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

HWY24MH001

TECHNICAL RECONSTRUCTION

Group Chair's Factual Report

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A. CRASH INFORMATION

Location: Etna, Licking County, Ohio
Date: November 14, 2023
Time: 08:47 a.m. EST

B. TECHNICAL RECONSTRUCTION GROUP

Group Chair	Robert Squire Investigator – Technical Reconstruction
Group Member	Sergeant Trevor Jasper Lead Crash Investigator Ohio State Highway Patrol

C. CRASH SUMMARY

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

D. DETAILS OF THE INVESTIGATION

The Technical Reconstruction Group was convened for this investigation to assist with providing on-scene documentation of the crash location and the involved vehicles; and to facilitate an analysis of certain collision events and causation factors. In support of these tasks the group relied upon information, data and documentation provided by the Ohio State Highway Patrol (OSHP) and other NTSB investigators. Factual reports prepared by other NTSB investigative groups should be consulted for information related to other aspects of the investigation, including information referenced within this report.

The crash involved a collinear collision of five motor vehicles – two commercial truck tractor-semitrailer combinations, two light duty passenger vehicles and a commercial motorcoach. The commercial combination vehicles included a 2019 Freightliner Cascadia truck-tractor coupled with a 2017 Strick dry van semitrailer (Freightliner combination) and a 2014 Volvo VNL truck tractor coupled with a 2022 Vanguard MaxCube dry van semitrailer (Volvo combination). The two passenger vehicles were identified as a 2015 Nissan Murano (Nissan) and a 2006 Toyota

Highlander (Toyota). The motorcoach was identified as a 2009 Van Hool c2045 (motorcoach).

At the time of the collision all five vehicles were in transit.

1.0 Introduction, Crash Location and Site Documentation

The crash events occurred on the westbound roadway of Interstate-70 (I-70) approximately 3,400 feet east of the State Route 310 overpass (exit #118) just east of Etna, Ohio. East of the crash location, the nearest cross highway is the TR-152 (Smoke Road SW) overpass, approximately 815 feet from the crash site. While an interchange is present at SR-310, no access exists between TR-152 and I-70. **Figure 1** presents a local map depicting the Etna city limits relative to the location of the collision.

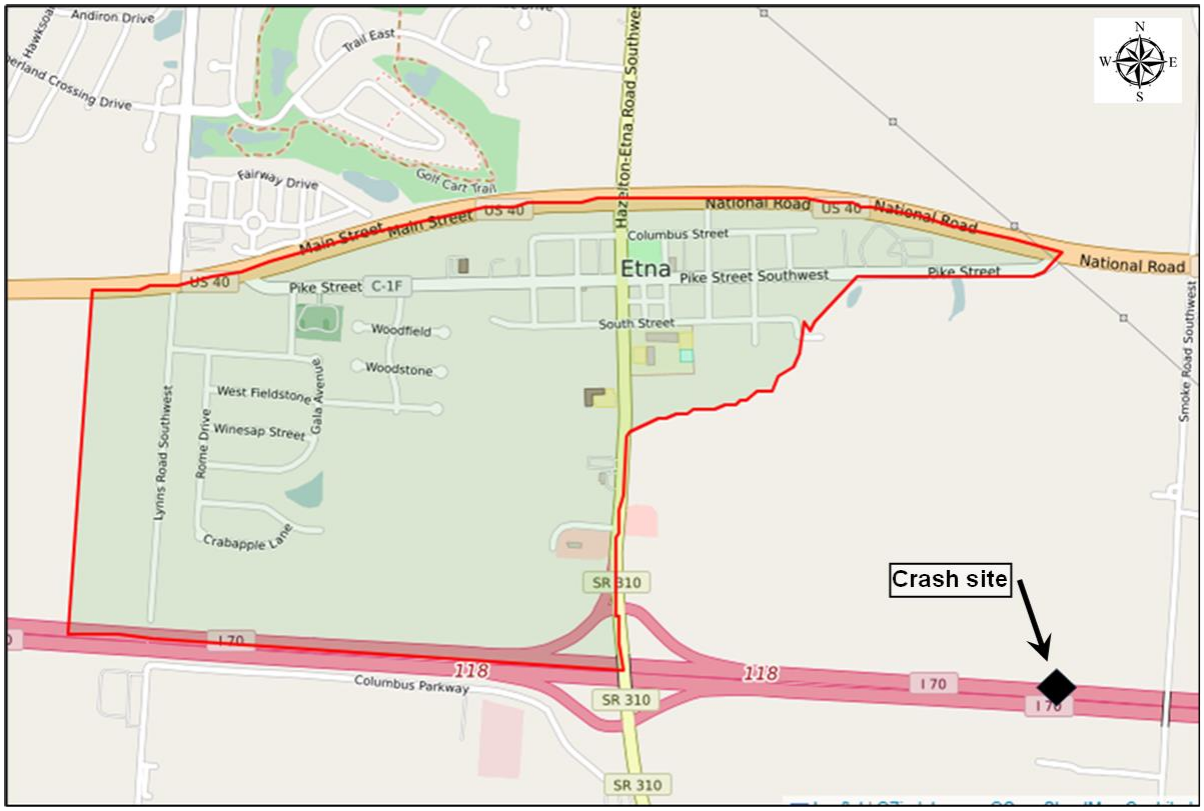

Figure 1: Map depicting the approximate crash site location relative to the town of Etna, OH. Source: Ohio zip code data - www.ZipDataMaps.com.

Interstate-70 is a major east–west interstate highway that traverses the state covering a distance of about 225.6 miles. Through the crash site the highway exhibits an east/west heading of 94/274 degrees, respectively. The westbound roadway consists of two travel lanes with contiguous left and right shoulders. The crash occurred

along a tangent segment (straight) that is essentially level. The tangent extends approximately 2.9 miles east of the site.

The crash site was documented by OSHP investigators with terrestrial and aerial (sUAS) photography.[1] Mitigation of crash-related damage to the road surface resulted in the resurfacing of the right travel lane where the crash occurred, thereby obliterating roadway evidence that might have otherwise remained (refer to the NTSB *Highway Factors Group Chair Report* for additional highway-related information). OSHP provided their photographs (taken prior to roadway repairs) to assist with the NTSB investigation.

The sUAS images were processed using Pix4DMapper photogrammetry software from which three-dimensional point clouds and two-dimensional orthomosaic images were created for analysis.[2]

2.0 Roadway Evidence

The OSHP site photographs depict a distinctive progression of roadway evidence that included pavement surface scars, tire friction marks, and vehicle debris in addition to cargo displaced from the Freightliner combination. The trail of pavement evidence and debris was continuous over approximately 274 feet as measured from the onset of evidence to the front of the Freightliner combination at its position of final rest. Within the trail of roadway evidence distinct areas of surface scaring and fluid debris were observed.

As depicted in **Figure 2**, the onset of roadway evidence was in the right travel lane, nearly centered in the lane although offset slightly toward the right shoulder. The initial onset consisted of linear pavement scars (scrapes and gouges) characteristic of vehicle components and structures having been forced into contact with the pavement. The onset of tire friction marks appeared contemporaneous with the pavement scars and were mostly outboard of the pavement scars on both the left and right sides. The tire marks exhibited characteristics of vertical loading deflection. Other linear tire marks characteristic of a dual wheel assembly also exhibited cyclical changes in intensity.

The tire marks continued westward to a second cluster of pavement scars (appeared as more intense gouging) and the deposit of fluid debris. The onset of this

[1] sUAS refers to Small Unmanned Aircraft (Aerial) System, colloquially referred to as a "drone".
[2] Pix4DMapper is a photogrammetry software package designed to use overlapping photographic images to generate 3D point clouds. Additional outputs from the generated point cloud include 3D models (textured mesh), digital surface and terrain models, and 2D orthomosaic maps. An orthomosaic is an image with high detail and resolution made by combining many smaller images and is corrected for lens distortion, camera tilt, perspective, and topographic relief.

second area was about 39 feet west of the initial onset of roadway evidence. Some of the linear gouging and tire marks continued westward over a distance of about 35 feet (~74 feet from the initial onset of roadway evidence) where a distinctive rightward redirection was observed. Additional pavement scars and fluid debris appear around this area. In addition, vehicle debris becomes more prevalent and widely displaced toward both sides of the roadway. Faint tire marks were still observable but were substantially obscured by fluid debris.

Figure 2: Photograph depicting the onset of roadway evidence as observed looking westward. Source: Ohio State Highway Patrol (cropped image).

Pavement scars and the fluid debris trail from the travel lane onto the right shoulder, leading to the Freightliner's position of rest. OSHP scene photographs depict displaced cargo (automotive lead-acid batteries) from the Freightliner along both sides of the westbound roadway adjacent to the vehicle.

A screen capture image of the scene 3D point cloud created from the OSHP aerial photography is depicted in **Figure 3**.

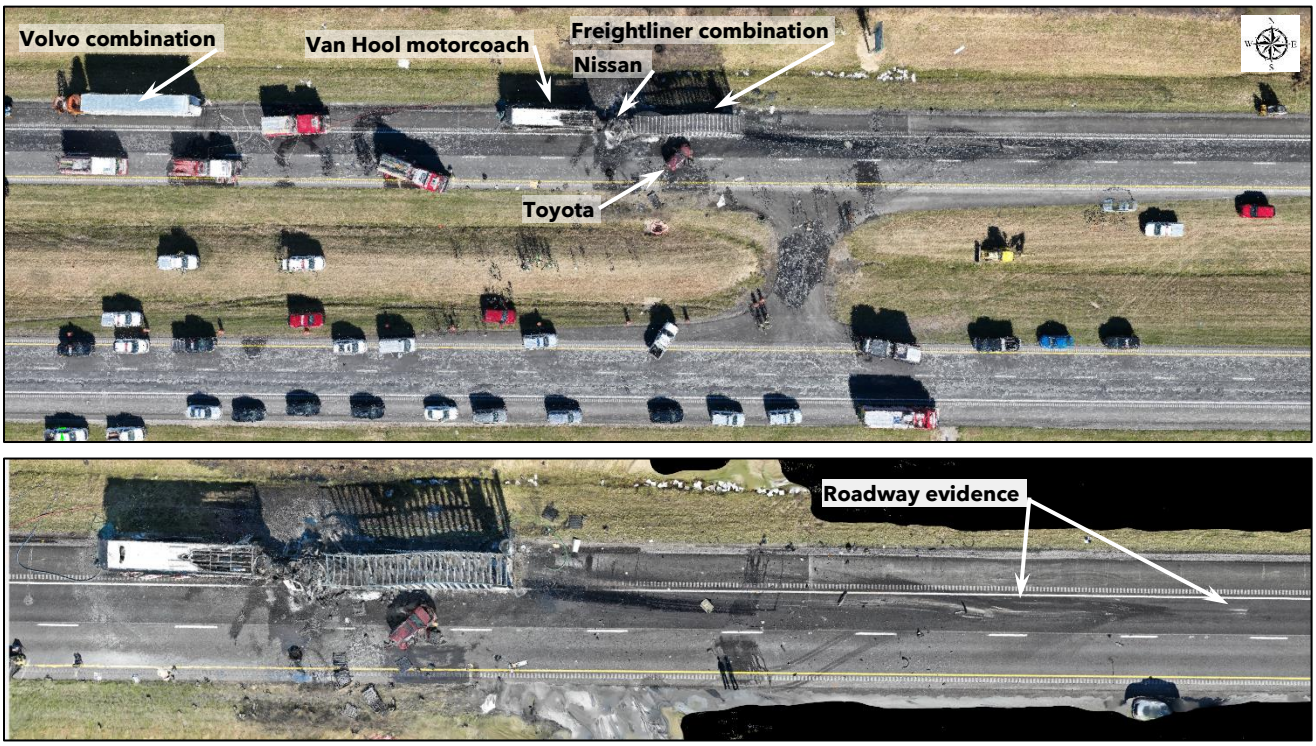

Figure 3: Screen capture image of the crash scene 3D point cloud and textured mesh created from the OSHP sUAS scene documentation flights.

3.0 Vehicles

A total of five vehicles were involved in the collision - two commercial combination vehicles, two light duty passenger vehicles and a motorcoach. At their positions of final rest, one of the passenger vehicles occupied the travelway while the remaining vehicles occupied the right shoulder. Except for one combination vehicle, the vehicles were placed into secure storage by OSHP for examination. For this investigation, 3D scan projects were completed for three of the four recovered vehicles. The FARO Premium 350 3D laser scanner was used to document the subject vehicles from multiple positions that were then registered into three-dimensional (3D) point clouds using FARO Scene® software. For this report select images have been included to illustrate certain perspectives of the scanned vehicles.

3.1 2019 Freightliner Cascadia truck-tractor coupled with a 2017 Strick semitrailer (Freightliner combination)

The Freightliner combination was identified as having initiated the collision sequence. At final rest, the vehicle was oriented westward on the right shoulder about 274 feet west of the initial onset of roadway evidence. Scene photographs depict that nearly the entire vehicle occupied the shoulder except the left wheels of the semitrailer that were atop the edge line. While the truck tractor and semitrailer remained coupled, both had been substantially destroyed by fire. Scene photographs further depict that at rest the front of the Freightliner was in contact with and partially intruded into the engine compartment of the motorcoach stopped ahead of it. The front of the truck tractor exhibited full overlap with the rear motorcoach although offset slightly toward the driver's side. Scene photographs depict, and the post-collision examination of the truck tractor revealed evidence of an upward vertical displacement of the longitudinal frame rails. Similarly, the passenger side longitudinal frame rail exhibited an upward vertical displacement between the steer and leading drive axles, just behind the fuel tank. Despite heavy fire damage, evidence of frontal contact damage was also observed.

The semitrailer towed by the Freightliner was identified as a 2017 dry van manufactured by Strick Trailers, LLC. Although the model was not immediately identified, it had originally consisted of an aluminum body with an overall length, width, and height of 53 feet by 8.5 feet by 13.5 feet, respectively. Examination of the vehicle after recovery to the storage yard revealed that the king pin plate and floor decking forward of the landing gear had separated from the vehicle. The semitrailer's side and roof panels were missing leaving only vertical framing on the sides and lateral framing across the top. The upper longitudinal framing was present but disfigured. The upper surface of the wooden floor deck was charred. The semitrailer exhibited no evidence of contact damage.

Figures 4 and **5** depict images of the 3D point clouds created for the Freightliner and Strick semitrailer.

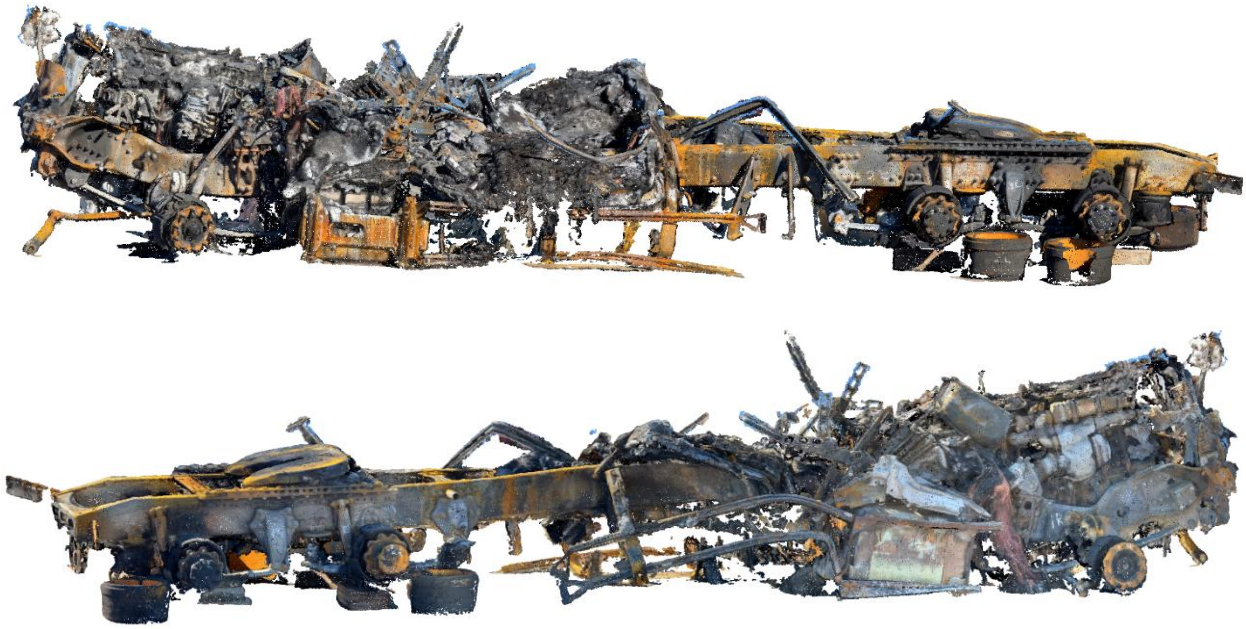

Figure 4: Screen capture image of the Freightliner truck tractor 3D point cloud depicting both sides as created from a lidar-assisted photogrammetry project.

Figure 5: Screen capture image of the Strick semitrailer 3D point cloud created from the laser scanning project.

3.2 2015 Nissan Murano

One of the light duty passenger vehicles involved in the collision was identified as a 2015 Nissan Murano, a crossover sport utility vehicle. The Nissan sustained catastrophic damage and was reportedly recovered in multiple pieces from the crash scene. The various component structures were examined at the storage facility.

Scene photographs of the vehicles at final rest depict the location of the vehicle's structure and components on the passenger side of the Freightliner truck tractor between the steer and leading drive axles with a portion of the wreckage apparently beneath the truck tractor's frame. The scene imagery also depicts the presence of the vehicle's roof structure resting atop the remnants of the Freightliner's radiator and the motorcoach engine. Examination of the vehicle at the storage facility revealed significant longitudinal deformation in addition to catastrophic fire damage.

At the position of final rest, the Nissan was located on the right shoulder about 264 feet west of the initial onset of roadway evidence (about 10 feet behind the motorcoach and front of the Freightliner). **Figure 6** is a photograph depicting the forward portion of the Nissan (as viewed from the passenger side forward) that was examined at the storage facility.

Figure 6: Post crash photograph of the Nissan depicting a portion of the passenger compartment and engine looking forward from the passenger side.

3.3 2009 Van Hool c2045 Motorcoach

The motorcoach involved in the crash was identified as a 2009 Van Hool c2045. The vehicle exhibited impact (contact) damage at both the front and rear, in addition to fire damage that consumed the aft half of the vehicle interior. While all the rear exterior panels (engine cover, upper panel, lights, etc.) had been displaced, the rear body framing appeared to remain in place. The engine exhibited evidence of both impact and fire damage. Observation of the interior fire damage was consistent with the fire having progressed forward from the rear of the vehicle inside the vehicle body. The exterior body sidewalls exhibited little evidence of having been displaced from the collision. At most, the lower sidewalls at bumper level exhibited a decrease in overall length of less than four inches when compared with the exemplar motorcoach.

Frontal impact damage exhibited two areas of overlapping contact. The first area was toward the driver's side that extended inboard from the left side about 33-37 inches and into the windshield area, which was missing. The second area was toward the driver's side edge of the vehicle that extended about 10-12 inches inboard from the left side. This area of contact extended vertically to the roofline of the vehicle and displaced the sidewall structure outboard of the driver's seat rearward. The outer sidewall exhibited a rearward displacement of about 44 inches that extended past the steer axle. Separation of the sidewall in this area created an opening around, and outboard of the driver's seat.

The motorcoach carrier provided access to an exemplar 2009 Van Hool for examination. **Figures 7** and **8** depict images of the 3D point clouds created for the involved motorcoach and the exemplar motorcoach.

Figure 8: Screen capture image of the Van Hool motorcoach 3D point cloud created from the laser scanning project and viewed from the driver side front (wheels removed for inspection). The top image is an exemplar motorcoach.

Figure 7: Screen capture images of the Van Hool motorcoach 3D point cloud created from the laser scanning project and viewed from the driver side rear. The top image is an exemplar motorcoach.

At its position of rest after the collision, the motorcoach occupied the right shoulder about 319 feet (as measured to the vehicle front) west of the initial onset of roadway evidence. The vehicle was in front of the Freightliner combination with the front of the truck tractor in contact with the rear of the motorcoach.

3.4 2006 Toyota Highlander

The second light duty passenger vehicle involved was identified as a 2006 Toyota Highlander midsize crossover sport utility vehicle. The vehicle exhibited two areas of contact. The first area was at the rear that was offset toward the passenger side. Evidence of contact extended laterally inboard about 36-37 inches from passenger's side and vertically to the roofline. The right rear fender/quarter panel had been displaced forward into contact with the rear tire.

The second area of contact was on the passenger side at about the C-pillar, about 10 inches forward of the rear axle. This area of impact exhibited a sharp-edge intrusion that displaced the C-pillar and trailing edge of the rear door laterally inward toward the occupant compartment. The exterior door panel from the passenger side rear door had been displaced from the vehicle and was located in the roadway about 79 feet to the east of the vehicle's position of rest. Some exterior surfaces of the Toyota also exhibited thermal (heat) damage to painted surfaces and plastic components.

At final rest, the Toyota was oriented northeastward in the travelway straddling the left and right lanes. At the nearest point, the left front of the vehicle was positioned about four feet from the driver's side of the Freightliner combination semitrailer and about 236 feet west of the initial onset of roadway evidence.

Figure 9 depicts the 3D point cloud created from the laser scans.

Figure 9: Screen capture image of the Toyota 3D point cloud created from the laser scanning project and viewed from the passenger side rear.

3.5 2014 Volvo VNL truck-tractor coupled with a 2022 Vanguard semitrailer

The second commercial combination vehicle was identified as a 2014 Volvo VNL truck tractor (day cab) coupled with a 2022 Vanguard MaxCube, 53-foot dry van semitrailer. The combination unit was not retained by OSHP investigators and was unavailable for NTSB examination.

OSHP photographs depict impact damage to the passenger side rear corner of the semitrailer. Evidence of contact extended vertically from the underride protection to the roofline. While no damage measurements were immediately available, visible evidence of contact around the taillight assembly indicates contact extended inboard less than 12 inches from the sidewall.[3] As depicted in **Figure 10**, a portion of the passenger side sidewall above the floor deck was displaced forward.

[3] Dimensional data was acquired from similar semitrailers.

Figure 10: Photograph depicting damage to the passenger side rear of the Vanguard semitrailer. Source: Ohio State Highway Patrol.

At final rest, the Volvo combination was stopped on the right shoulder with the rear of the semitrailer positioned about 150 feet west of the front of the motorcoach.

4.0 Electronic Data

Several sources of electronic data useful to identify certain aspects of the collision event or vehicle position and speed relative to time were recovered for analysis. The various data sources and pertinence to the reconstruction of the crash events are discussed in this section. Certain data, such as that originating from electronic logging devices (ELD), may be further discussed by the NTSB Motor Carrier Group.

4.1 2015 Nissan Murano Event Data

With limited exceptions, light duty vehicles (GVWR of 3,855 kg/8,500 pounds or less) manufactured on or after September 1, 2012, if equipped with an event data recorder must comply with rules promulgated under 49 Code of Federal Regulations Part 563. As defined by Part 563, an event data recorder (EDR) means a device or function in a vehicle that records the vehicle's dynamic time-series data during the time

period just prior to a crash event (e.g., vehicle speed vs. time) or during a crash event (e.g., change in velocity (delta–V) vs. time). The regulation defines data elements, sample rate, range, accuracy, and resolution. In most all cases, the light duty EDR function is contained within the supplemental restraint system airbag control module (ACM).[4] EDR records are typically written when the ACM interprets that an event threshold is met based on data received by sensors within or linked to the module.[5] Most ACM EDRs are capable of recording multiple events depending upon timing, event thresholds and magnitude and recording priority.[6] Events not reaching a threshold for being "locked" can be overwritten by subsequent events of greater magnitude. When data is "locked," subsequent events may not be recorded. As a result, data depicting multiple events may not include all events in the chain of events and may not completely describe the chronology of a multiple event crash. For this crash, the ACM exhibited external fire damage when recovered from the vehicle. An NTSB specialist performed a memory chip transplant and was subsequently able to image relevant crash data. Information regarding the memory chip transplant and data imaging is available in the NTSB *Chip-Level Forensics Specialist Report*. Two event records were recovered.

System status data indicate that the driver and right front passenger safety belts were fastened. Both recorded events occurred on the same ignition cycle. Event record 1 was consistent with a rearend impact and produced a recorded maximum longitudinal change in velocity of 57 mph.[7] No airbag or seat belt pretensioner deployment were reported. Event record 2 was consistent with a frontal impact and produced a recorded maximum longitudinal change in velocity of -37 mph. Airbag (multiple) and seat belt pretensioner deployments were commanded for this event beginning about 0.22 seconds after module wake-up.[8] Roll data were also associated

[4] Nissan references the module as the "airbag control unit" (ACU).

[5] Nissan data limitations specify that crash data is measured internally in the ACU while precrash data is not but is transmitted from other control units through the Controller Area Network (CAN). Precrash data elements are asynchronous.

[6] (a) Nissan defines a Multi-Event occurrence when the time between Event 2 trigger threshold and Event 1 trigger threshold is less than or equal to 5 seconds during the same ignition cycle. (b) The Nissan ACU can store two types of events: Non-Deployment Events and Deployment. A Non-Deployment Event is a crash or other physical occurrence which causes the ACU algorithm to be activated, but in which deployment thresholds are not reached. A Deployment Event is a crash or other physical occurrence which causes ACU deployment thresholds to be reached or exceeded. Depending on the vehicle model, one or more of the following may be activated during a Deployment Event: front air bags, seat-mounted side airbags, roof-mounted or door-mounted curtain air bags, pretensioners, or pop-up roll bars.

[7] Where polarity is reported, positive values in the longitudinal direction indicate a forward speed change/acceleration that is characteristic of a rear impact.

[8] "Time zero" as defined in 49 CFR Part 563, means whichever comes first (1) systems with "wake-up" air bag control systems, the time at which the occupant restraint control algorithm is activated; (2) for continuously running algorithms, (a) the first point in the interval where a longitudinal cumulative delta-V of over 0.8 km/h (0.5 mph) is reached within a 20 ms time period; (b) for vehicles that record "delta-V, lateral," the first point in the interval where a lateral cumulative delta-V of over 0.8 km/h (0.5 mph) is reached within a 5 ms time period; (3) deployment of a non-reversible deployable restraint. Time zero

with event record 2, where a maximum roll of -60 degrees (passenger side toward driver side) was recorded.[9] The time interval between events 1 and 2 was reported as 0.1 seconds.

Certain data for the two event records are provided in **Tables 1** and **2**.

Table 1: Nissan Event Record 1 Recorded Data

Longitudinal	Maximum change in velocity	57 mph
	Time to maximum change in velocity	165ms
	Maximum acceleration	46.5g
	Time to maximum acceleration	80ms
Lateral	Maximum change in velocity	-1 mph
	Time to maximum change in velocity	92.5ms
	Maximum acceleration	-33.5g
	Time to maximum acceleration	80ms
Deployment timing		NA

typically represents the beginning of the crash event, All the precrash, event, cumulative change in velocity data, deployment times etc., are relative to "time zero".

[9] For event data positive polarity represents forward longitudinal acceleration and change in velocity; left to right for lateral acceleration and change in velocity; left to right for roll angle; and a left turn for steering.

Table 2: Nissan Event Record 2 Recorded Data

Longitudinal	Maximum change in velocity	-37 mph
	Time to maximum change in velocity	297.5ms
	Maximum acceleration	-49g
	Time to maximum acceleration	237.5ms
Lateral	Maximum change in velocity	2 mph
	Time to maximum change in velocity	270ms
	Maximum acceleration	49g
	Time to maximum acceleration	265ms
Deployment timing	Driver frontal airbag 1st stage	229ms
	Driver frontal airbag 2nd stage	232ms
	Passenger frontal airbag 1st stage	229ms
	Passenger frontal airbag 2nd stage	232ms
	Driver side airbag	250ms
	Passenger side airbag	247ms
	Side curtain airbag driver	250ms
	Side curtain airbag passenger	247ms
	Belt pretensioner driver side	229ms
	Belt pretensioner passenger side	229ms

Five (5) seconds of precrash data (leading to time zero) where multiple vehicle performance parameters were reported were also retrieved. The data were reported at a rate of 2Hz (twice per second).[10] Precrash data was acquired for the two event records. While most of the precrash data for the two events were duplicative, the final sample in Event Record 2 appears to include a data sample after onset of the first crash event. The precrash data are summarized in **Tables 3** and **4**.

In general, the precrash data indicate the Nissan was steadily decreasing speed, slowing from about 24 mph to 15 mph. In Event Record 2, the last sample indicates an

[10] Recorded asynchronously and reported to nearest interval.

increase in vehicle speed (forward acceleration) and substantial change in steering angle.

Table 3: Nissan Precrash Data for Event Record 1

Time	Speed (mph)	Brake Switch (on/off)	Accelerator Pedal (%)[1]	Engine RPM	Motor RPM[2]	Steering Input (degrees)[3]
-5	24	ON	0	1000	1000	0
-4.5	22	ON	0	1000	1000	2.5
-4	21	ON	0	1000	1000	2.5
-3.5	20	ON	0	1000	1000	0
-3	19	ON	0	1000	1000	0
-2.5	18	ON	0	1000	1000	0
-2	17	ON	0	1000	1000	0
-1.5	17	ON	0	900	1000	0
-1	16	ON	0	900	1000	0
-0.5	16	ON	0	1000	1000	2.5
0	15	ON	0	900	900	0

[1] Percent of full throttle
[2] For internal combustion engines indicates gearbox input shaft revolution
[3] Positive integer indicates a leftward steering input

Table 4: Nissan Precrash Data for Event Record 2

Time	Speed (mph)	Brake Switch (on/off)	Accelerator Pedal (%)[1]	Engine RPM	Motor RPM[2]	Steering Input (degrees)[3]
-5	24	ON	0	1000	1000	0
-4.5	22	ON	0	1000	1000	2.5
-4	21	ON	0	1000	1000	2.5
-3.5	20	ON	0	1000	1000	0
-3	19	ON	0	1000	1000	0
-2.5	18	ON	0	1000	1000	0
-2	17	ON	0	1000	1000	0
-1.5	17	ON	0	900	1000	0
-1	16	ON	0	900	1000	0
-0.5	16	ON	0	1000	1000	2.5
0	24	OFF	0	1100	1400	-22.5

[1] Percent of full throttle
[2] For internal combustion engines indicates gearbox input shaft revolution
[3] Positive integer indicates a leftward steering input

The precrash data are depicted in graphical format in **Figure 11**.

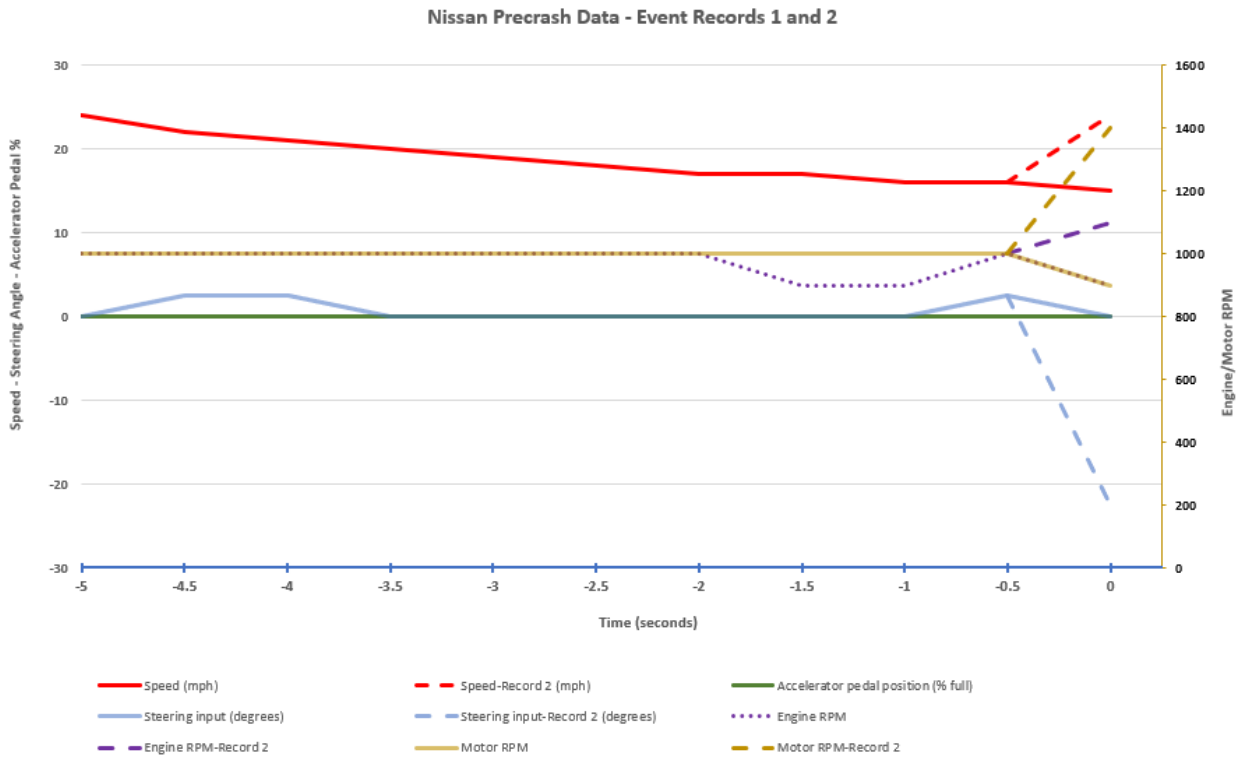

Figure 11: Precrash data for the Nissan Event Records 1 and 2. Dashed lines denote difference from Event Record 1 to Event Record 2. Note that data elements are asynchronously sampled.

4.2 2009 Van Hool Motorcoach

Two sources were examined for potential data useful for analysis of the crash. Those sources included certain vehicle electronic control modules and a Garmin GNSS navigation device.[11] As referenced in the *NTSB Vehicle Factors Group Chair Factual Report*, the motorcoach was powered by a Detroit Diesel Corporation diesel engine that is electronically managed by multiple electronic control modules (ECMs). Peripheral to engine management and operation, these various electronic control modules communicate certain data related to engine usage, fault codes and event data that may be stored and later retrieved. On March 12, 2024, the requisite combination of ECMs were transported by NTSB investigators to Detroit Diesel Corporation (DDC) to facilitate imaging of any stored data. The imaged data was provided to NTSB and OHSP investigators.

[11] GNSS refers to global navigation satellite system (GNSS), which is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis. This includes the United States' Global Positioning System (GPS) constellation of satellites.

The imaged data included engine ECM configuration and programming as well as certain engine and transmission usage and events related to a last stop record, hard brake record, and diagnostic or fault code records. The event records are reported as time-series data and can include up to two hard brake events, one last stop event, and three most-recent diagnostic trouble code (DTC) conditions or events. Engine use data can include certain daily engine use activity, histograms related to engine load, engine speed, idle time, speed range, etc., a three-month engine use summary, certain configuration, and life-to-date data.

Regarding event data, two hard brake and one last stop records were imaged. After adjusting for ECM (internal) clock drift and comparison of the data with the vehicle positioning recorded by the Garmin navigation device, none of the events were related to the crash event.[12] The last stop record (most recent event) was identified as having occurred at the school complex where the student trip had originated. Any additional findings related to the ECM data pertinent to vehicle operation will be addressed in the *NTSB Vehicle Factors Group Chair Factual Report*.

Following the crash, OSHP investigators recovered a Garmin GNSS personal navigation device from the motorcoach.[13] Data stored on the device was subsequently imaged by the OSHP Computer Crimes Unit. OSHP investigators provided NTSB investigators with a copy of a retrieved .GPX file and a summary of time and position data covering the final 9 minutes, 46 seconds of recorded data.[14] This final time and position data summarized by OSHP was presented as 48 data samples that featured intervals ranging from one to 23 seconds, and covering about 10.8 miles on I-70 between 08:38am and 08:47am. Vehicle (segment) speed was also reported with the position and time data. The data are presented in **Table 5**.

The data are consistent with the motorcoach approach to the crash site. At the 08:47:28 time stamp the speed data indicates a reduction in vehicle speed from an initial speed of 71 mph. At this position the vehicle was west of the Route 152 overpass nearing the crash site.[15]

[12] At the time of data imaging the ECM clock time is compared with current time (including time zone and daylight savings time) to account for clock drift. The adjusted event records indicate the last stop occurred 11/14/2023 about 06:14 am; the two hard brake events occurred 09/16/2023 and 08/26/2023.
[13] OSHP identified the device as a Garmin Nuvi model 2539LMT (LMT-lifetime maps and traffic). See Technical Reconstruction Group attachments for a more extensive list of data.
[14] .GPX is a GPS Exchange Format file, which is a text file with geographic information such as waypoints, tracks, and routes saved in it. GPX files facilitate the transfer of information between GPS units and computers.
[15] Garmin advertises a positional accuracy of within 15 meters, although 5–10-meter accuracy is common.

Table 5: Final position, time and speed data imaged from Garmin navigation device recovered from motorcoach.

Sample	Latitude	Longitude	Time	Speed
1	39.946331	-82.468081	8:38:08 AM	71 mph
2	39.945826	-82.474696	8:38:26 AM	71 mph
3	39.945281	-82.480908	8:38:43 AM	71 mph
4	39.944782	-82.487139	8:39:00 AM	71 mph
5	39.944464	-82.490971	8:39:11 AM	64 mph
6	39.94401	-82.496444	8:39:27 AM	64 mph
7	39.943634	-82.501	8:39:40 AM	71 mph
8	39.943177	-82.50654	8:39:55 AM	71 mph
9	39.942706	-82.512244	8:40:11 AM	64 mph
10	39.942218	-82.518292	8:40:29 AM	68 mph
11	39.941978	-82.523019	8:40:42 AM	71 mph
12	39.942126	-82.527796	8:40:55 AM	71 mph
13	39.942458	-82.534732	8:41:14 AM	64 mph
14	39.942685	-82.539821	8:41:29 AM	64 mph
15	39.942879	-82.54453	8:41:43 AM	64 mph
16	39.943122	-82.550813	8:42:02 AM	64 mph
17	39.943307	-82.555618	8:42:16 AM	64 mph
18	39.943508	-82.560811	8:42:32 AM	64 mph
19	39.943693	-82.565599	8:42:46 AM	68 mph
20	39.943876	-82.570343	8:42:59 AM	71 mph
21	39.944134	-82.57697	8:43:17 AM	71 mph
22	39.944387	-82.583188	8:43:34 AM	71 mph
23	39.94464	-82.589062	8:43:50 AM	71 mph
24	39.944896	-82.595312	8:44:07 AM	71 mph
25	39.945351	-82.60079	8:44:22 AM	71 mph
26	39.945882	-82.606227	8:44:37 AM	71 mph
27	39.945756	-82.610285	8:44:48 AM	71 mph
28	39.945748	-82.615083	8:45:01 AM	71 mph
29	39.946058	-82.622036	8:45:20 AM	71 mph
30	39.946335	-82.628257	8:45:37 AM	71 mph
31	39.946655	-82.635604	8:45:57 AM	71 mph
32	39.946976	-82.642986	8:46:17 AM	71 mph
33	39.947359	-82.651437	8:46:40 AM	71 mph
34	39.947694	-82.658458	8:46:59 AM	71 mph
35	39.948045	-82.66581	8:47:19 AM	71 mph
36	39.948199	-82.668862	8:47:28 AM	46 mph
37	39.948245	-82.669739	8:47:33 AM	25 mph
38	39.948279	-82.670617	8:47:42 AM	43 mph
39	39.948288	-82.67083	8:47:43 AM	34 mph
40	39.948296	-82.670997	8:47:44 AM	31 mph
41	39.948308	-82.671232	8:47:46 AM	21 mph
42	39.948315	-82.671379	8:47:48 AM	21 mph
43	39.948318	-82.671436	8:47:49 AM	18 mph
44	39.948319	-82.671462	8:47:50 AM	9 mph
45	39.948321	-82.671491	8:47:51 AM	6 mph
46	39.948322	-82.671513	8:47:52 AM	3 mph
47	39.948323	-82.671532	8:47:53 AM	3 mph
48	39.948323	-82.671539	8:47:54 AM	3 mph

The recovered .GPX file included a current track record that indicated two tracks on the day of the crash. The first track record ended at 06:09:59 a.m. with indicated geographic coordinates consistent with the school complex where the student trip originated. The second track indicates a start time of 06:11:56 a.m. with an indicated vehicle speed of 0 mph. **Table 6** depicts data from the start of the second track until the vehicle begins to move.

Table 6: Initial position, time and speed indicated at start of second vehicle track.

Sample	Latitude	Longitude	Time	Speed
1	N40° 36.123'	W81° 24.325'	06:11:56	0.0 mph
2	N40° 36.123'	W81° 24.325'	06:14:51	0.0 mph
3	N40° 36.123'	W81° 24.325'	06:19:44	0.0 mph
4	N40° 36.123'	W81° 24.324'	06:23:08	0.0 mph
5	N40° 36.123'	W81° 24.324'	06:27:22	0.0 mph
6	N40° 36.123'	W81° 24.324'	06:31:53	0.0 mph
7	N40° 36.123'	W81° 24.324'	06:36:10	0.0 mph
8	N40° 36.123'	W81° 24.324'	06:39:09	0.0 mph
9	N40° 36.123'	W81° 24.324'	06:41:07	0.0 mph
10	N40° 36.123'	W81° 24.324'	06:43:03	0.0 mph
11	N40° 36.123'	W81° 24.324'	06:44:58	0.0 mph
12	N40° 36.123'	W81° 24.325'	06:46:55	0.0 mph
13	N40° 36.123'	W81° 24.325'	06:49:50	0.0 mph
14	N40° 36.123'	W81° 24.325'	06:52:29	0.0 mph
15	N40° 36.123'	W81° 24.325'	06:54:07	0.0 mph
16	N40° 36.123'	W81° 24.325'	06:55:42	0.0 mph
17	N40° 36.123'	W81° 24.325'	06:57:24	0.1 mph
18	N40° 36.121'	W81° 24.325'	06:59:26	7.0 mph
19	N40° 36.098'	W81° 24.325'	06:59:40	6.0 mph

4.3 2006 Toyota Highlander

Although the model year of the Toyota predated the Part 563 EDR requirements, the vehicle's airbag module had EDR capability. A record was recorded as a result of the airbag control module deployment algorithm wake-up (enabled) with a front/rear crash type indicated. While the record indicated that no frontal airbag deployment was commanded (none was exhibited), post-crash examination of the vehicle revealed the right-side curtain airbag was no longer stowed and had apparently deployed. No deployment data record was provided for this restraint.[16] Precrash data was limited but indicated no seat belt buckled for the driver and an unoccupied front passenger seat. No diagnostic codes were set. For this module the crash pulse is measured for 150ms

[16] This model year vehicle incorporate a Gen1 airbag control module, which did not universally record deployment data for side/lateral impacts.

after module wake-up. A maximum change in velocity of 32.1 mph was recorded at 150ms. The change in velocity was reported as a positive value indicating a forward acceleration characteristic of a rear impact.

The record conveyed certain precrash data that was reported at one second intervals for a period of up to five seconds. For this event, the time interval between the last precrash sample and module wake-up was 400ms. Certain precrash data are presented in **Table 7**.

Table 7: Precrash data imaged from Toyota airbag control module.

Time[1]	Speed[2] (mph)	Brake Switch	Accelerator Rate[3]	Engine RPM[4]
-4.4	16.2	OFF	OFF	800
-3.4	16.2	OFF	OFF	400
-2.4	14.9	ON	OFF	800
-1.4	11.2	ON	OFF	800
-0.4	8.7	ON	OFF	400
0	8.7	OFF	OFF	400

[1] One second intervals from deplyment command (+0.4 seconds)
[2] Resolution 1.2 mph rounded down
[3] Voltage level expressed as "FULL / MIDDLE / OFF"
[4] Resolution 400 RPM rounded down

Figure 12 depicts a graphical representation of the precrash data.

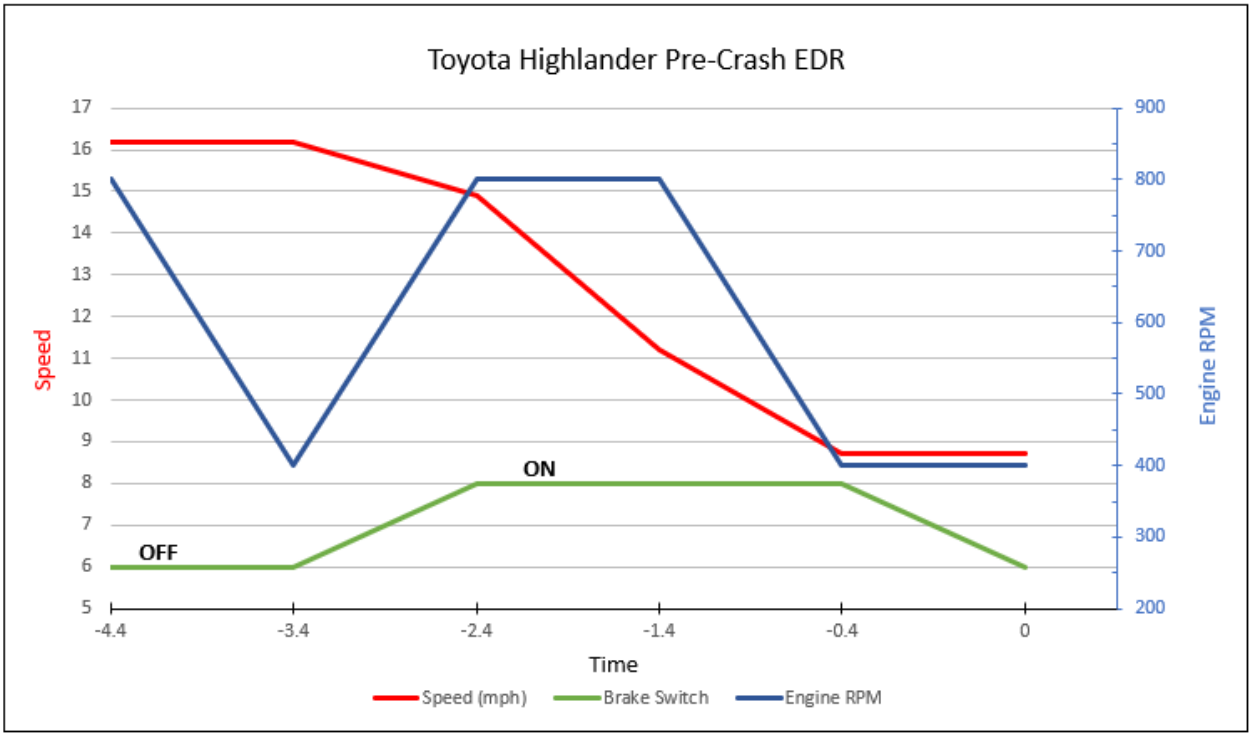

Figure 28: Graphical depiction of Toyota precrash data. Note that data elements are asynchronously sampled.

4.4 Other Data Sources

Other sources of data relevant to the investigation were identified and provided to NTSB investigators. Of the data acquired, certain sources were potentially useful for the analysis of the crash.

4.4.1 Trailing Vehicle Video

OSHP investigators acquired a forward-facing (i.e., dash camera) exterior view video segment from a commercial vehicle traveling behind the Freightliner combination.[17] The video, which is about one-minute in length, depicts the Freightliner combination and camera supporting truck traveling in the right lane approaching the State Route-310 interchange (as indicated by roadside signage). The Freightliner combination leads the camera-bearing vehicle by a substantial distance. As the camera-bearing vehicle nears the TR-152 overpass, debris and flames can be seen being displaced ahead of and adjacent to the Freightliner combination. The video imagery displays no additional data, such position, heading or speed.

[17] Commercial carrier was identified as McKesson Medical Surgical, Inc.

Regarding the observation of fire, flames initial appear as beneath the Freightliner. Shortly thereafter a flame plume, mostly distributed to the passenger side of the truck. The plume dissipates and as the Freightliner comes to stop, the fire is concentrated to the passenger side of the vehicle.

The video segment was analyzed by the NTSB Office of Research and Engineering for analysis with the following results reported.

Introduction to the Video Data

A video from a forward-facing camera on a tractor-trailer traveling west on I-70 behind the Freightliner was evaluated as part of the study. This video consisted of 60-seconds of video and contained 2000 frames of 1920x1080 images in the mpeg format. The reported frame rate was 30 fps. The file name for the video contained the nomenclature "transcoded" which indicates the video may have been altered from its original format. Further examination of the metadata found evidence that is consistent with transcoding. For example, there was only 8 independent I-frames to 1792 dependent B and P frames and the GOP was large.[18] Because of the way in which the video was transcoded it could not be determined from metadata if the frame rate/timing information provided was correct, and it is possible that the frame rate may have been alter ed during the transcoding. Therefore, the reported video duration in the header may be incorrect or unreliable. The image quality and aspect ratio of the video images can also be altered as result of transcoding. Later in this report a method of verifying the timing of the video based on other information available from the crash is described.

Description of the Video and Estimates of the Timing of key Events Based on the Reported Frame Rate of 30 fps.

The following video times are based on the reported frame rate of 30 fps. The collision between the Freightliner and the Nissan occurs approximately 33.2±0.4 seconds into the video (frames 984 to 1005). The portion of the video used in the study is the first 33.6 seconds prior to impact. Negative times described in this section indicate time prior to the collision between the Freightliner and the Nissan (Time-to-Collision (TTC)). The word "collision" in this section refers to the collision between the Freightliner and the Nissan as presented in the video by the discernible displacement of debris outward from the front of the Freightliner.

The video begins at -33.2±0.4 seconds prior to the collision. When the video begins the Freightliner is traveling in the right-hand lane of westbound I-70 and there are no other vehicles visible in the camera view except for the Freightliner. In the video

[18] GOP or "*Group of Pictures*" is a term that refers to the video structure representing how digital video is grouped.

the Freightliner remains in the right-hand lane of I-70 west until the collision with the Nissan. About -27±0.4 seconds prior to the collision between the Freightliner and the Nissan, an unidentified vehicle begins to become visible in the left-hand lane of westbound I-70. This vehicle is traveling in the left-hand lane of I-70 and is located west (forward) of the Freightliner (which is traveling in the right-lane). At -17.7 seconds prior to the collision between the Freightliner and the Nissan, the right-side trailer tires of the Freightliner briefly cross onto the solid white line on the right side of the travel lane. At -9.0±0.4 seconds prior to the collision between the Freightliner and the Nissan, a white van that was initially traveling in the right-hand lane ahead of the Freightliner, begins to move to the left lane. This van is fully established in the left-hand lane at -6.4 ±0.4 seconds prior to the collision between the freightliner and the Nissan. At -2.7±0.4 seconds prior to the collision, the freightliner begins to move to the right and the right-side trailer tires appear to be on the (right) solid white line when the crash occurs.

Discussion of Frame Rates and its Effect on Timing

The times described in the previous section are based on the reported frame rate of 30 fps. As indicated earlier, since the video was transcoded, it cannot be determined if the reported frame rate is the actual frame rate. If the actual frame rate was different from the reported rate of 30 fps, the event timings described in the previous section would be incorrect. For example, if the actual frame rate was 60 fps (a common rate for dashcams), the time the white van is established in the left lane would be 4.5 seconds instead of the 9.0 seconds for 30 fps.

Verifying the Frame Rate using Video analysis

To determine if the reported frame rate of 30 fps was the actual frame rate of the video, vehicle speeds were estimated using the accident video and video tracking software. The results of the video speeds estimated at 30-fps were then compared with other known information on vehicle speeds to determine if the 30-fps frame rate was consistent with the actual accident speeds. The vehicle speeds estimated in the video are dependent on the frame rate. Therefore, if the 30-fps frame rate in the metadata was incorrect, the speed estimates made at 30-fps would differ from the actual speed data for the accident. For example, if the actual frame rate of the video was 60 fps (a common frame rate used in dash cameras) and the Freightliner was going 72 mph (as crash speed estimates based on the EDR data from the Nissan indicate), the speed estimated at a frame rate of 30 fps would be 36 mph, which is clearly inconsistent with the Freightliner speed based on the EDR information (72 mph) and the posted speed limit of 70 mph.

The Video tracking/matchmoving software used in the study, SynthEyes, is a commercially available camera tracking software that can be used to examine an image sequence and determine the motion of the camera and objects in the video relative to landmarks in the real world. The software determines the camera position and

properties by using non-linear least squares optimization and adjusting the camera properties, the camera location, and the camera orientation simultaneously over all frames to minimize the error between the survey measurements, the image data, the mathematical lens model, and the solved points. (The mathematical lens model used in the study was the Brown-Conrady model). The resulting "camera solve" contains a mapping of the 3D "real world" survey space to the 2D image space for all frames of the video as well as the camera location and orientation for all frames. It also contains "solved points" which can be compared to points in the real world to verify accuracy. The root mean square (rms) accuracy of the solved points for this accident was 0.14 feet. (The solve was scaled based on the broken white lines which separated the westbound lanes, using a 10-foot length for the lines with a 30-foot spacing between the broken lines.) The rms Horizontal Pixel (HPIX) error, which measures the "tightness" of the fit of the camera model to the image data, was 1.2 pixel which is acceptable for a project of this type.

Once a camera solve has been estimated, the camera solve can be used to determine how objects located in the 3D space would appear in the 2D image space of the accident video. The motion of objects can be estimated by matching the motion of properly scaled objects (in this case the Freightliner trailer) in the 3D real world survey space to the 2D image data from the accident video using the camera solve.

The results of the video speed measurements performed at the reported frame rate of 30 fps indicated the speed of the Freightliner over the final 5.8 seconds prior to the collision was between 70 ±5.0 mph and the speed of the truck behind the Freightliner (the camera truck) was 65±5.0 mph. These speeds are consistent with EDR data from the Nissan which were used to calculate the impact speed of the Freightliner at about 72 mph. The results are also consistent with the posted speed limit of 70 mph. The fact that the speeds estimated at 30-fps are consistent with the accident speeds supports that the frame rate of 30 fps listed in the metadata for the video is the correct frame rate for the video. As indicated earlier, if the actual frame rate of the video was different from the 30-fps then you would expect the speed estimates made at 30 fps to differ from the collision speeds.

Emergency Braking by the Freightliner

There were no clear indications of rapid slowing by the Freightliner consistent with emergency braking prior to the collision noted in the video. However, due to the distance between the camera and the Freightliner it is possible that this would not be detected if the total speed change is relatively small.

Summary of Findings from the Video Study

The results of the video study support that the reported frame rate for the video of 30 frames per seconds, is the correct frame rate.

The timing of key events based on the 30-fps frame rate is described earlier in this report. The speed estimates from the video support that the Freightliner was traveling about 70 mph when it crashed into the Nissan.

4.4.2 Volvo Combination Video and ELD Data

Also acquired was a 50-second-long forward-facing exterior view (i.e., dash camera) video segment depicting movement of the Volvo combination and the apparent impact to that vehicle.[19] Embedded in the video imagery was the display of additional data that included date, time, vehicle speed and highway speed limit. The time stamp at the beginning of the segment displays 08:47:28 with a vehicle speed of 51 mph. The data displays a decrease in speed and at a time stamp of 08:47:43, and a displayed speed of 10 mph, a noticeable jolt is observed in the imagery.[20] Immediately following the jolt, the vehicle moves onto the right shoulder and continues a distance before coming to stop straddling the pavement edge. The time stamp at the cessation of movement was 08:48:01.

The electronic logging device (ELD) data from the Volvo also provided some corroborating data. The ELD data provided information on time, vehicle position and vehicle speed. The time interval for data samples was one-minute, so it is of limited corroborative value. As depicted in **Table 8**, the data reviewed covered eight minutes. For the initial six minutes the vehicle is reportedly traveling just over 72 mph. By 08:47am the data indicate the vehicle as stopped. Comments on the ELD record indicate "movement ended" at 08:47 and "vehicle stopped" at 08:48. The geographic position of the last sample was consistent with the position of rest documented by OSHP.

Latitude	Longitude	Time	Speed
39.94205	-82.52655	8:41:00 AM	72.7 mph
39.943109	-82.55076	8:42:00 AM	72.5 mph
39.943962	-82.57235	8:43:00 AM	72.8 mph
39.944876	-82.59471	8:44:00 AM	72.1 mph
39.945792	-82.61608	8:45:00 AM	72.7 mph
39.946793	-82.63804	8:46:00 AM	72.7 mph
39.947832	-82.66083	8:47:00 AM	0.0 mph

Table 8: Electronic logging device (ELD) data from the Volvo combination covering the final eight minutes of vehicle movement.

[19] Commercial carrier was identified by OSHP as G.A. Wintzer & Son, Co. (also see NTSB Motor Carrier Factual Report)

[20] An indeterminate latency exists between the vehicle's change in speed and the data displayed in the video.

4.4.3 Freightliner Combination ELD Data

A printed document reporting certain location, speed and time data accompanied the information received from the carrier. While the file was titled telematics, the data is characteristic of an ELD record. The record contained five lines of data that included date, time, location, mileage, speed, and vehicle unit number. The data samples began at 07:49 a.m. and were reported at intervals from 11 to 17 minutes. The earliest three samples reported a vehicle speed of 0 mph and change in mileage of 0.3 miles. At 08:32 a.m. the reported vehicle speed was 71.6 mph with the location identified as I-70. The final data sample 16 minutes later at 08:48 am recorded a vehicle speed of 0 mph with a location of I-70.

Additional ELD data was later acquired by OSHP investigators. That data provided additional intervals at times ranging from one to five minutes. **Table 9** conveys the additional data samples acquired between 07:49 a.m. and 08:48 a.m.

Time (hh:mm:ss)	Odometer (miles)	Speed (mph)	Tachometer (rpm)	Distance Between Samples (miles)	Change in Speed (mph)
8:17:00	529873.1	0	552		
8:18:00	529873.2	38.6	1507	0.1	38.6
8:20:00	529875.5	66	1243	2.3	27.4
8:22:00	529877.4	74	1393	1.9	8
8:25:00	529881.7	75.2	1412	4.3	1.2
8:30:00	529887.9	64.6	1215	6.2	-10.6
8:32:00	529889.8	71.6	1201	1.9	7
8:33:00	529891.1	62.8	1182	1.3	-8.8
8:34:00	529891.8	74.6	1400	0.7	11.8
8:34:00	529892.5	66.9	1255	0.7	-7.7
8:35:00	529893.1	73.6	1388	0.6	6.7
8:36:00	529893.8	74.1	1396	0.7	0.5
8:41:00	529900.1	74.5	1398	6.3	0.4
8:43:00	529902.9	64.2	1210	2.8	-10.3
8:44:00	529903.5	71.5	1344	0.6	7.3
8:46:00	529906.3	74.7	1405	2.8	3.2
8:48:00	529908.1	0	566	1.8	-74.7

Table 9: Freightliner ELD data. Note that the last two columns represent changes in the succeeding data samples and are not part of the actual ELD record.

4.4.4 Other Vehicle Forward-Facing Video

OSHP investigators also acquired were three consecutive, one-minute-long forward-facing exterior view video segments acquire from another commercial vehicle that was trailing the involved vehicles at an undetermined, but considerable distance.[21] Embedded in the video imagery was the display of additional data that included date, time, vehicle speed and highway speed limit. The time stamp at the beginning of the segment displays 08:47:30 with a vehicle speed of 74 mph. The vehicle is traveling in the right lane with other traffic, including a combination vehicle ahead of it. As depicted in the imagery, the vehicle is approaching the TR-152 overpass. At a time stamp of 08:47:50, the vehicle is passing beneath the TR-152 overpass and begins to transition to the left lane. The indicated speed at this time is 73 mph and black smoke can be seen further ahead adjacent to the right roadside. The vehicle continues to slow to a creep, with a complete cessation of movement about 08:48:44. The imagery depicts the Freightliner combination on the right shoulder with smoke and flames rising from the front and right side of the vehicle. The Toyota can also be seen straddling the two travel lanes. The successive video imagery depicts the spread of fire along the right side of the Freightliner combination.

4.4.5 Ohio Department of Transportation Traffic Camera

As noted in the NTSB *Highway Factors Group Chair Factual Report*, the Ohio Department of Transportation provided the NTSB with about three hours of video imagery covering I-70 near the SR-310 interchange. The pole-mounted camera was positioned along the westbound right roadside on the west side of the SR-310 overpass.

While the camera video was not directed toward the area of the collision at the time it occurred, the footage was useful for discerning visual changes in traffic density and flow beginning about one hour and 47 minutes before the crash.

Table 10 provides a summary of the image orientation and observations relative to the imagery time stamp and the approximate time of the crash.[22]

[21] Commercial carrier was identified by OSHP as GLM Transport, Inc.
[22] In addition to roadway imagery, data including date, time, direction, compass heading, and location (I-70 at SR-310) were overlaid on the video.

Table 10: Summary of visual observation from Ohio Department of Transportation highway traffic video imagery.

Indicated Time[1]	Time Difference Relative to Crash Event[2]	Observation
06:59:58	01:47:00	Begin recording: Westward view – traffic flowing, volume increasing with time
07:27:24	01:20:00	Camera view redirected to eastward view
07:42:34	01:04:00	Camera view redirected to westward view
07:50:00	00:57:00	Traffic slowed to camera location at SR-310
08:12:42	00:34:00	Redirected to eastward view. Slowed traffic extending eastward of SR-310
08:27:52	00:19:00	Redirected to westward view. Left lane more fluid, heavy traffic merging from SR-310
08:53:46	+00:07:00 (after)	Redirected eastward, crash had already occurred
09:59:59	+01:13:00	End recording provided

[1] As displayed in recording (HH:MM:SS)
[2] Rounded to nearest minute

E. DOCKET MATERIAL

LIST OF ATTACHMENTS

Technical Reconstruction Attachment – Motorcoach Garmin Positional Data

Submitted by:
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