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

TECHNICAL RECONSTRUCTION GROUP CHAIRMAN'S FACTUAL REPORT

A. CRASH INFORMATION

Location:	4600 block of North State Route 25 in Rochester, Fulton County, Indiana
Vehicle 1:	2017 Toyota Tacoma pick-up truck
Operator:	Private Operator
Pedestrian #1:	6-year-old male
Pedestrian #2:	9-year-old female
Pedestrian #3:	6-year-old male
Pedestrian #4:	11-year-old male
Date:	October 30, 2018
Time:	Approximately 7:12 a.m. EDT
NTSB #:	**HWY19MH003**

B. TECHNICAL RECONSTRUCTION GROUP

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

C. CRASH SUMMARY

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

D. DETAILS OF THE TECHNICAL RECONSTRUCTION INVESTIGATION

The Technical Reconstruction Group for this investigation was convened after NTSB Office of Highway Safety investigators initiated an investigation of this crash and determined that data acquired during the investigation could benefit from additional analysis. The portion of the

investigation undertaken by the Technical Reconstruction Group was limited to analyzing data that was received from the Indiana Department of Transportation (INDOT), Indiana State Police (ISP), Fulton County Sheriff's Office (FCSO) and NTSB investigators.

1. Introduction, Data Sources, Collision Site and Highway Description

The collision occurred October 30, 2018, at approximately 7:12 a.m. EDT, during darkness in clear weather with dry road surface conditions. The crash involved a single vehicle, a 2017 Toyota Tacoma pickup truck, that collided with four juvenile pedestrians as they attempted to cross Indiana State Route 25 (SR-25) to board an awaiting school bus. The collision occurred at an entrance to a mobile home court where the pedestrians resided. The investigation revealed that the Toyota, traveling southbound, failed to stop for an opposing (northbound) school bus that was stationary with its warning lights activated awaiting the children. The four children, who were grouped while crossing the highway, were struck in the southbound lane adjacent the front of the school bus.

The collision area was at the intersection of an access road to the mobile home park, identified by sources as the Riverview Mobile Home Court, located on the northwest side of SR-25 about 4.6 miles north-northeast of the city of Rochester in Fulton County, Indiana. The highway had a posted speed limit of 55 miles per hour.

1.1. Data Sources

Data used by the Technical Reconstruction Group included material received from Indiana Department of Transportation (INDOT), Indiana State Police (ISP), Fulton County Sheriff's Office (FCSO) and other NTSB investigators. ISP provided the NTSB with site documentation data consisting of a limited number of sUAS aerial images along with other site measurements.[1] ISP also provided a copy of Crash Data Retrieval report that contained collision-related event data recovered from the Toyota's airbag control module. Additional on-scene photographs were provided by FCSO investigators. In addition to other information, INDOT provided highway design plans and survey plans from a pavement resurfacing project covering the crash area.

1.2. Basic Highway Site Description

SR-25 through the area of the collision is a north-south two-lane highway with a posted speed limit of 55 miles per hour. The collision occurred along a 960-foot tangent segment of highway, about 70 feet north of the southern end. The tangent exhibited a west-southwest to east-northeast orientation. The area of impact between the Toyota and the pedestrians was identified as about midway across the southbound travel lane near the southern edge of the middle of three paved access roadways for the mobile home court. In the Toyota's direction of travel the area of impact was about 890 feet into the tangent segment. The three access roadways intersected SR-25 from the west (north side relative to the highway heading at this location) at right angles. The distances between the southern and northern access roadways relative to the middle access roadway were approximately 412 and 252 feet respectively.

[1] sUAS – "small unmanned aircraft system" as defined by 14 CFR Part 107. Also commonly referred to as a "drone".

The through lanes of travel were approximately 12 feet wide with a cross slope of 2%. Paved shoulder areas about two feet wide with an additional two-foot of aggregate material were contiguous with the travel lanes. Double yellow line pavement striping separated the opposing travel lanes while solid white line pavement striping separated the travel lanes from the shoulder area. The pavement surface was dry, and free of deficiencies and contaminants.

The collision occurred at about 7:12 a.m. EDT during darkness, about 61 minutes before sunrise and 29 minutes before civil twilight.[2] The highway approach to and through the collision area had no street lighting or other sources of supplemental roadway lighting.

1.3. Highway Alignment and Collision Location Approach

The highway exhibits curves at the northern and southern approaches to the tangent segment. Northward from the tangent segment, the first curve was approximately 890 feet from the collision site and began a transition of the highway toward a more north-south heading. This would be a rightward curve for the Toyota traveling southbound toward the collision site. This curve exhibits a radius of approximately 1,910 feet over a distance of about 544 feet with a heading change of 16.3°. Northward of this curve is a tangent segment approximately 730 feet in length.

Approximately 2,164 feet northward of the collision area a second curve begins. This curve continues the highway transition to a more north-south heading, making it also a rightward curve for the southbound Toyota. This curve exhibits a radius of approximately 1,432 feet over a distance of about 710 feet with a heading change of 28.4°. A lengthy tangent segment follows this curve with the highway exhibiting a northeast-southwest heading. The southbound Toyota would have entered the first of the two curves about 2,874 feet before the area of impact.

South of the collision, the area of impact was located about 70 feet north of a curve transitioning the highway to a more southerly heading. This curve has a radius of approximately 1,520 feet over a distance of 703 feet with a heading change of 26.4°. In the southbound direction of travel, this would be a leftward curve. Following this curve southward is a tangent segment approximately 673 feet in length. Another leftward curve followed this tangent segment.

1.4. Highway Signage

Curve warning signs (W1-2) preceded each curve indicating the change in direction in advance of the curve. No additional advisories were posted with the curve warning signs at the time of the crash along the southbound roadway.

Along the southbound approach to the collision area a WATCH FOR SCHOOL BUS warning sign (S3-2) was installed about 868 feet before the collision area. This sign was identified as “oversized” by INDOT thereby increasing its dimensions to 36 inches by 36 inches. This is a diamond-shaped sign featured black lettered text on a yellow background. The sign was located adjacent the right shoulder and approximately 22 feet into the highway tangent.

[2] Civil twilight represents the period preceding sunrise when the sun is about six degrees below the horizon but during which there is sufficient natural light to engage in typical outdoor activities without artificial lighting.

A SCHOOL BUS STOP AHEAD warning sign (S3-1) was installed about 9,706 feet north of the collision area. This was also a diamond-shaped sign with black lettering on a yellow background.

In the southbound direction the nearest speed limit sign was located about 2.46 miles before the collision site, just south of the town of Talma.

1.5. Highway Sightline

At the request of NTSB on-scene investigators, INDOT personnel conducted a static line of sight measurement from the area of the collision northward. INDOT reported that as a six-foot tall subject stood in the center of the northbound lane adjacent to the collision site, an approaching southbound observer was able to "see" the subject at a distance of 1,233 feet. The observation was conducted during daylight hours with the observer aware of the purpose for the observation.

The unobstructed sightline measurement provided by INDOT was consistent with measurements acquired from a scaled diagram based on highway plans and collision site measurements. Using this methodology, the unobstructed line of sight for a southbound driver, positioned approximately three feet inward of the centerline, was estimated at 1,185 feet. This line of sight estimation was restricted to the inside face of the adjacent guard rail, although a clear zone area was available on the backside. In principle this sightline presented an unobstructed view of the left front of the stopped school bus without having to look through the clear zone.

As conveyed by on-scene NTSB investigators, as the pedestrians awaited the arrival of the school bus, they stood along the access roadway off the highway behind a fence line that paralleled the highway. The fence was setback approximately 26 feet from the pavement edge. The pedestrians reportedly stood further behind the fence line which also effectively placed several mobile homes within their northward line of sight and would block their view of the highway in that direction. While the width of the clear zone between the fence line and highway pavement was about 26 feet along most of the tangent segment, an area of dense foliage occupied a location along the fence line about 80 feet north of the access road. As this foliage extended toward the highway from the fence line, the clear zone decreased to about 13 feet. Considering these limitations, the unobstructed northward sightline from the access roadway at the fence line could have been as short as about 265 feet.[3] The line of sight would steadily improve as the observers (pedestrians) moved toward the roadway.

2. Scene Documentation

The crash site was documented by ISP investigators who provided the NTSB with sUAS photographs and a series of measurements but no identification of possible roadway evidence. The sUAS images were rendered in a commercial software package to generate a 3D point cloud from which additional measurements could be acquired.[4] While the individual aerial images depicted greater coverage of the highway adjacent to the mobile home court, the rendered point cloud

[3] An unobstructed line of sight does not consider that light sources, such as approaching vehicle headlamps, could be visible through the foliage.
[4] A total of 84 out of 89 images provided were successfully rendered into a point cloud using Pix4D® software.

effectively covered about 225 to 280 feet of the highway south and north of the area of impact respectively.

A total of 26 ground-level photographs taken around the area of impact were acquired from ISP and FCSO investigators. The ground level photographs were taken while fire and emergency medical services personnel worked on-scene while the sUAS photographs were taken later in morning after sunrise with the scene still secured by law enforcement. At the time they were taken, the ground-level photographs depicted the roof-top red warning lights and stop signal arm on the school bus in operation.

2.1. Scene Evidence and Vehicle Position

The Technical Reconstruction Group utilized the sUAS imagery and subsequent point cloud rendering to identify vehicle positions and possible roadway evidence. The school bus had apparently been secured at its stopped position when the collision occurred. The post-impact positions of the Toyota and pedestrians (other than the injured pedestrian) had likewise been secured or otherwise marked when the images were taken.

The school bus was positioned approximately centered within the northbound lane with the front bumper an estimated 11.5 feet south of the access road centerline but still within the flared portion of the access road pavement curb radii. The Toyota pickup was positioned approximately 170.6 feet south of the school bus as measured from their respective front bumpers. At final rest the Toyota was positioned off the right side of the southbound travel lane with its right (passenger) side wheels off the pavement. The left (driver) side wheels remained on the pavement with the front wheel atop the edge line and the rear wheel just to the right of the edge line.

While the photographs depicted the presence of debris and tire friction marks on the road surface, the point cloud rendering lacked sufficient density to identify these features (additional photographs with greater overlap were required). As a consequence, detailed measurements could not be made. Imagery did depict multiple tire friction marks about the area of the intersection with many clearly unrelated to this crash. Within the southbound lane beginning near the center of the intersecting access road, a tire friction mark exhibiting characteristics of vertical loading was observed. The mark appeared to be just to the right (toward the road edge) of the lane center and exhibited a slight angular heading toward the southbound pavement edge. The mark terminated across from the trailing edge of the left front fender on the school bus. The appearance of pavement discoloration characteristic of material scuffing was observed trailing southward from the tire friction mark and terminated adjacent to the bus driver's seating position. Measurements in the approximated area estimated the tire mark length at about 12 feet and the area of material scuffing at about five feet.

White sheeting material in the sUAS images depicted the positions of rest for the three deceased pedestrians. Two were located near the center of the southbound lane about 45.6 feet southward from the front bumper of the school bus. The third pedestrian was located on the southbound right roadside about 8.5 feet from the pavement edge line and 78.8 feet south of the front bumper of the school bus. As described by NTSB investigators, the location of the fourth pedestrian following the collision was off the right side of the southbound travel lane an estimated 130 feet from the front bumper of the school bus.

Figure 1 depicts a scaled post-collision diagram based on available data. The location of the fourth (injured) pedestrian is approximated.

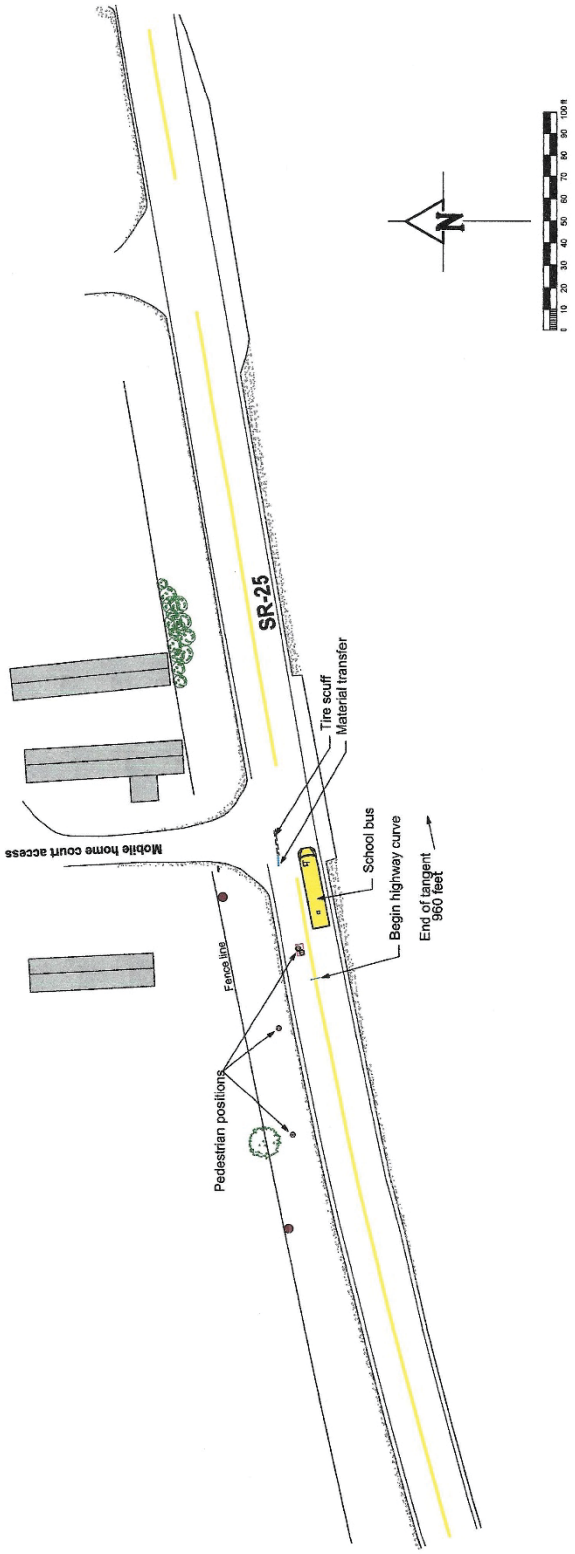

Figure 1: Post-collision site diagram depicting post-collision positions of the school bus, Toyota pickup truck and four pedestrians.

3. Vehicle Damage Documentation

Examination and documentation of the Toyota and resulting collision damage was undertaken by the NTSB Vehicle Factors Group. Examination of photographs depicted contact damage to the front of the vehicle beginning toward the right (passenger side) of centerline and extending outward to the left front fender leading edge. In the photographs, the grill and most of the front bumper cover were missing. The leading edge of the hood was displaced rearward and exhibited evidence of contact deformation. Likewise, the leading edge of the left front fender was displaced rearward.

Additional vehicle dimensional data was acquired for analysis and is summarized in **Table 1**.

Table 1: Toyota Tacoma select vehicle specifications

2017 Toyota Tacoma	
TRD 4X4 double cab	
Overall length	212.3 inches
Overall width	74.4 inches
Wheelbase	127.4 inches
Front overhang	37 inches
Normal height top front bumper	25 inches
Normal height center headlamps	40 inches
Normal height hood leading edge	45 inches
Overall height	71 inches

The school bus was identified as a 2015 Thomas Built Saf-T-Liner C2, Type-C school bus. Built on a Freightliner chassis, this bus had a seating capacity of 72 plus the driver. There was no evidence of contact with the bus during the collision.

Additional dimensional data for the vehicle is summarized in **Table 2**.

Table 2: Thomas Built school bus select vehicle specifications

2015 Thomas Built Buses	
Saf-T-Liner C2	
Overall length	449.7 inches
Overall width	94 inches
Wheelbase	258.9 inches
Front overhang	41.4 inches
Normal height center headlamps	40 inches (estimated)
Normal height center roof warning lamps	109 inches (estimated)
Overall height	123 inches

4. Electronic Event Data

The Toyota was equipped with pyrotechnically deployed supplemental occupant restraints that included frontal, knee, side (seat) and side-curtain airbags and seat belt pretensioners.[5] Deployment or activation of these supplemental restraints devices is commanded by the airbag control module (ACM) based on a programmed algorithm. In the event of a deployment command, or certain non-deployment events where the command algorithm has enabled, certain data can be recorded. The recording of certain "event" data defines a capability of the ACM as an *Event Data Recorder* (EDR). The EDR functionality of the Toyota ACM is compatible with the requirements of 49 Code of Federal Regulations Part 563.[6]

The ACM type installed in the Toyota was a 13EDR that had the capability to store crash data for multiple events such as two front or rear impacts, two side impacts and two rollover events, although pre-crash data is limited to two events (identified as most recent event and first prior event). The requirements for establishing an event differ depending on event type. An event record includes crash data related to activation of the supplemental restraint system and pre-deployment vehicle performance data that are recorded in discrete intervals, although the data may be asynchronous. The term "Time Zero" is the point where the restraint control algorithm was activated in any sensing direction, while the term "Trigger" references the command signal to deploy a supplemental restraint. In a frontal collision, time zero typically occurs at the first point where a longitudinal cumulative change in velocity of over 0.8 km/h (0.5 mph) is reached.

Pre-deployment, or pre-crash data is reported for five seconds at ½-second intervals extending back from the point where the restraint control algorithm was activated. Pre-crash data include certain vehicle performance parameters. Crash data includes parameters such as deployment timing, longitudinal change in velocity (Δv) and lateral acceleration as related to time zero in 10ms intervals for up to 250ms. The end of an event is typically the moment at which the cumulative Δv within a 20ms time period does not change by more than 0.8 km/h (0.5 mph) or the moment at which the crash detection algorithm of the ACM resets. Some events may lead to the recording of data over different durations as provided for by 49 CFR Part 563.

For this vehicle, the ACM data was retrieved by ISP investigators using the Bosch Crash Data Retrieval (CDR) system, version 17.4. As the data was downloaded from the vehicle it was simultaneously interpreted by the CDR software and output in a .pdf format. The data reported a total of 3,204 ignition cycles at the time of data download with no recorded diagnostic trouble codes. The record freeze signal was active indicating that non-volatile memory could not be overwritten or deleted by the ACM.

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[5] Side airbags deployed from the outboard edge of the front seat seatback. Side curtain or curtain shield airbags deployed along the inside roof rail covering front and rear side windows.

[6] In summary, 49 CFR Part 563 defines an Event Data Recorder as 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., delta–V vs. time), intended for retrieval after the crash event. This regulation defines the minimum data set that must be collected if a manufacturer decides to voluntarily install an EDR in their vehicle, along with requirements for the range and accuracy of the data. Part 563 is applicable to vehicles manufactured after September 1, 2010 and applies to vehicle with a GVWR of 8,500 pounds or less.

4.1. Crash data

The ACM download report depicted one event, the "most recent event", with multiple supplemental systems deployed that could be related to this collision. The report recorded deployment of the driver side frontal and knee airbags, seat belt pretensioner, side airbag and side-curtain airbag. On the passenger side, the side and side-curtain airbags recorded a deployment. Neither the seat belt pretensioner nor frontal airbag were reported as having deployed on the passenger side. The status of the multiple airbag deployments was corroborated by photographs. Deployment for all the devices, except the driver side-curtain airbag, was triggered 53ms after time zero or algorithm activation. The driver side-curtain airbag deployment command occurred 103ms after time zero. The front passenger safety belt status was reported as "OFF" indicating that the latch and buckle were not engaged, and the occupant size classification sensor indicated "NOT OCCUPIED". The reported safety belt status of the driver was "ON". Given the circumstances of this crash, time zero would have approximated the time of impact but may not reflect the first contact. The time series data or length of the crash pulse, recorded at 10ms intervals, spanned 140ms. The peak change in longitudinal velocity was report as 5.6 miles per hour at 142ms. The reported ignition cycle at the time of deployment event was 3,203.

4.2. Pre-collision data

Pre-crash data reported certain vehicle parameters for up to five seconds before time zero (algorithm active) at ½-second intervals. While the data is reported at discrete ½ second intervals, it may can be received or processed by the ACM asynchronously. Certain pre-crash parameters reported included:

- Vehicle speed – having a resolution 1 km/h (0.6mph) with the value rounded down for reporting.
- Engine RPM - number of engine revolutions per minute with a resolution of 100 rpm with the reported value rounded down. The recorded value has an upper limit of 12,800 rpm.
- Percent accelerator pedal - the percent of full application of the accelerator pedal with a resolution to the nearest one-half of a whole percent and rounded down for reporting.
- Percent of engine throttle - the percent of full application of the engine throttle with a resolution to the nearest one-half of a whole percent and rounded down for reporting.
- Service brake - indicates the status of the brake pedal as reported by the brake lamp switch with the possible values as "On" (switch contact open/pedal moved) and "Off" (switch contact closed).
- Brake oil pressure – reports the brake oil pressure at the master cylinder in megapascal units (Mpa). The upper limit is 12.14 Mpa.
- Longitudinal acceleration – as calculated by data from the vehicle stability control sensor and reported in meters per second^2. The upper and lower limits for the recorded

value are 8.973 m/s^2 and -8.973 m/s^2 respectively. The acceleration sensor does not sense collisions.

- Steer input - the measured rotational angle of the steering wheel between +375 degrees and -375 degrees at a resolution of 1.5 degrees with the value rounded down for reporting.

- Yaw rate – calculated value and reported as degrees per second. Positive values indicate a left turn.

- Cruise control – reported as "ON" or "OFF" to indicate whether or not the system is actuated. "OFF" may also indicate that vehicle is not equipped with the system.

- Shift position – indicates the transmission shift range.

The final pre-crash data were recorded 300ms (0.3 seconds) before module wake-up. From this point the time-series data were reported at ½ second intervals. As conveyed in the report, the vehicle exhibited a relatively constant speed of 58-59 miles per hour beginning approximately 4.8 seconds before deployment. The cruise control was not actuated.

At the reported time of 2.8 seconds before module wake-up, the accelerator pedal and engine throttle percentages substantially decrease. Vehicle speed begins to slightly decrease but remains relatively constant as do other parameters.

Two seconds later at 0.8 seconds before module wake-up, the service brakes are reported as "ON" and brake oil pressure begins to increase. Simultaneously, the accelerator pedal and engine throttle percentages decrease to zero and a rightward steering input is recorded. The reported speed at this time sample was 55.9 mph.

At the reported time of 0.3 seconds before module wake-up, the brake oil pressure is recorded at near maximum and the rightward steering input increases. The vehicle speed has decreased to 48.5 mph.

At time zero, module wake-up, the vehicle speed decreased to 41 mph, the service brake continued to be indicated as "ON" and the rightward steering input decreased. Deployment of the SRS devices began 53ms later.

Table 3 provides a summary of the EDR pre-crash data.

Table 3: Summary of Select Pre-Crash Data from ACM Download Report

Time	4.8	4.3	3.8	3.3	2.8	2.3	1.8	1.3	0.8	0.3	Trigger
Speed MPH	58.4	59	58.4			57.8	57.2	57.2	55.9	48.5	41
Accelerator Percent	22.0	19.0	19.0	17.0	4.0	5.5	6.5	5.0	0.0		
Engine throttle Percent	12.0	10.0			1.0	0.5	1.5	1.5	0.0		
Engine RPM	1500					1400				1100	1000
Service brake	OFF								ON		
Brake oil pressure (Mpa)	0.00								5.47	11.71	9.79
Longitudinal acceleration m/sec^2	-0.144	-0.072	0.072	-0.359	-0.431	-0.502	-0.431	-0.574	-3.374	-7.250	Invalid
Steering input Degrees	3.0	4.5	6.0	7.5		3.0	9.0		-3.0	-18.0	-3.0
Yaw rate Degrees/second	0.00			0.49		-0.49	0.00	0.49	0.00	-5.86	-3.90
Cruise control	OFF										
Shift position	D										

E. REFERENCES

- NTSB Highway Factors Group Factual report
- NTSB Vehicle Factors Group Factual report

F. DOCKET MATERIAL

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

LIST OF ATTACHMENTS

See Vehicle Factors Group docket attachment for Toyota CDR report.

END OF REPORT

Robert J. Squire
Highway Accident Investigator