the crash scene and transported to J.E Herring Motor Co. in Somerset, PA. prior to the NTSB's arrival.

Front:

The front of combination unit #1 sustained substantial contact and induced damage. The front bumper cover was missing, and the front bumper was bowed rearward at the approximate center.

The hood sustained contact damage, with more damage on the right side than the left, and the right-side fender was missing. Both headlamp assemblies were broken. The radiator was displaced rearward, and the engine cooling fan blades were broken.

Cab:

The cab had separated from its mounts and was displaced to the left of centerline. The floorboard, on the left side of the cab, was buckled upward and contacting the accelerator and brake pedals. The rear of the sleeper berth had been crushed forward. All the airline connections were broken at the rear of the sleeper berth.

Rear:

At the rear of the sleeper berth, the frame rails and multiple crossmembers were bent. The fifth wheel plate had been displaced forward, through the forward stops and was located between the frame rails at the rear of the sleeper berth. The locking fingers on the fifth wheel slider rail were bent in a forward direction.

Semitrailer Front:

The front of the semitrailer had contact damage and puncture holes. The front of the semitrailer has been displaced rearward and the leading edge of the roof was buckled. The right-front corner was abraded and dented. The left-side landing gear leg was bent rearward.

Semitrailer Rear:

The right rear of the semitrailer sustained significant impact damage. The cargo doors, steel door frame, rear bumper and rear impact guard were missing from the rear of the semitrailer. The rear bumper and rear impact guard were eventually located on a flatbed trailer and were subsequently inspected and photographed. The wooden floor of the semitrailer was broken and splintered. The right side of the crossmembers were buckled and displaced towards the front. The tandem slider rails were twisted and distorted.

2.3. Weights and Measurements:

For uniform description, the axles are numbered 1 through 5 with 1 being the steering axle on the truck-tractor and 5 being the last axle on the semitrailer.

The PSP weighed combination unit #1 and provided the NTSB with the following information – see **Table 4.**

Table 4: Combination unit #1 weights.

Axle Number	Weight
AXLE 1	10,800 LBS.
AXLE 2	5,150 LBS.
AXLE 3	3,450 LBS.
TRACTOR TOTAL	19,400 LBS
The semitrailer was weighed utilizing a truck-tractor owned by the tow yard. (Unladed weight of truck-tractor = 18,150 LBS.)	
AXLE 1	*8,600 LBS.*
AXLE 2	*11,600 LBS.*
AXLE 3	*11,000 LBS.*
AXLE 4	9,750 LBS.
AXLE 5	7,000 LBS.
SEMITRAILER TOTAL	47,950 – *18,150* = 29,800 LBS.
COMBINATION TOTAL	49,200 LBS

The truck-tractor and semitrailer were scanned using a 3-diminsional (3D) laser scanner to allow for the creation of a 3D model, from which scaled measurements can be taken.

2.4. Steering System:

This truck-tractor was equipped with a hydraulic power assisted steering system which consisted of a pitman arm, a drag link, steering knuckles, a tie rod, and ball joint connectors.

There were no obvious damages or defects identified with the steering system.

2.5. Suspension System:

The suspension on each side of axle 1 consisted of a non-independent system with a solid axle, tapered leaf springs, and shock absorbers. There was no obvious damage or defects with the axle 1 suspension system.

The suspensions on each side of axles 2 and 3 consisted of non-independent systems with solid axles air springs, shock absorbers, leaf springs, adjustable and non-adjustable torque arms. On the right side of axle 3, the leaf spring tips were broken.

The suspensions on each side of axles 4 and 5 consisted of non-independent systems with solid axles, leaf spring packs, adjustable torque arms, and non-adjustable torque arms. There was no obvious damage or defects detected to the semitrailer suspension.

2.6. Tires and Wheels:

Truck-tractor:

Per the manufacturer's specification label, attached on the inside of the left-side door frame, the truck-tractor was specified to be equipped with 295/75R22.5 tires, mounted on 22.5X8.25 rims. The tires were specified to be inflated to 110 psi for axle 1 and 110 psi for the axles 2 and 3.

General information about each of the tires on the truck-tractor at the time of the inspection is included in **Table 5.** All the wheels were inspected for cracks, welds, and elongated lug nut holes. There were no non-crash related defects discovered on any of the wheels. The rolling radius was not obtained.

Table 5: Truck-Tractor Tire and Wheel Information.

Axle 1	**Left**		**Right**	
Tire Make	BRIDGESTONE R284		FIRESTONE FS591	
Tire Size	295/75R22.5		295/75R22.5	
Pressure	114 psi		100 psi	
Tread Depth	17/32 inch		13/32 inch	
DOT #	2CBT3UB4019		4DBT65N5218	
MLR	7,140 lbs. @ 123 psi (single)		6,175 lbs. @ 110 psi (single)	
Tire Plies	Tread 5-steel Sidewall 1-Steel		Tread 5-steel Sidewall 1-Steel	
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	BRIDGESTONE M770	BRIDGESTONE M770	BRIDGESTONE M770	BRIDGESTONE M770
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Pressure	98 psi	96 psi	98 psi	98 psi

Tread Depth	17/32 inch	17/32 inch	17/32 inch	17/32 inch
DOT #	Recap# RDNY 0119	Recap# RDNY 0119	Recap# RDNY 0119	Recap# RDNY 0119
MLR	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)
Tire Plies	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel
Axle 3	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	DAYTON D510S	ROADMASTER	BRIDGESTONE M770	AZOLUS HN308
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Pressure	100 psi	92 psi	DEFLATED	94 psi
Tread Depth	14/32 inch	14/32 inch	17/32 inch	21/32 inch
DOT #	Recap# RDNY 0918	4Y37LW14618	Recap# RDNY 0119	Not Found
MLR	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)
Tire Plies	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 4-steel Sidewall 1-Steel

The tire damage observed during the tire and wheel examination:

- On axle 1 the right-side tire sustained a slice to the outboard sidewall, which had an approximate length of 5 ½-inches, and the sidewall was scuffed.
- On the left side of axle 1 the outboard tire sidewall was scuffed and there were longitudinal striations in the tread area.
- The tires mounted on both sides of axles 2 and 3 had roadway abrasions in the tread area.
- The tire mounted at the inside tire position on axle 3 sustained a puncture through the outboard tire shoulder, and the tire was debeaded from the wheel.

Semitrailer:

Per the manufacturer's specification label, attached to the front of the semitrailer, the semitrailer was specified to be equipped with 295/75R22.5 tires, mounted on 8.25X22.5 rims. The tires were specified to be inflated to 110 psi for both axles.

General information about each of the tires mounted on the semitrailer at the time of the inspection is included in **Table 6.** All the wheels were inspected for cracks, welds, and elongated lug nut holes. There were no non-crash related defects discovered on any of the wheels. The rolling radius was not obtained.

Table 6: Semitrailer Tire and Wheel Information.

Axle 4	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Pressure	100 psi	98 psi	100 psi	102 psi
Tread Depth	8/32 inch	9/32 inch	10/32 inch	10/32 inch
DOT #	A337LM0W3518	A337LM0W3518	A337LM0W3518	A337LM0W3518
MLR	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)
Tire Plies	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel
Axle 5	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Pressure	100 psi	100 psi	98 psi	100 psi
Tread Depth	10/32 inch	10/32 inch	10/32 inch	10/32 inch
DOT #	A337LM0W3518	A337LM0W3518	A337LM0W3518	A337LM0W3518
MLR	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)
Tire Plies	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel

There was no tire or wheel damage identified for the semitrailer.

2.7. Brake System:

Combination unit #1 was equipped with a dual air ABS with drum brakes on all (5) axles. The dual air brake system for a combination unit works the same as what was described for the motorcoach except for how the brake systems are divided. The dual air brake system for a truck-tractor in combination with one or more trailers is divided with the brakes on the steering axle (axle 1) and the trailer brakes on one side[28] and the brakes on axles 2 and 3 along with the trailer

[28] Referred to as the secondary side.

brakes on the other side.[29] For combination vehicles, the trailer brakes will always have braking capabilities should either air brake system fail on the truck-tractor.

The tires and wheels were not removed during this inspection. A visual inspection of the brake linings and drums did not reveal any worn or defective foundation brake components. **Table 7** and **Table 8** show the brake adjustment measurements recorded by the PSP.

Table 7: Truck-Tractor Brake Measurements.

Brake Location	Axle 1		Axle 2		Axle 3	
	Left	Right	Left	Right	Left	Right
Brake Type[30]	Haldex 24/Drum[31]	Haldex 24/Drum	Haldex 30/30 Drum[32]	Haldex 30/30 Drum	Haldex 30/30 Drum	Haldex 30/30 Drum
Pushrod Stroke (inches)	1 1/2	1 5/8	1	1	1	1

Table 8: Semitrailer Brake Measurements.

Brake Location	Axle 4		Axle 5	
	Left	Right	Left	Right
Brake Type[33]	Haldex 30/30 Drum	Haldex 30/30 Drum	Haldex 30/30 Drum	Haldex 30/30 Drum
Pushrod Stroke (inches)	1 1/4	1 1/4	1 1/4	1 1/2

2.7.1. Anti-Lock Brake System (ABS):

The function of an ABS is described in section 1.9.1 of this report.

The truck-tractor was equipped with a Wabco 6S/6M ABS with hill start aid.[34] The ABS sensors, modulators, and wiring were in place and intact at all wheel locations. No electrical power was supplied to the truck-tractor during the inspection, so the ABS light function could not be verified.[35] The ABS sensors, wiring, and module were in place and intact on the semitrailer.

2.8. Driver Controls:

The driver controls were photographed, but not many could be documented as to their operation at the time of the crash since most of the switches were the self-centering rocker type.

[29] Referred to as the primary side.

[30] All brake chambers on the truck-tractor were long stroke.

[31] According to the North American Standard Out-of-Service Criteria the maximum pushrod stroke is 2-inches.

[32] According to the North American Standard Out-of-Service Criteria the maximum pushrod stroke is 2 ½-inches.

[33] The brake chambers on the semitrailer were long stroke.

[34] Hill start aid assists by preventing a vehicle that is on an incline from moving until the vehicle is in gear and accelerating.

[35] No power was used because the data from the ECMs had not been downloaded yet.

A self-centering rocker or toggle switch contain a mechanism or spring inside that causes the switch to return to the center position once the switch has been released. The accelerator and brake pedals were trapped in the unapplied position due to the upward buckling of the driver's side floorboard. An inspection of the foot pedals did not reveal any pre-crash damage.

2.9. Vehicle Logged Data:

The Detroit Diesel DD15 engine was controlled by a DDEC ECM system consisting of three separate units: A Motor Control Module (MCM), a Common Powertrain Controller (CPC), and an Aftertreatment Control Module (ACM). The primary function of the ECM is to control the engine's performance, fuel efficiency, and emissions based on various engine and sensor inputs. The ECM may be capable of storing or recording diagnostics associated with engine and/or sensor faults, which may then activate warnings on the dash, as well as record vehicle speed, engine speed, and other parameters during triggered events. There is an internal clock and calendar, with an internal battery, which tracks time and stamps event-based occurrences such as hard braking incidents and last stop logs.

The CPC receives data from the accelerator pedal, switches, various sensors, and other electronic control units and then transmits the received data to the MCM.

The ACM monitors the emission system. The ACM receives data from multiple sensors located throughout the exhaust system. Once certain parameters are met, the ACM will illuminate a light on the instrument panel indicating that a regeneration cycle is required.

The purpose of the regeneration cycle is to reduce NOx and capture and burn off (regenerate) the particulate matter (soot) in the engine's exhaust gas. It does this using a diesel oxidation catalyst (DOC) and a diesel particulate filter (DPF). By monitoring exhaust gas temperature and system back pressure, the DDEC® control module determines the most efficient way required to ensure complete regeneration of the soot captured in the DPF. There are two types of regeneration cycles: stationary and active. Stationary regeneration cycles require the vehicle to be parked and takes approximately 45-minutes to complete. Active regeneration cycles happen during the normal operations of the vehicle and takes approximately 40 – 45 minutes to complete.

The FedEx truck-tractor ECMs were successfully downloaded, via the J1939 diagnostic connector, at the tow yard on January 16, 2020, by the PSP. The NTSB investigator was present during the download and received a copy of the downloaded data.[36]

A review of the FedEx truck-tractor downloaded data revealed "hard brake" and "last stop" events had been logged.[37]

2.10. Maintenance History, Recalls, and Warranty Work:

Maintenance and inspection records for the truck tractor and semitrailer were obtained from FedEx Ground, by the NTSB Motor Carrier Factors Group Chairman. All carrier maintenance records along with any recall and warranty work documentation, obtained from the

[36] See Vehicle Attachment – *FedEx DDEC Data* for the full data set.

[37] See *Technical Reconstructionist Factual Report* for more detailed information.

manufacturer were reviewed. There were no discrepancies identified with the maintenance records.

Truck-Tractor

Warranty work and recall information was obtained from Daimler Trucks North America (DTNA). There were two recalls and three field service items, and four warranty work items.

Recalls:

- Campaign FL780-A: Cascadia ICUC Bulb Check Function – completed.
- Campaign FL780-B: Cascadia ICUC Bulb Check Function – remains open.

Field Service:

- Campaign SF583-A: Freightliner Cascadia Software Update – completed.
- Campaign SF578-A: Forward Chassis Wiring Harness – remains open.
- Campaign SF583-A: Freightliner Cascadia Cab Shock Mounts – completed.

Warranty Work:

- June 19, 2018: overhauled engine due to compression issues.
- August 3, 2018: replaced defective exhaust clamp.
- August 26, 2019: remove, repair, and replaced leaking water pump.
- August 27, 2019: replaced fan belt tensioner, radiator, fan blade, and fan clutch.

Semitrailer

The following information was obtained from the maintenance records provided by FedEx Ground. There were no recall or warranty records located for the semitrailer.

- October 30, 2018: miscellaneous door repair, install bar code, and install and remove glad hand lock.
- April 10, 2019: torn glad hand seals were replaced, and leaking body panels were sealed.
- April 21, 2019: replaced missing door rollers, replaced leaking glad hand seals, replaced 7-way plug receptacle, replaced ABS light, secured side skirts and roof bows, and completed PM service.

September 28, 2019: completed PM service, resecured e-track to wall, and inspected the cargo net and track.

3. Vehicle #3 - 2018 Freightliner Cascadia truck-tractor towing a 2018, 53-foot Stoughton semitrailer (Combination Unit #2)

3.1. General Information:

TRUCK TRACTOR:[38]

Make:	Freightliner
Model:	Cascadia
VIN:	3AKJGLDV8JSJG8209
Model Year:	2018
Date of Manufacture:	January 2017
Mileage:[39]	621,393 miles
Company Unit #:	UPS233759
GVWR:	53,220 lbs
GAWR (Axle 1):	13,220 lbs
GAWR (Axle 2):	20,000 lbs
GAWR (Axle 3):	20,000 lbs
Engine:	Detroit DD13, 12.8-liter, 470 HP.
Engine #:	471928S0463807
Fuel Capacity:	300 Gallons (2 150-gallon saddle tanks)
DEF Capacity:	23 Gallons
Transmission:	DT12-OB-1650 HD, Automatic 12-Speed Overdrive
Steering Gear:	TRW, THP-60
Brake Type:	Wabco, 4S/4M, Air-Operated Antilock Brake System with Hill Start Aid, Automatic Traction Control, and Automatic Traction Control Off-Road Switch

SEMITRAILER:

Make/Model:	2018 Stoughton, AVW-535T-S,
VIN:	1DW1A5329JS794816
Company Unit #:	844716
Date of Manufacture:	May 2017
GVWR:	70,000 lbs
GAWR (per axle):	20,000 lbs
Brake Type:	Air-Operated, Antilock Disc Brakes

3.1. Damage Description:

For uniform description, "left" will refer to the driver's side, and "right" will refer to the curb side of the vehicle. Combination unit #2 had been removed from the crash scene and transported to J.E Herring Motor Co., in Somerset, PA. prior to the NTSB's arrival.

[38] See Vehicle Attachment - *UPS #1 Freightliner Build Sheets* for additional Information.

[39] Obtained from the downloaded information from the Detroit Diesel Electronic Control module.

Truck-Tractor

The impact damage was heaviest on the left side of the vehicle. The hood and cab were displaced to the right. The left side of the cab, including the driver's door and 2/3rds of the sleeper berth had been sheared off and were no longer attached to the vehicle. The driver's side floorboard was displaced up and to the right. The steering wheel and column were displaced to the right. The driver's seat was displaced to the right, and all interior driver controls were damaged or missing. The electrical and air systems were compromised. The left-side fuel tank was ruptured with only a trace of fuel remaining at the bottom. The right-side fuel tank did not appear to be ruptured, but it was not full.

Semitrailer

The front of the semitrailer sustained impact damage along with multiple punctures. The left side of the upper fifth wheel plate was curled upward. The left-front corner of the semitrailer sustained major crash damage with approximately 4-feet of the left-side exterior sheet metal torn open, exposing the cargo inside. Along the full length of the left side top edge there were numerous gouges and tears.

3.2. Weights and Measurements:

The PSP weighed the UPS #2 truck-tractor and semitrailer and provided the NTSB with the following information in **Table 9.**

Table 9: Combination unit #2 weights.

Axle	Weight
AXLE 1	8,600 LBS.
AXLE 2	3,300 LBS.
AXLE 3	3,000 LBS.
TRACTOR TOTAL	14,900 LBS
The semitrailer was weighed utilizing a truck-tractor owned by the tow yard. (Unladed weight of truck-tractor = 18,150 LBS.)	
AXLE 1	*8,750 LBS.*
AXLE 2	*11,150 LBS.*
AXLE 3	*10,900 LBS.*
AXLE 4	8,100 LBS.
AXLE 5	8,950 LBS.
SEMITRAILER TOTAL	47,850 – *18,150* = 29,700 LBS.

COMBINATION TOTAL	44,600 LBS

The truck-tractor and semitrailer were scanned using a 3-diminsional (3D) laser scanner to allow for the creation of a 3-D model, from which scaled measurements can be taken.

3.3. Steering System:

This truck-tractor was equipped with a hydraulic power assisted steering system which consisted of a pitman arm, a drag link, steering knuckles, a tie rod, and ball joint connectors.

The tie rod was bowed rearward. The steering column and steering wheel were displaced to the right, and the intermediate steering shaft was separated from the lower steering shaft at the splined connection.

No other damage to the steering system was identified.

3.4. Suspension System:

The suspension on axle 1 was a non-independent system which consisted of a solid axle, tapered leaf springs, and shock absorbers.

The suspensions on axles 2 and 3 were non-independent systems which consisted of air springs, shock absorbers, leaf springs, adjustable and non-adjustable torque arms.

The left-side spring hanger for axle 2 was broken, which allowed the left side of the axle to shift rearward. The tire mounted to the inside position on the left side of axle 2 was wedged against the spring hanger for axle 3.

No other suspension damage was identified for the truck-tractor or the semitrailer.

3.5. Tires and Wheels:

The axles are numbered from axle1 (steering axle) rearward to the last axle on the trailer (axle 5).

There was no manufacturer's specification label located on this vehicle. The information used for this section came from the manufacturer's specification label mounted on the UPS #2 truck-tractor since they are the same make and model.

The truck-tractor was specified to be equipped with 295/75R22.5 tires, mounted on 22.5X8.25 rims. The tires were specified to be inflated to 110 psi for axle 1 and 110 psi for the axles 2 and 3.

General information about each of the tires on the truck-tractor semitrailer combination at the time of the inspection is included in **Table 10 and Table 11**. All the wheels were inspected for cracks, welds, and elongated lug nut holes. There were no non-crash related defects discovered on any of the wheels.

Table 10: Truck-Tractor Tire and Wheel Information.

Axle 1	**Left**		**Right**	
Tire Make	BRIDGESTONE R283A		BRIDGESTONE R283A	
Tire Size	11R/22.5		11R/22.5	
Pressure	DEFLATED		DEFLATED	
Tread Depth	8/32 inch		12/32 inch	
DOT #	2C3T3WR0219		2C3T3WR0219	
Maximum Load Rating	6,610 lbs. @ 120 psi (single)		6,610 lbs. @ 120 psi (single)	
Tire Plies	Tread 5-steel Sidewall 1-Steel		Tread 5-steel Sidewall 1-Steel	
Axle 2	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	TIRE MISSING	BRIDGESTONE R283A	BRIDGESTONE M726 EL	BRIDGESTONE R268
Tire Size	N/A	11R/22.5	11R/22.5	11R/22.5
Pressure	N/A	104 psi	102 psi	102 psi
Tread Depth	N/A	20/32 inch	21/32 inch	19/32 inch
DOT #	N/A	RECAP DNL 4618	RECAP # NOT FOUND	RECAP RDK 3419
Maximum Load Rating	N/A	6,005 lbs. @ 120 psi (Dual)	6,005 lbs. @ 120 psi (Dual)	6,005 lbs. @ 120 psi (Dual)
Tire Plies	N/A	Tread 5-Steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel
Axle 3	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	BRIDGESTONE R197	CONTINENTAL	BRIDGESTONE R268	BRIDGESTONE R268
Tire Size	11R/22.5	295/75R22.5 (G)	11R/22.5	11R/22.5
Pressure	102 psi	102 psi	100 psi	100 psi
Tread Depth	17/32 inch	14/32 inch	13/32 inch	13/32 inch
DOT #	# NOT OBTAINED	# NOT OBTAINED	RECAP DNL 3918	RECAP # NOT FOUND
Maximum Load Rating	5,675 lbs. @ 120 psi (Dual)	5,675 lbs. @ 120 psi (Dual)	6,005 lbs. @ 120 psi (Dual)	6,005 lbs. @ 120 psi (Dual)
Tire Plies	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel	Tread 5-steel Sidewall 1-Steel

Table 11: Semitrailer Tire and Wheel Information.

Axle 4	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	BRIDGESTONE R283	BRIDGESTONE M720	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	295/75R22.5
Tread Depth	8/32 inch	11/32 inch	11/32 inch	11/32 inch
DOT #	RECAP	# NOT OBTAINED	A337LM0W3518	A337LM0W3518
Maximum Load Rating	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 120 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)
Tire Plies	Tread 4-steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel
Axle 5	**Left**		**Right**	
	Outside	Inside	Inside	Outside
Tire Make	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	CONTINENTAL Conti EcoPlus HT3	MICHELIN X Line Energy
Tire Size	295/75R22.5	295/75R22.5	295/75R22.5	275/80R22.5
Tread Depth	8/32 inch	8/32 inch	8/32 inch	4/32 inch
DOT #	A337LM0W3518	A337LM0W3518	A337LM0W3518	RECAP
Maximum Load Rating	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	5,675 lbs. @ 110 psi (Dual)	8,270 lbs @ 130 psi (dual)
Tire Plies	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 5-Steel Sidewall 1-Steel	Tread 4-Steel Sidewall 1-Steel

Tire and Wheel damage:

On axle 1, the right-side tire sustained an approximate 19-inch puncture through the outboard sidewall. The outboard side of the tire was debeaded from the wheel seat, and the inboard tire sidewall sustained an approximate 6 ½ by 2 ½ -inch puncture. The right-side wheel sustained a radial collapse, and the outboard wheel flange was abraded.

The left-side tire sustained an approximate 2 ½ by 4 ½-inch puncture through the sidewall, and the tire was completely separated from the wheel. The left-side wheel sustained radial and axial collapses to the outboard wheel flange, and both inboard and outboard wheel flanges were abraded.

On axle 2, the left-outside tire was missing, and the wheel sustained multiple axial and radial collapses. The axle 2 left-inside tire tread was missing chunks of rubber and was tight against the mounting bolt for the axle 3 left-side spring hanger.

On axle 3, the right-inside tire tread contained abrasions with the striations going in multiple directions.

3.6. Brake System:

The truck-tractor semitrailer combination was equipped with a dual air ABS with disc brakes on all axles.

The tires and wheels were not removed during this inspection. A visual inspection of the brake linings and rotors did not reveal any worn or defective foundation brake components. The brake chambers for the truck-tractor semitrailer combination unit were manufactured by Bendix and there were no brake measurements to be checked.

3.6.1. Antilock Brake System (ABS):

The function of an ABS is described in section 1.9.1 of this report.

The truck-tractor was equipped with Wabco, 4S/4M, Air-Operated Antilock Brake System with Hill Start Aid, Automatic Traction Control, and Automatic Traction Control Off-Road Switch. The ABS sensors, modulators, and wiring were in place and intact at all wheel locations. No damage to the truck-tractor semitrailer combination unit ABS system was identified

3.7. Driver Controls:

The driver controls were photographed, but not many could be documented as to their operation at the time of the crash since most of the switches were destroyed or broken, and the remaining switches were the self-centering rocker style. The accelerator pedal was broken, and the brake pedal was trapped between the floorboard and firewall

3.8. Vehicle Logged Data:[40]

The Detroit Diesel DD13 engine was controlled by a DDEC ECM system which consisted of three separate units: a MCM, CPC, and an ACM. Combination unit #2 ‘s system functions the same as was described for combination vehicle #1’s truck-tractor (a complete description of these components and their functions is described in section 2.9 of this report).

Combination unit #2’s truck-tractor ECMs were successfully downloaded, via the J1939 diagnostic connector, at the tow yard on January 16, 2020. An NTSB investigator was present during the download and received a copy of the downloaded data for review.

Although the DDEC was capable of being successfully downloaded, there was no crash relevant data available due to the catastrophic power loss at the time of the crash. DDECs require a proper shutdown in order to store the recorded events that occur between power-up and shutdown. If a proper shutdown sequence does not occur, all data between the last proper shutdown and the current event is lost. This truck-tractor sustained crash damage at the fuse panel, located

[40] See Vehicle Attachment – *UPS #1 Freightliner DDEC Data* for additional information.

on the left side of the firewall, which severed multiple wires and damaged the fuse block causing an instantaneous and improper shutdown of the electrical system.

3.9. Maintenance History, Recalls, and Warranty Work:

Maintenance and inspection records for the truck tractor and semitrailer were obtained from UPS. All carrier maintenance records along with any recall and warranty work documentation, obtained from the manufacturer, were reviewed. There were no discrepancies identified with the maintenance records.

A total of seven DVIRs, dated from September 12, 2019, to December 18, 2019, were provided to the NTSB by UPS. Of the 7 reports only one had a defect listed, which was due to the passenger-side windshield being broken. Warranty work and recall information was obtained from DTNA. There were 2 recalls and 10 warranty work items.

Recalls:

- Campaign FL756-A: Brake Light Pressure Switch – Completed.
- Campaign FL775-A: Brake Caliper Mounting Bolts – Completed.

Warranty Work:

- January 20, 2017: Reseal and retorque airline fittings at rear of air tank.
- April 13, 2018: Replaced oil pan gasket.
- June 1, 2018: Replaced power inverter.
- June 13, 2018: Replaced belt tensioner and belt.
- August 24, 2018: Replaced DEF doser.
- September 9, 2018: Replaced DEF metering unit.
- December 27, 2018: Replaced camshaft housing gasket and engine oil pan gasket.
- March 2, 2019: Replaced NOX sensor.
- March 15, 2019: Replaced second NOX sensor.
- May 8, 2019: Replaced fuel injector nozzle.

4. Vehicle #4 (Sedan)

4.1. General Information:

Make:	Mercedes
Model:	C280W4
VIN:	WDBRF92HX7Fxxxxxx
Model Year:	2007
Transmission:	Automatic
Steering Gear:	Rack and Pinion
Brake Type:	Hydraulic Actuated 4-wheel Antilock Brake System

4.2. Damage Description:

The sedan sustained damage to all four quadrants of the vehicle. There was a crease that extended from the right-front headlamp assembly rearward towards the left-rear taillamp assembly. The windshield was broken, and the sunroof glass was missing. The roof of the passenger compartment had been crushed downward at the creased location.

The left A-pillar was damaged, and the left rearview mirror was hanging by the adjustment cable. The left-front tire was flat and debeaded from the wheel. The left side of the vehicle sustained multiple striations and gouge marks, and there was mud compacted between the leading edge of the driver's door and the front fender. The left-rear suspension was damaged, and the tire and wheel had a positive camber orientation.

The right-rear corner sustained numerous scrapes, gouges, and dents, and the taillamp lens cover was missing. There was black transfer located on the right-rear quarter panel and right side of the rear bumper cover. The right-rear tire had been punctured, was flat, and had a toe-in orientation.

4.3. Vehicle Logged Data:

The sedan was equipped with airbags and seatbelt pre-tensioners. However, the threshold and algorithm required to activate the Airbag Control Module (ACM) did not occur and there would have not been any crash-relevant data to obtain from downloading the ACM.

5. Vehicle #5 - 2018 Freightliner Cascadia truck-tractor towing a 2020, 28.5-foot Stoughton semitrailer (Combination Unit #3)

5.1. General Information:

TRUCK TRACTOR:[41]

Make:	Freightliner
Model:	Cascadia (PX125064S T)
VIN:	1FUJGLDV9JLJX7288
Model Year:	2018
Date of Manufacture:	October 2, 2017
Placed into Service:	October 16, 2017
Mileage:[42]	525,683 miles
Company Unit #:	UPS233928
GVWR:	53,220 lbs
GAWR (Axle 1):	13,220 lbs
GAWR (Axle 2):	20,000 lbs
GAWR (Axle 3):	20,000 lbs
Engine:	Detroit DD13, 12.8-liter, 470 HP., MFG. 9/2017 SN: 47192850522912

[41] See Vehicle Attachment - *UPS#2 Freightliner Build Sheets* for additional Information.

[42] Obtained From the data downloaded from the Detroit Diesel Electronic Control Module.

Fuel Capacity:	300 Gallons (2 - 150-gallon saddle tanks)
DEF Capacity:	23 Gallons
Transmission:	DT12-OB-1650 Heavy Duty 12-Speed Overdrive Automated Manual
Steering Gear:	TRW, THP-60
Brake Type:	Wabco, 4S/4M, Air-Operated Antilock Brake System with Hill Start Aid, Automatic Traction Control, and Automatic Traction Control Off-Road Switch

SEMITRAILER:

Model Year:	2020
Make:	Stoughton,
Model:	DAVW-285 S Semitrailer
VIN:	1DW1A2819LSA38178
Company Unit #:	381083
Date of Manufacture:	July 2019
GVWR:	40,000 lbs
GAWR (per axle):	20,000 lbs

5.2. Damage Description:

The damage sustained by this truck-tractor semitrailer combination was limited to the front and left side of the truck-tractor.

The front plastic bumper covering was missing. There was compacted dirt and debris on the front axle, around the leaf-spring packs, and brake assemblies. There were scrapes and gouges that started at the driver's-side entry steps, continued rearward across the front of the DEF tank, and along the side of the 150-gallon fuel tank. The fuel tank sustained a large dent at the rear mounting strap. The tank remained securely mounted and had not been punctured. The bottom entry step on the driver's-side was missing. The left-rear corner of the cab sustained damage in the form of some scrapes, a dent, and torn fiberglass trim, and the top mount for the right-rear cab shock absorber was broken.

There was no other damage identified to this truck-tractor or semitrailer.

5.3. Vehicle Logged Data:[43]

The Detroit Diesel DD13 engine was controlled by a DDEC ECM system which consisted of three separate units: a MCM, CPC, and an ACM. A complete description of these components and their functions is described in section 2.9 of this report.

Combination unit #3's truck-tractor ECMs were downloaded, via the J1939 diagnostic connector, at the tow yard on January 16, 2020. An NTSB investigator was present during the download and received a copy of the downloaded data for review.

[43] See Vehicle Attachment – *UPS #2 Freightliner DDEC Data* for additional information.

The downloaded data contained both "last stop" and "hard brake" events. The time stamps for these two events were separated by a few seconds, but it was determined these events resulted from this crash. The "Hard Brake" event logged on January 5, 2020, at 3:30 a.m. (EST) indicated this truck-tractor went from a speed of 69.0 mph, 17 seconds prior to event, down to 49.5 mph at the time of event. The "Last Stop" log also indicated a speed of 69.0 mph at 25 seconds prior to the last stop and speed of 49.5 mph ("Hard Brake" event) at 8.0 seconds prior to coming to a complete stop.

6. Collision Mitigation System:

6.1. Overview

The primary goals of Collision Mitigation System (CMS) technology are to prevent or reduce the severity of crashes by detecting a conflict and alerting the driver, and, in many systems, aiding in brake application or automatically applying brakes. There are multiple systems working together to make up a collision mitigation system such as radar, sensors, cameras, powertrain, and brake systems. According to the operator's manual, a Detroit Assurance Suite of Safety Systems brochure, and guidance received from consultation with Daimler Trucks North America engineers, the following bullets describe the intent and capabilities of the system.

7. Daimler Collision Mitigation Systems:

Daimler began placing collision mitigation systems on their vehicles, manufactured in the United States, in 2008. In 2008, the collision warning system only consisted of a visual warning. Starting in 2015, Daimler introduced a proprietary suite of safety features called Detroit Assurance™.

Detroit Assurance 2.0 first became available on Cascadia truck-tractors beginning with the 2015 model year. After two years, advancements in technology and software were made to the system and beginning with the 2017 model year Cascadia truck-tractors, Detroit Assurance 4.0 was introduced – see **Table 12** for 2.0 and 4.0 systems comparison.

The Detroit Assurance collision mitigation system utilizes a bumper mounted radar unit, for both the 2.0 and 4.0 systems to monitor objects ahead of the vehicle. The system functions by having the ability to command the ABS, transmission, and other engine functions in a potential crash situation.[44] The radar and Video Radar Decision Unit can track up to 40 objects at once and identify the top 6 immediate risks.

[44] https://demanddetroit.com/technology/safety/radar-system/

Table 12: Detroit Assurance 2.0 and 4.0 Systems Comparison**.**

Detroit Assurance 2.0	Detroit Assurance 4.0
Active Brake Assist (radar only) (Always on)	**Active Brake Assist** (radar only) (Always on)
• Full braking on moving objects[a]	• Full braking on moving objects
• Full braking on stopped objects[b]	• Full braking on stopped objects
• Partial braking on stationary objects[c]	• ***Full***[45] braking on stationary objects
Adaptive Cruise Control	• ***Warning and partial braking on moving pedestrians***[d]
• Automatically adjusts vehicle cruising speed to maintain a safe following distance	**Adaptive Cruise Control**
• Optional headway switch allows the driver to adjust the following distance from 2.3 seconds to 3.5 seconds in 3-seconds intervals	• Optional headway control is in the interactive dash display, and allows the driver to adjust the following distance from ***2.4*** seconds to ***3.6*** seconds in ***2 and 4***-seconds intervals
• Uses torque reduction, engine braking, and service brakes to reduce the speed of the vehicle	• Uses torque reduction, engine braking, and service brakes to reduce the speed of the vehicle
• Maintains the reduced cruising speed and returns to the set cruise speed once the slower vehicle has moved from the path of the vehicle	• Maintains the reduced cruising speed and returns to the set cruise speed once the slower vehicle has moved from the path of the vehicle
Lane Departure Warning	**Lane Departure Warning**
• Only available as an additional option to the radar system	• Only available as an additional option to the radar system
• Tracks the position of the vehicle and sounds a warning if the vehicle veers out of the intended travel lane without utilizing a turn signal	• Tracks the position of the vehicle and sounds a warning if the vehicle veers out of the intended travel lane without utilizing a turn signal
• Optional Video Capture camera continuously records video to capture any severe collision mitigation events – 10-15 seconds before and after the event along with other vehicle parameters are captured for analysis by fleet owners	• Optional Video Capture camera continuously records video to capture any severe collision mitigation events – 10-15 seconds before and after the event along with other vehicle parameters are captured for analysis by fleet owners
	Tailgate Warning
	• ***System is independent of the Active Brake Assist and Adaptive Cruise Control systems***
	• ***Warning is activated at speeds*** ***1. Above 45 mph if the vehicle is within 2.7 seconds behind the front vehicle for 10 seconds or more*** ***2. Between 35 and 45 mph if the vehicle is between 1.8 and 2.7 seconds behind the front vehicle 10 seconds or more*** ***3. Between 25 and 35 mph if the vehicle is at 1.8 seconds or less behind the front vehicle***
	• ***Tailgate warning will only deactivate at speeds below 20 mph***
	• ***If tailgate warning exceeds 10 seconds in duration, the warning becomes a reportable event via the J1939***

[a] Vehicles that are still moving but are moving slower than the approaching vehicle.
[b] Vehicles that were moving and then came to a stop all while being detected by the radar.
[c] Parked vehicles, stopped traffic in vehicle's path that has not moved while being detected by the radar.
[d] Pedestrians must be in motion and remain in motion to be detected, system only works at speeds below 25 mph.

[45] ***Bold Italicized*** text denotes changes or new systems between the Detroit Assurance 2.0 and 4.0 safety systems.

Active Brake Assist, Adaptive Cruise Control, and Tailgate Warning (4.0 only) safety systems are radar based and are the only systems offered as standard equipment since 2018 on Cascadia truck-tractors. Lane Departure Warning (LDW) requires a camera to be installed which is optional equipment.

The three truck-tractors involved in this crash were 2018 Freightliners, and all three were equipped with a Detroit Assurance safety system. The truck-tractor operated by FedEx Ground was equipped with Detroit Assurance 4.0. Although the FedEx Ground truck-tractor had a Lytx DriveCam video system,[46] it was not part of the Detroit Assurance 4.0 safety system, and it is not used to verify objects with radar system. The two truck-tractors operated by UPS had Detroit Assurance 2.0 with forward facing cameras for LDW.

7.1. Daimler Assurance Results

FedEx Ground truck-tractor (equipped with Detroit Assurance 4.0)

A review of the Detroit Assurance data by DTNA did not reveal any abnormalities or crash related information. The system was functioning normally as indicated by the DTNA analysis at the time crash.

UPS #1 truck-tractor (equipped with Detroit Assurance 2.0)

Between June 1, 2019, and the day of the crash, the Freightliner underwent 4 diagnostic checks on its software. An active fault code pertaining to the headway parameters of the AEB system was present in all downloads.[47] A review of the vehicle data by DTNA revealed a fault with the radar unit, substantiating the fault code identified in the diagnostic records. On June 4, 2020, at the request of the NTSB, the radar unit was removed from this truck-tractor and shipped to the NTSB headquarters for further examination.

The radar was shipped to DTNA's headquarters for examination and testing. DTNA engineers confirmed there was an active fault regarding the misalignment and calibration of the radar unit. DTNA engineers determined the fault appeared on June 2, 2019, and that was active until the time of the crash.[48] Due to this fault, a warning message was displayed in the instrument cluster and the use of the Collision Mitigation Technology was not available at any period after June 2, 2019. The system was functioning normally as indicated by the DTNA analysis prior to June 2, 2019.

UPS #2 truck-tractor (equipped with Detroit Assurance 2.0)

A review of the Detroit Assurance data by DTNA did not reveal any abnormalities or crash related information.

[46] The LYTX DriveCam video System is an independent fleet management system.

[47] Referred to as "headway ECU" in see Vehicle Attachment – *UPS #1 Freightliner Diagnostic and Maintenance Records.* See this attachment for more information.

[48] See Vehicle Attachment – *Daimler Detroit Assurance Report*.

8. Vehicle-to-Vehicle (V2V) System Technology:

Vehicle-to-Vehicle (V2V) systems transmit warnings and basic safety information (speed, position, heading, brake status, etc.) among vehicles. For years, the National Highway Traffic Safety Administration (NHTSA) has encouraged the development of connected vehicle technology and crash avoidance systems that could improve intersection safety (Harding 2014, p. 10).

For V2V systems to function properly, all vehicles on the roads must be equipped with on-board communication capabilities. Also, the communication spectrum frequency for Dedicated Short Range Communication Services must be allocated to intelligent vehicle technologies.[49] In 1995, based on the investigation of a heavy truck crash that took place in Menifee, Arkansas, the NTSB recommended that the Federal Communications Commission (FCC) allocate frequencies that would enhance collision warning systems (NTSB 1995).[50] A 2015 NTSB *Special Investigation Report* includes a summary of the many recommendations concerning crash avoidance systems that the NTSB issued to NHTSA in the years following the Menifee investigation (NTSB 2015, p. 11), including V2V systems.

In 2014, researchers categorized the precrash scenarios involving heavy trucks that could be addressed by V2V systems. Of the 37 scenarios considered, 17 were evaluated. The researchers found that a fully mature V2V system could potentially prevent about 267,000 police-reported crashes involving heavy trucks each year. The annual comprehensive costs of those crashes were estimated at $24.7 billion.

In July 2016, NHTSA released a report addressing V2V for heavy vehicles (Chang 2016). That report summarized research that began in the 1990s and covered the development of systems for integrated truck and retrofit V2V systems, including real-world evaluations (Safety Pilot Model Deployment) and test track experience. The report also addressed the safety benefits provided by V2V systems. The report stated that—

> Analysis of the potential safety benefits associated with heavy-vehicle V2V systems has shown good promise based on initial results. In 2013 there were 3,964 people killed and 95,000 people injured in crashes involving at least one large truck. Based on data from police-reported crashes, 70 percent of crashes involving trucks occurred in scenarios that could potentially be addressed by V2V systems.

In early 2017, NHTSA proposed rulemaking on a new Federal Motor Vehicle Safety Standards (FMVSS) for V2V communication technology.[51] However, NHTSA's proposed FMVSS 150 does not address V2V applications or requirements for heavy commercial vehicles. These vehicles travel more miles than light vehicles and are over-represented in fatal crashes;

[49] See 47 *CFR* Parts 90 and 95.

[50] Safety Recommendation H-95-46 to the Federal Communications Commission was classified "Closed—Acceptable Action" in 1999.

[51] See Notice of Proposed Rulemaking, "Federal Motor Vehicle Safety Standards (FMVSS); Vehicle-to-Vehicle (V2V) Communications," published at 82 *Federal Register* 3854, January 12, 2017.

consequently, the omission of heavy commercial vehicles from FMVSS 150 is a missed opportunity to significantly improve highway safety.

As the NTSB's response to the proposed rule stated, "Widespread use throughout the vehicle fleet—including all heavy vehicles and motorcycles—is required to capitalize on the full lifesaving benefits of V2V technology" (NTSB 2017).

Following an investigation into a 2012 collision between a school bus and a heavy truck near Chesterfield, New Jersey, the NTSB issued Safety Recommendations H-13-30 and -31 to NHTSA, which read as follows (NTSB 2013):

> H-13-30
>
> Develop minimum performance standards for connected vehicle technology for all highway vehicles.
>
> H-13-31
>
> Once minimum performance standards for connected vehicle technology are developed, require this technology to be installed on all newly manufactured highway vehicles.

The status of these two recommendations is "Open—Initial Response Received". Then in 2016, the NTSB investigated a crash between a car operating with automated vehicle control systems and a truck-tractor in combination with a semitrailer near Williston, Florida in which Safety Recommendations H-13-30 and -31were reiterated. These two recommendations remain "Open – Unacceptable Action".

F. DOCKET MATERIAL

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

LIST OF ATTACHMENTS:

Vehicle Attachment - *Motorcoach Build Sheets*

Vehicle Attachment - *Motorcoach DDEC Download*

Vehicle Attachment - *Motorcoach Steering Gear Inspection Report*

Vehicle Attachment - *FedEx Freightliner Build Sheets*

Vehicle Attachment - *FedEx Freightliner DDEC Data*

Vehicle Attachment - *UPS #1 Freightliner Build Sheets*

Vehicle Attachment - *UPS #1 Freightliner DDEC Data*

Vehicle Attachment - *UPS # 1 Freightliner Diagnostic and Maintenance Records*

Vehicle Attachment - *UPS #2 Freightliner Build Sheets*

Vehicle Attachment - *UPS #2 Freightliner DDEC Data*

Vehicle Attachments- *Daimler Detroit Assurance Report*

Vehicle Attachment - *Vehicle Factors Photographs*

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