# Commercial Vehicle
# Onboard Video Systems

## Safety Report

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PB2015-102744

**National**
**Transportation**
**Safety Board**

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# Safety Report

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## Commercial Vehicle Onboard Video Systems

**National**
**Transportation**
**Safety Board**

490 L'Enfant Plaza SW
Washington, DC 20594

**National Transportation Safety Board. 2015.** ***Commercial Vehicle Onboard Video Systems.*** **Safety Report NTSB/SR-15/01. Washington, DC.**

**Abstract:** The National Transportation Safety Board (NTSB) has investigated many highway accidents where onboard video systems recorded critical crash-related information. This safety report discusses two recent crashes where continuous video systems were installed on commercial vehicles. In a 2012 school bus crash in Port St. Lucie, Florida, the video recording system captured all three phases of the crash, including precrash driver and passenger behaviors and vehicle motion; vehicle and occupant motion during the crash; and postcrash events, such as passenger evacuation, short-term injury outcomes, and emergency response. In a 2011 motorcoach crash in Kearney, Nebraska, the video recording system captured critical precrash information but had certain limitations that negated the potential benefits of crash and postcrash event data. This report summarizes the analysis of the onboard video systems from these two crashes in particular. Further, to advance biomechanical and pediatric trauma-based research, it presents the video analysis and subsequent extensive injury documentation from the Port St. Lucie investigation. The NTSB makes recommendations to the National Highway Traffic Safety Administration; to the American Bus Association, United Motorcoach Association, American Trucking Associations, American Public Transportation Association, National Association for Pupil Transportation, National Association of State Directors of Pupil Transportation Services, and National School Transportation Association; and to 15 manufacturers of onboard video systems.

For more detailed background information on this report, visit www.ntsb.gov/investigations/dms/html and search for NTSB accident numbers HWY12FH008 and HWY12FH003. Recent publications are available in their entirety at www.ntsb.gov. Other information about publications may be obtained from the website or by contacting:
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# Contents

# Figures

# Acronyms and Abbreviations

| | |
|---|---|
| AIS | abbreviated injury scale |
| AOI | area of impact |
| CFR | *Code of Federal Regulations* |
| CIREN | Crash Injury Research program (NHTSA) |
| CR | County Road |
| FARS | Fatality Analysis Reporting System (NHTSA) |
| FMCSA | Federal Motor Carrier Safety Administration |
| I | Interstate |
| ICAO | International Civil Aviation Organization |
| ISS | injury severity score |
| LOC | loss of consciousness |
| MAIS | maximum abbreviated injury scale |
| MCI | Motor Coach Industries Inc. |
| NASS | National Automotive Sampling System (NHTSA) |
| NHTSA | National Highway Traffic Safety Administration |
| NTSB | National Transportation Safety Board |
| SCI | Special Crash Investigations system (NHTSA) |
| SR | State Road |
| USC | *United States Code* |
| VHS | video home system |

# Executive Summary

The National Transportation Safety Board (NTSB) has investigated many highway accidents where onboard video systems recorded critical crash-related information. Onboard video systems are ***continuous***, recording uninterrupted audio and video footage while the vehicle ignition is in the “on” position—or ***event-based***, recording for a short time surrounding a triggering event, such as a crash or hard braking. This safety report focuses on commercial vehicle onboard video systems as they relate to the evaluation of both driver and passenger behaviors and collision analysis. We feature two recent crashes where continuous video systems were installed on commercial vehicles:

- ***2012 school bus crash in Port St. Lucie, Florida:*** The video recording system captured all three phases of the crash, including precrash driver and passenger behaviors and vehicle motion; vehicle and occupant motion during the crash; and postcrash events, such as passenger evacuation, short-term injury outcomes, and emergency response.
- ***2011 motorcoach crash in Kearney, Nebraska:*** The video recording system captured critical precrash information but had certain limitations that negated the potential benefits of crash and postcrash event data.

This report summarizes the documentation and analysis of the onboard video systems from these two crashes in particular. We also discuss the benefits of onboard video systems and recommend specific improvements. Further, the video analysis and subsequent extensive injury documentation from the Port St. Lucie investigation are presented to advance biomechanical and pediatric trauma-based research.

The NTSB makes safety recommendations to the National Highway Traffic Safety Administration; to the American Bus Association, United Motorcoach Association, American Trucking Associations, American Public Transportation Association, National Association for Pupil Transportation, National Association of State Directors of Pupil Transportation Services, and National School Transportation Association; and to 15 manufacturers of onboard video systems.

# 1 Introduction

Commercial vehicle onboard video systems can be separated into two categories: continuous and event-based recording systems. Current continuous video systems are capable of recording uninterrupted footage from multiple interior and exterior cameras. Event-based video systems record for a designated time both before and after an event, such as a crash or hard braking. The National Transportation Safety Board has previously recommended the installation of event-based video systems (NTSB 2010).[1] Since that time, however, the market prevalence and quality of continuous video systems have increased substantially.

School districts and bus operators commonly use continuous video systems for increased security, behavior monitoring, operational efficiency, vehicle tracking, and real-time vehicle diagnostics (Gissendaner 2014). These systems started with simple video home system (VHS)-based recordings in the mid-1990s and have now advanced to digital, solid-state, high-definition, wireless multicamera systems. Seon Design Inc.—the largest provider of continuous video systems—estimates that more than 150,000 of its systems are installed in school buses in North America.[2,3] Continuous video systems are installed in some motorcoaches and transit buses, as well.

This safety report focuses on two recent crashes involving large buses with continuous video systems—Port St. Lucie, Florida, and Kearney, Nebraska—and also reviews other NTSB investigations where the data recorded from both continuous and event-based systems were of value in the investigative process. The objectives of the report are to highlight the strengths of onboard video systems in capturing precrash, crash, and postcrash information and also to address system limitations. To complement the detailed video evaluation, we describe the extensive injury documentation from the Port St. Lucie crash (NTSB 2013) to assist researchers in advancing the biomechanical and pediatric trauma-based work initiated during that investigation.

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[1] Safety Recommendations H-10-10 and -11 to the Federal Motor Carrier Safety Administration are currently classified "Open—Unacceptable Response."

[2] Personal communication, K. Poland, NTSB, with L. Jetha, Seon Design Inc., June 23, 2014.

[3] The American School Bus Council estimates that 480,000 school buses are currently operating in the United States. See www.americanschoolbuscouncil.org/issues/environmental-benefits, accessed September 19, 2014.

# 2 Crash Narratives

In both the Port St. Lucie, Florida, and Kearney, Nebraska, crashes, the commercial vehicles were equipped with continuous video systems. The Port St. Lucie school bus crash was unique in that the videos captured an extremely severe side impact crash involving lap-belted school children and contained valuable data about precrash, crash, and postcrash events. The Kearney motorcoach video system captured critical precrash information but had certain limitations in visibility and data capture for crash and postcrash events.

## 2.1 Port St. Lucie, Florida, School Bus Crash

On March 26, 2012, about 3:45 p.m., a 1998 Peterbilt truck-tractor semitrailer traveling eastbound on Okeechobee Road (State Road [SR]-70) at 63 mph struck a westbound school bus preparing to turn off SR-70, resulting in a severe lateral impact collision.[4] The school bus—which was operated by the St. Lucie County School District—was occupied by the driver and 30 elementary school students. The bus was equipped with lap belts at all passenger seating positions. The truck-tractor in combination with a flatbed semitrailer was loaded with sod and occupied by the driver only. At this location, Okeechobee Road was configured as a divided four-lane highway with a speed limit of 55 mph.

The school bus driver had entered a left-turn-only lane to travel across the center median and eastbound lanes onto Midway Road (County Road [CR]-712). The bus driver turned in front of the eastbound truck, which collided with the right side of the bus in the vicinity of the rear axle (figure 1). Following the impact, the school bus spun clockwise approximately 180 degrees and came to rest facing Okeechobee Road (figure 2). The truck departed the roadway onto the grassy right-of-way along the southeast side of the intersection and rolled to the left, coming to rest on its left side, with the trailer resting upside down (figure 3). As a result of the crash, one student on the bus was fatally injured. Eight students were seriously injured, 11 sustained minor injuries, and 10 were uninjured. The bus driver also sustained minor injuries. The operator of the combination vehicle refused medical treatment.

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[4] See the NTSB public docket for Port St. Lucie, Florida (HWY12FH008). The Port St. Lucie crash is discussed in the Chesterfield, New Jersey, highway accident report (NTSB 2013), section 1.13.

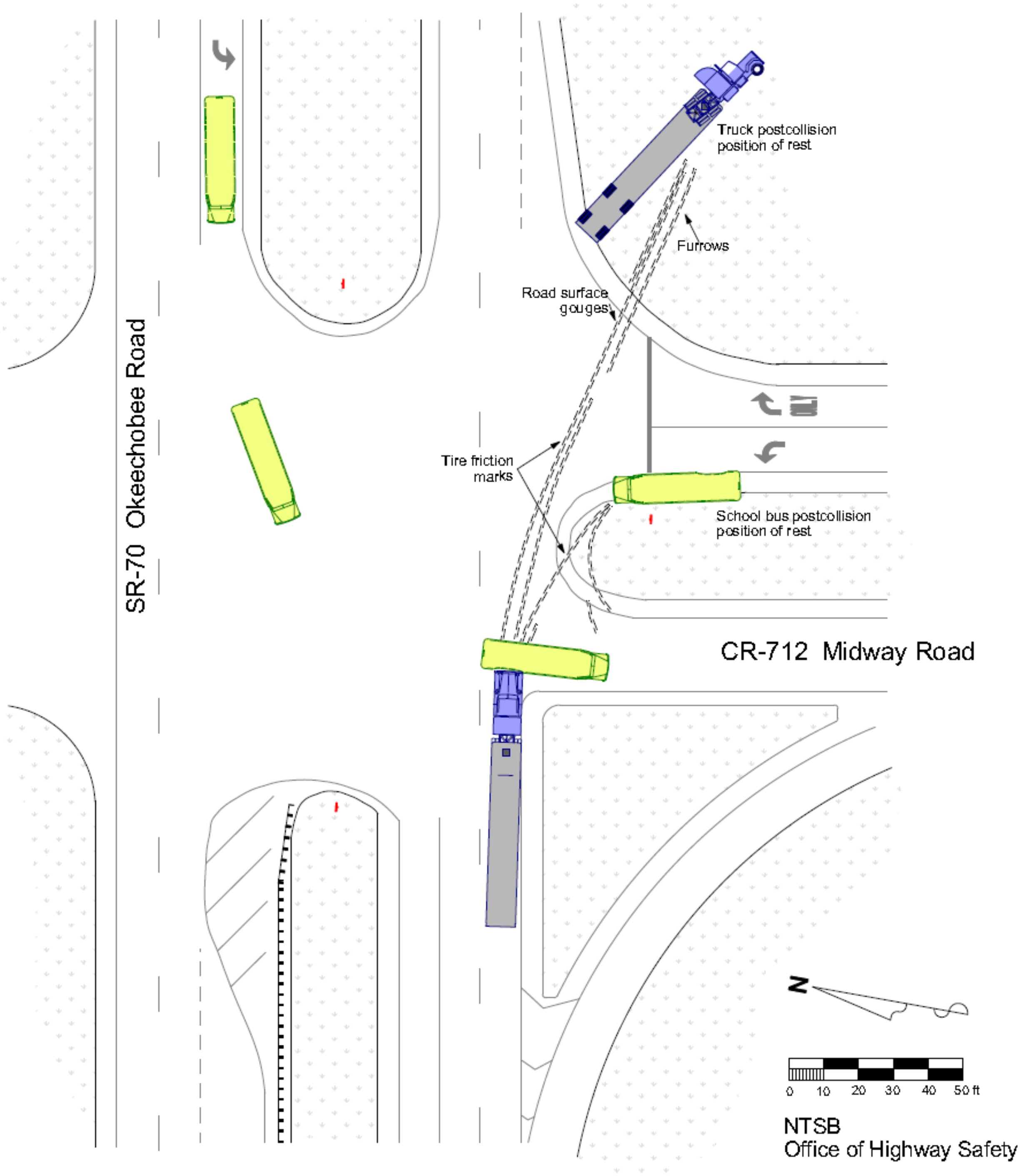

**Figure 1.** Port St. Lucie crash scene diagram based on accident reconstruction diagram provided by Florida Highway Patrol.

**Figure 2.** School bus, postcrash, at SR-70–CR-712 intersection, March 26, 2012. (Source: Florida Highway Patrol)

**Figure 3.** Truck-tractor semitrailer, postcrash, at SR-70–CR-712 intersection, March 26, 2012. (Source: Florida Highway Patrol)

The school bus was equipped with a continuous audio and video system manufactured by Seon Design Inc. The system had four active cameras, which recorded at 15 frames per second. A total of 55 minutes 39 seconds was recorded on each of the four interior video files.[5] The videos began prior to the loading of the school children and continued through the bus trip to the point of the collision and after. The 15 minutes of video recorded postimpact included vehicle motion; occupant motion; and postcrash events capturing short-term injury outcomes, passenger egress, and the initial response of passersby and emergency medical personnel.

## 2.2 Kearney, Nebraska, Motorcoach Crash

A three-event crash began about 2:00 a.m. on October 6, 2011, when the driver of a 2011 Volvo truck-tractor semitrailer combination unit was traveling westbound on Interstate 80 (I-80), near Kearney, and drifted off the roadway into the median.[6] As the driver attempted to re-enter the westbound travel lanes, he overcorrected and the vehicle rolled 90 degrees onto its left (driver) side and came to rest across both westbound lanes of the interstate, with the undercarriage, wheels, and landing gear of the overturned semitrailer oriented toward oncoming traffic.[7]

A short time later, two westbound commercial vehicles—a 1998 Kenworth truck-tractor semitrailer combination unit and a 2012 Motor Coach Industries Inc. (MCI) D4505 motorcoach operated by Burlington Trailways—came upon the overturned Volvo combination unit. The Kenworth truck was traveling in the right lane, and the MCI motorcoach had moved into the left lane to pass the truck. Shortly thereafter, the truck moved onto the right shoulder, sideswiping the Volvo's front bumper, and it then came to rest in the north ditch of the westbound lanes. After braking, the motorcoach collided with the overturned Volvo's semitrailer between the rear frame and the landing gear, separating it into two sections, and came to rest in the median (figure 4). The motorcoach had extensive front-end intrusion and deformation damage, as shown in figure 5.

The motorcoach, occupied by the driver and 35 passengers, had departed from Omaha, Nebraska, and was en route to Denver, Colorado. It was equipped with lap/shoulder belts at all passenger seating positions. As a result of the crash, the motorcoach driver and three passengers were seriously injured. Twenty-three motorcoach passengers and the driver of the Volvo truck received minor injuries, and nine motorcoach passengers and the driver of the Kenworth truck were uninjured.

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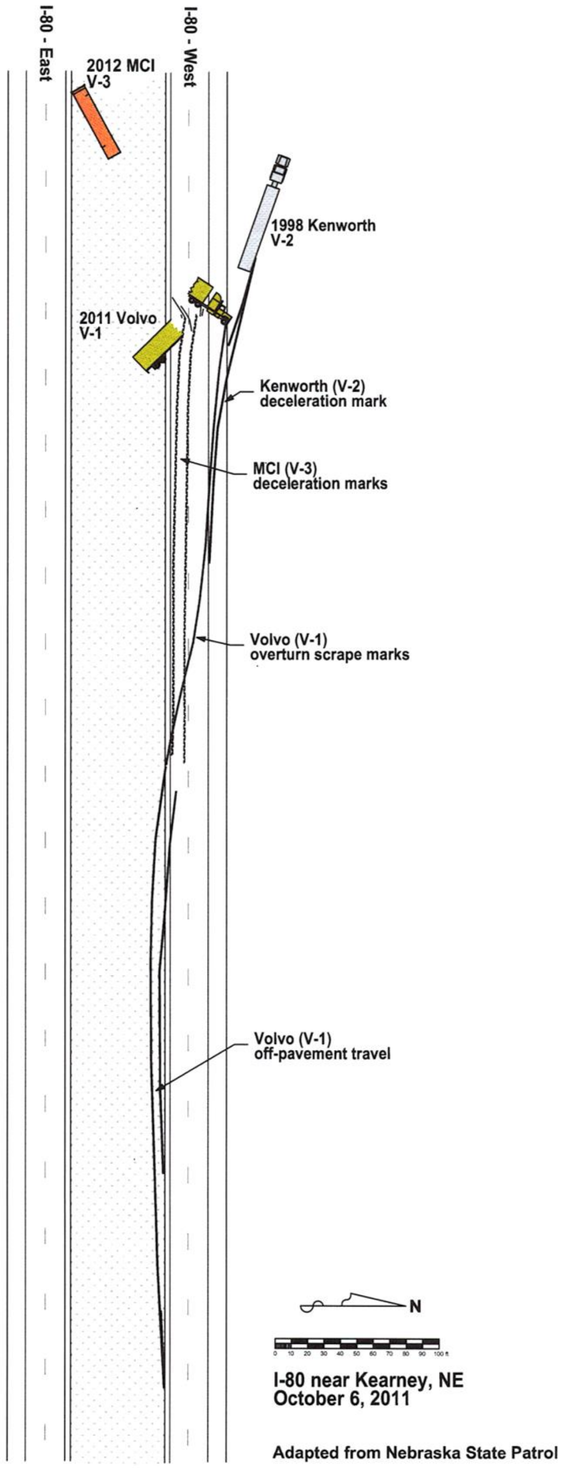
[5] Digital video recording systems can record for weeks, depending on the number of cameras and the selected system settings.

[6] See the NTSB public docket for Kearney, Nebraska (HWY12FH003).

[7] Landing gear, or legs, can be raised or lowered to support the trailer when it is not coupled to a tractor.



Adapted from Nebraska State Patrol

**Figure 4.** Kearney crash scene diagram depicting vehicle dynamics (adapted from Nebraska State Patrol diagram).

**Figure 5.** Burlington Trailways MCI motorcoach postcrash. (Source: Nebraska State Patrol)

The motorcoach was equipped with a continuous audio and video system manufactured by Safety Vision LLC.[8] The system had four active cameras, which each recorded a total of 30 minutes 44 seconds. The recordings began prior to the bus departure and continued through the bus trip to a point immediately prior to the collision. Due to impact damage, data were not recorded during or after the crash.

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[8] The system was purchased through a grant from the US Department of Homeland Security under the Over-the-Road Bus Security Assistance Program, as authorized by Section 1532 of Public Law 110-53 (the Implementing Recommendations of the 9/11 Commission Act of 2007), 6 *United States Code* (USC) 1182, with funds made available in the Department of Homeland Security Appropriations Act, 2010 (Public Law 111-83). The program provided funding to protect both private operators of over-the-road bus transportation and the traveling public from terrorism. One allowable cost under the program was the installation of cameras and video surveillance equipment on over-the-road buses.

# 3 Commercial Vehicle Onboard Video Systems

## 3.1 History

The original commercial vehicle onboard video systems were continuous systems installed on school buses using interior roof-mounted camcorders with super 8-millimeter film. Because the cameras were expensive and cumbersome, every bus was equipped with a housing box, but camcorders were placed only in specific buses to record either driver or passenger behavior. In the mid-1990s, single camera systems with a separate VHS-based recording system were used in school buses to monitor student behavior. In the early 2000s, event-based systems emerged for a variety of commercial vehicles, focusing on safe driving feedback programs. These systems are commonly referred to as video event recorders. Since September 11, 2001, onboard video systems have also been recognized in the United States as a means of enhancing commercial vehicle security (Paul 2004).

The two types of onboard video systems—continuous and event-based—have distinct features. Continuous video systems start recording when the vehicle ignition is turned on and typically record for a programmed period ranging from 1 to 60 minutes after the ignition is turned off. These systems may capture video data surrounding an event, such as a crash, but—because they record continuously—they also capture data that a triggered system may not record. Currently available continuous video systems advertise frame rates from 10 to 60 frames per second, depending on the number of cameras. The long duration of continuous recording limits frame rate capabilities, though recent advances in camera and hard-drive technology are quickly improving these systems. Higher frame rates enhance the analysis of events that happen rapidly, such as collisions.

Event-based video systems capture and save recorded data when an event such as a crash or hard braking triggers the system.[9] A recording period usually captures 15–30 seconds prior to the event and ends 30–60 seconds after the event. Less than 2 minutes of data is typically recorded for each triggered event. The video frame rate varies depending on the storage capability of the system and the video settings. Today, event-based systems are often used in conjunction with driver feedback programs to increase safe operations.

Commercial vehicle onboard video systems are installed for multiple purposes, including driver monitoring, passenger monitoring (especially to address bullying and security), and vehicle safety. Greyhound Lines Inc. was an early adopter of onboard video systems. In petitioning the Federal Motor Carrier Safety Administration (FMCSA) for an exemption to mount the video recorder on the lower windshield, Greyhound described three safety benefits of onboard video systems: identification and remediation of risky driving behaviors, such as distracted driving and drowsiness; enhanced monitoring of passenger behavior; and enhanced

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[9] The event trigger is usually based on measured vehicle acceleration with a set point above the normal operating environment.

collision review and analysis.[10] These safety benefits highlight the advantages of onboard video systems.

### 3.1.1 Driver Behavior

Fleet operators increasingly use video recorder technology to monitor their drivers. These video systems serve as a proactive tool to identify and reduce risky driving behavior, such as speeding, distracted driving, or drowsy driving.

In January 2013, Greyhound announced implementation of the DriveCam driver risk management and fleet management system, an event-based onboard video system installed across its entire fleet of buses.[11,12] Greyhound described the system as combining data and video analytics with real-time driver feedback and coaching to identify behavioral improvement opportunities for increased safety and to improve fuel efficiency and reduce emissions.

A recent study by the Virginia Tech Transportation Institute assessed the effectiveness of DriveCam when equipped on heavy trucks and buses (Soccolich and Hickman 2014). The study examined 10,648 crashes involving heavy trucks and buses from the National Highway Traffic Safety Administration General Estimates System (NHTSA 2011) from 2010 to 2012. The DriveCam event-based video system, combined with the driver behavior modification system, accounted for estimated reductions in fatal and injury crashes of 20 percent and 35 percent, respectively. Although the quantitative model used to derive these estimates has limitations, the results illustrate the significant potential benefit of commercial vehicle onboard video systems.[13]

### 3.1.2 Passenger Behavior

Advancements in technology have made it easier and less expensive to install onboard video systems incorporating multiple cameras and an expanded field of view that records not only the actions of the driver but also those of the passengers. School bus and motorcoach operators increasingly use continuous video systems as a tool for tracking the behavior of passengers, providing a means of increasing security and limiting liability. School buses often use video recordings to account for which students have boarded or exited the bus, and for compliance and enforcement of rules. In addition, *School Transportation News* has reported that, combined with a comprehensive training program, onboard cameras can improve seat belt usage rates and student behavior (Metea 2014b).

Continuous video systems were recently used in a 3-year pilot study to assess the effects of lap/shoulder seat belt installation in school buses. To follow up on a school bus crash that occurred in Huntsville, Alabama, in 2006, the Alabama State Department of Education provided

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[10] See 74 *Federal Register* 11807–11808, March 19, 2009.

[11] In November 2013, DriveCam Inc. changed its company name to Lytx Inc.

[12] See www.greyhound.com/en/newsroom/viewrelease.aspx?id=519&year=2013, accessed July 9, 2014.

[13] The study used sample crash data to represent the large truck and bus population, accident type was used as a surrogate measure of fault, proper and full use of the program was assumed, and vehicles that may have had the system installed were not screened out.

allocations to 10 participating local school systems to purchase 12 new buses equipped with lap/shoulder belts (Turner and others 2010; NTSB 2009b). Four interior roof-mounted video cameras were installed on each of the 12 buses to evaluate passenger behavior, including belt use compliance, appropriate belt fit, passenger discipline, and driver response.

The study—conducted by the University Transportation Center for Alabama—revealed considerable variability in seat belt usage, with an average usage rate of 61.5 percent over the 3-year period. Usage rates were higher for elementary-aged students and higher on afternoon routes than on morning routes. Specifically, the study found that driver behaviors, such as consistently encouraging seat belt use, resulted in increased seat belt usage among occupants. Onboard video systems were viewed as an aid to the driver, as a second set of "eyes on the bus" for disciplinary purposes—especially given the high seatbacks required for lap/shoulder belt installation, which can reduce the driver's ability to see passengers.

### 3.1.3 Collision Review and Analysis

In addition to the benefits of documenting both driver and passenger behaviors, onboard video systems provide crash-related data. The NTSB commonly uses both continuous and event-based video systems in crash investigations.

In January 2008 near Mexican Hat, Utah, a motorcoach equipped with a DriveCam II event-based video system ran off the road and overturned (NTSB 2009a). The recorded data were used to determine the speed of the motorcoach and to confirm that its headlights were on at the time of the evening crash. The video, recorded at four frames per second, also provided the basis for evaluations of the driver and passengers, such as verifying that the driver was not using a cell phone and examining both driver and passenger actions in the moments leading up to the roadway departure. Although the DriveCam II system recorded only 20 seconds surrounding the crash event, the recorded data were critical to the investigation.

The investigation of a truck-tractor semitrailer rear-end collision into passenger vehicles on I-44 near Miami, Oklahoma, resulted in the NTSB issuing two recommendations (Safety Recommendations H-10-10 and -11) to the FMCSA concerning event-based video systems in commercial vehicles weighing over 10,000 pounds (NTSB 2010). The objective of these two recommendations was to monitor and modify risky driver behaviors and to improve investigative data collection.

Although event-based video systems are designed to record data surrounding a triggered event, such as a crash or a hard brake, continuous video systems can also record nontriggered crash-related information prior to the crash event and even information from prior trips. A continuous video system provided critical data in the investigation of a March 2000 collision between a school bus and a freight train in Conasauga, Tennessee (NTSB 2001). School bus drivers are required to stop, look, and listen at all passive grade crossings. The 1999 accident school bus was equipped with one of the first continuous video systems available.[14] The onboard

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[14] The continuous video system on the accident bus was a Silent Witness model SW210. The single camera was mounted on the interior roof at the front and center of the bus and pointed down the length of the passenger compartment.

video showed that the school bus driver had disregarded safety procedures and crossed the tracks without stopping on the day of the crash and on at least eight previous occasions. One aspect of the resulting NTSB recommendation to the states (Safety Recommendation H-01-45) was to periodically review onboard videotapes, especially with regard to driver performance at grade crossings.

More recently, the NTSB (2011) investigated a multivehicle crash that occurred in Gray Summit, Missouri, involving two school buses, a truck-tractor, and a pickup truck. In this case, the continuous video system on the school bus that had been following the lead school bus provided information essential to the analysis of precollision events. Using the video, NTSB investigators were able to determine:

- The speed of the GMC pickup truck involved in the crash approximately 1 minute prior to the school bus collision.

- The speed of the following bus (and also to infer the speed of the lead school bus).

- When the driver of the following school bus began to take evasive action.

As a result of this investigation, the NTSB reiterated and reclassified the event-based video recorder recommendations (H-10-10 and -11) from the Miami, Oklahoma, report (NTSB 2010).

The vehicles in the Port St. Lucie and Kearney accidents were equipped with continuous video systems that provided considerable precrash information, as discussed in sections 3.2 and 3.3. The Port St. Lucie video system documented precrash, crash, and postcrash data; the Kearney system stopped recording immediately before impact.

## 3.2 Port St. Lucie Crash

The Port St. Lucie continuous video system captured useful data prior to, during, and after the crash. The Seon Design system consisted of four separate video cameras that recorded at 15 frames per second, positioned as described below:

- The first camera was oriented toward the passenger loading door and provided a view looking out the loading door, to the right side of the windshield, and to the first passenger side window. The camera also provided a view of the steering wheel and a portion of the driver’s upper body from behind. Although not forward-facing, this camera provided exterior views.

- The second camera provided a view of the interior of the school bus, showing seat rows 1 through 4 in detail.

- The third camera showed a portion of row 5 on the passenger side of the bus up to a small portion of row 10 on the passenger side, and rows 7 through 9 on the driver side of the bus.

- The fourth camera, mounted on the interior roof in the back of the bus, showed the tops of the seatbacks starting at row 9 and looking forward, including rows 9 through 6 in detail.

Figure 6 provides a close-up view of the interior Seon camera located at the back of the school bus. Figure 7 shows the positions of the three cameras located at the front of the bus. The four cameras collectively provided data on driver actions; the environment outside the bus (primarily from the first camera); and the interior environment, including passenger movements (primarily from the second, third, and fourth cameras).

**Figure 6.** Seon Design interior roof-mounted camera lens in Port St. Lucie school bus.

**Figure 7.** Interior of Port St. Lucie school bus, postcrash, showing locations of three Seon Design interior roof-mounted cameras (circled in red).

### 3.2.1 Precrash Driver and Passenger Behaviors

The continuous video system on the Port St. Lucie school bus provided data to confirm that the driver was not distracted by a cell phone or other portable electronic device and that he had both hands on the steering wheel during the left turn maneuver just prior to the collision. In addition, it was apparent that the driver perceived the impact threat, though too late, because he turned his head toward the oncoming truck. The onboard videos and associated audio recordings showed that the driver encouraged seat belt use at the beginning of the trip and that he did not appear to be distracted by students just prior to the collision.

The video recording system also yielded information on passenger behavior. The continuous recordings documented student loading onto the bus, the use of seat belts for most students (some views were partially obscured, including the seating position of the fatally injured student), and occupant positions throughout the bus trip. These data helped investigators establish an accurate seating chart, preimpact positions, and the level of restraint for most of the passengers. Precrash video and audio documentation showed that the driver's attentiveness to passenger safety and seat belt rules was a factor in the number of students who properly wore and adjusted their seat belts.

### 3.2.2 Collision Review and Analysis

The most beneficial data obtained from the Port St. Lucie onboard video system were related to the crash sequence and the postcrash environment. The four interior cameras remained in place and functional throughout the crash event and continued recording for more than 15 minutes after the initial impact.

**3.2.2.1 Vehicle Dynamics.** Although the school bus was not equipped with a forward-facing camera, the available videos provided valuable information concerning vehicle dynamics both prior to and during the crash. Analysis of the videos allowed investigators to determine the speed and the position of the school bus prior to the collision. The position, orientation, and speed of the bus throughout the crash sequence were derived through the evaluation of street markings, light changes (and shadows), and other visual reference points.[15]

**3.2.2.2 Occupant Kinematics.** Occupant kinematics—or occupant motion—was documented throughout the entire crash event for each occupant who was visible on one or more of the interior videos. Because of the extensive amount of occupant kinematics captured, the NTSB worked with a team of outside experts to document the content of the videos and to ensure that the data were both accessible and useful to the research community.[16] The resulting factual report documents unique information on preimpact occupant positions, occupant-to-vehicle and

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[15] See the video study, which documents the motion of the bus, in the NTSB public docket for this crash (HWY12FH008).

[16] The outside experts were Richard Kent, PhD, from the University of Virginia; and Kristy Arbogast, PhD, and Mark Zonfrillo, MD, both from the Children's Hospital of Philadelphia.

occupant-to-occupant impacts during the crash, flailing characteristics and ranges, rebound severities, and occupant final rest positions.[17]

The continuous video system offered the first such documentation of lap-belted children involved in a severe side impact collision. The videos further highlight differences in occupant kinematics across a range of collision severity, which were evident when contrasting occupant motion in the front of the bus with occupant motion in the back of the bus. Because of the length of the school bus and the center of rotation at the front axle, the crash was much more severe for rear-seated occupants than for those seated in the front of the bus. The NTSB concludes that the continuous video system in the Port St. Lucie school bus provided valuable kinematics data on the complexity and duration of motion for occupants involved in a severe collision.

**3.2.2.3 Postcrash Environment.** After the school bus came to final rest, the videos documented many of the occupants evacuating from the front loading door. One passenger seated in the back of the bus evacuated from the front after being directed forward by an adult passerby who had entered the bus through the rear emergency exit. The videos provided comprehensive documentation of the school bus evacuation—including paths taken, time to evacuate, and interaction with adults who boarded the bus after the crash. Appendix A provides additional details on the occupant evacuation.

Many passengers in the rear of the bus lost consciousness during the crash. Some regained consciousness during the 15 minutes recorded postimpact and were able to evacuate the bus either alone or with assistance. Others either partially or fully regained consciousness but remained on the bus at the time the recording ended. (See appendix B for a summary of passenger loss of consciousness [LOC].)

Because of the positioning of the cameras, neither the kinematics nor the final rest position of the fatally injured passenger was visible during the crash event or when the bus came to final rest. Observations of other bus occupants and the responding passersby provided limited information about this passenger. The NTSB concludes that though the continuous video system in the Port St. Lucie school bus documented critical postcrash information regarding passenger evacuation and LOC, it provided inadequate visibility of all passenger seating positions.

## 3.3 Kearney Crash

The Kearney accident motorcoach was equipped with a Safety Vision continuous video system that included four cameras, as follows:

- The first camera was a forward-facing camera located at the front of the motorcoach.
- The second camera was focused on the passenger loading door.

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[17] See the school bus video documentation group factual report in the NTSB public docket for this crash (HWY12FH008).

- The third and fourth cameras were mounted to the interior roof, with the third located near the front of the motorcoach and the fourth positioned midway in the motorcoach.

### 3.3.1 Precrash Driver and Passenger Behaviors

Although the motorcoach driver was not visible in any of the cameras, her actions could be inferred from the vehicle motion captured by the forward-facing camera. Images captured by the three other cameras—though intended to show the passengers inside the bus—were of extremely limited value. All three cameras were poorly aligned or rotated sideways such that only a very small portion of the passenger space was visible. Moreover, because the bus lights were off and the video system lacked the capability to "see" (record useful images) in low-light conditions, the recording provided no precrash occupant position or restraint use information for the majority of the passengers.[18] The NTSB concludes that improper camera positions and the lack of low-light recording capabilities on the Kearney motorcoach resulted in inadequate capture of occupant precrash position and restraint usage video data.

Improper camera positions may occur during installation or over the lifetime of use and may not be limited to the Safety Vision system. Many other manufacturers supply similar onboard video systems. Both original and subsequent vehicle owners would benefit from having information on how to properly install and maintain onboard video systems; however, few manufacturers make such information publicly available.

Therefore, the NTSB recommends that AngelTrax Bus Video, Apollo Video Technology, Eye3Data, Fortress Systems International Inc., Idrive Inc., Lytx Inc. (DriveCam), MobilEye Inc., Planet Halo Inc., Pro-Vision Video Systems, Radio Engineering Industries Inc., Rosco Vision Systems, Safety Vision LLC, Seon Design Inc., SmartDrive Systems Inc., and 247 Security Inc. develop written guidance for the initial installation and long-term maintenance of onboard video systems, and publish that guidance on their websites and in future owner's manuals.

### 3.3.2 Collision Review and Analysis

The forward-facing camera on the Kearney motorcoach provided critical precrash information on the relative positions of the involved vehicles and some information about the sequence of events. This video recording showed the following:

- Roadway scrape marks from the first event, when the Volvo truck overturned.
- Lighting conditions of the overturned Volvo as seen from the approaching motorcoach.
- Initial position of the motorcoach behind the Kenworth truck.
- Motorcoach movement into the left lane to pass the Kenworth truck.

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[18] Some video systems record useful images even in low-light situations. For example, the DriveCam II system in the Mexican Hat, Utah, motorcoach yielded useful video images, despite dark conditions (NTSB 2009a).

- Kenworth truck initial motion toward the right shoulder.

However, the camera did not record vehicle dynamics data during the crash or the motion to final rest because the continuous video system was partially damaged as a result of the collision. Additionally, occupant kinematics during the crash sequence could not be evaluated because the interior video system lacked the capability of "seeing" in low-light conditions, and the recording ended prior to the collision.

Although higher video frame rates typically improve the visibility of rapidly changing events, such as vehicle dynamics or occupant motion during a collision, they can negatively affect visibility in low-light conditions. Thus, there is a need for video system manufacturers to optimize the balance between a higher frame rate and low-light visibility.

The NTSB is aware that some school districts in the United States have already installed—or will soon install—continuous video systems on every school bus in their fleets.[19] Onboard video systems are also becoming more prevalent on transit buses, as well as on many other heavy commercial vehicles. These systems have had a direct benefit in the Port St. Lucie, Kearney, Conasauga (NTSB 2001), Mexican Hat (NTSB 2009a), and Gray Summit (NTSB 2011) accident investigations, especially regarding driver and passenger behaviors. Proactive use of this recorded information can result in long-term safety benefits.

The NTSB concludes that onboard video systems, both continuous and event-based, can provide valuable information for evaluating the circumstances leading to a crash, as well as critical vehicle dynamics and occupant kinematics data for assessing crash survivability. The NTSB recommends that the American Bus Association, United Motorcoach Association, American Trucking Associations, American Public Transportation Association, National Association for Pupil Transportation, National Association of State Directors of Pupil Transportation Services, and National School Transportation Association encourage their members to ensure that any onboard video system in their vehicles provides visibility of the driver and of each occupant seating location, visibility forward of the vehicle, optimized frame rate, and low-light recording capability.[20]

Recent research highlights the potential safety benefits of onboard video systems. For example, the FMCSA has conducted field operational tests of driver behavior monitoring using event-based video systems (Hickman and Hanowski 2010). The study results showed a significant reduction in safety-related events with the monitoring system, which combined the video recording with a driver feedback program.[21] Continuing this effort, the FMCSA is currently conducting field operational tests of event-based video systems in conjunction with

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[19] For example, school districts in Buffalo, New York, and Palm Beach County, Florida, have committed to installing onboard camera systems in their entire bus fleets (Metea 2014a; 2014b).

[20] Many commercial vehicles are not passenger-carrying operations. However, interior visibility of the occupants—including the driver and possibly a front seat passenger, occupant actions, and occupant kinematics—is critical to understanding all phases of a crash.

[21] The program included driver counseling by safety managers, who coached drivers as necessary concerning the behaviors that may have caused or led to a safety-related event. The safety manager used the recorded video and other associated information to identify specific driver actions and coach the driver accordingly.

intelligent transportation systems, such as collision avoidance technologies, lane departure warning, drowsy driving detection, and driver feedback.

To date, the FMCSA has focused its research efforts on event-based video systems as they relate to commercial driver performance. As documented in this safety report, however, the NTSB continues to see benefits with both continuous and event-based video systems. As a result, the NTSB concludes that both continuous and event-based onboard video systems, along with a driver feedback program, may provide a long-term safety benefit for equipped vehicles.

The NTSB developed an article summarizing the main issues of this safety report for use by the associations receiving the above recommendation. In addition, we issued a safety alert on commercial vehicle onboard video systems and tips for improving their utility, which is provided in appendix C.

# 4 Occupant Injury

## 4.1 Port St. Lucie Data

The Port St. Lucie crash investigation generated valuable and extremely detailed information about school bus occupant kinematics, seat belt use, and restraint performance, as addressed in section 3.2 of this report and in the report on the Chesterfield, New Jersey, school bus and truck collision (NTSB 2013). The complexity of the Port St. Lucie crash—coupled with the presence and use of passenger lap belts and the video recordings—prompted the NTSB to work with researchers at the Children's Hospital of Philadelphia and the University of Virginia in documenting the injuries, occupant kinematics, evacuation information, and LOC duration in a manner conducive to facilitating future pediatric trauma research. One of the technical experts coded the injuries using the abbreviated injury scale (AIS) and the injury severity score (ISS).[22,23]

Figure 8 shows the Port St. Lucie seating chart developed from the onboard video recordings. Injuries are marked in both the traditional International Civil Aviation Organization (ICAO) code and the comprehensive AIS.[24] Appendix D summarizes the Port St. Lucie occupant injury documentation.

To document the traumatic impact injuries and outcomes, the video documentation report includes occupant positioning, kinematics and interactions with other occupants and the vehicle interior, evacuation, and LOC duration for passengers in a range of seating positions.[25] (See appendixes A and B for additional occupant evacuation and LOC information, respectively.) The additional detailed passenger injury data developed through AIS and ISS coding, in combination with the recorded passenger kinematics and behavior response, established novel data for the pediatric injury research and biomechanics communities. Moreover, the documentation of head injury—including the source of trauma, short- and long-term injury outcomes, and state of consciousness—is a unique data set for impact injury to the brain.

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[22] The AIS was developed by a joint committee, led by the Association for the Advancement of Automotive Medicine. The scale is an anatomically based, consensus-derived global severity scoring system that classifies each injury by body region according to its relative importance on a 6-point ordinal scale (1=minor and 6=maximal). It is the basis for the ISS calculation for the patient with multiple injuries. See www.aaam.org/about-ais.html, accessed September 2, 2014.

[23] The ISS is calculated by squaring the AIS score of the three most severely injured body regions and adding those squared values. For each body region, only the highest AIS score is used.

[24] The ICAO code uses the same injury classifications as the 49 *Code of Federal Regulations* (CFR) 830.2 injury categories of uninjured, minor, serious, or fatal.

[25] See the school bus video documentation group factual report in the NTSB public docket for this crash (HWY12FH008).

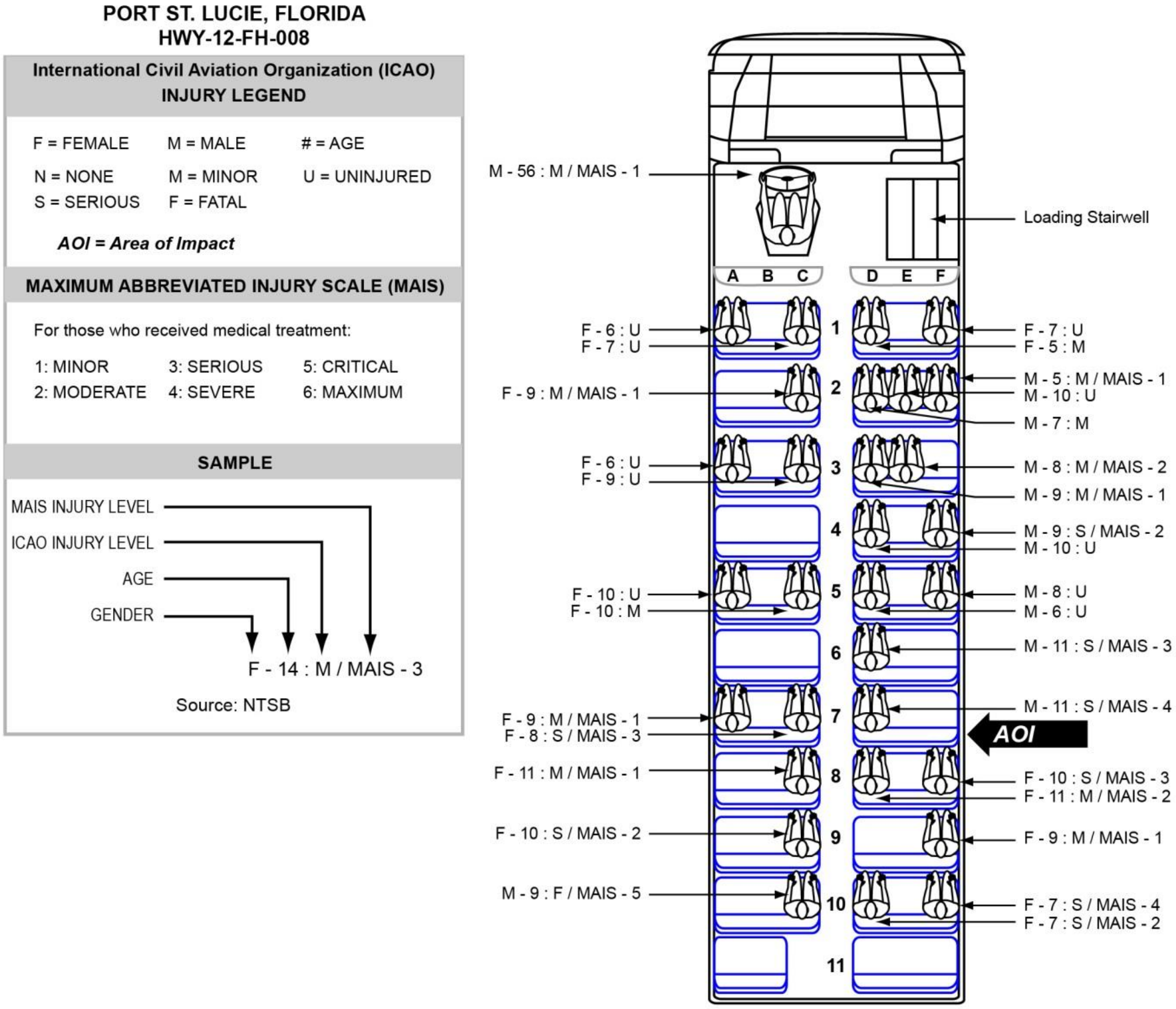

**Figure 8.** Port St. Lucie school bus passenger seating chart, with ICAO injury level, MAIS injury level, and demographic information.

Because of the length of the school bus and its rotation postimpact, occupant injuries vary according to the seating locations within the bus. The NTSB used video analysis software to quantitatively document the motion of the heads and pelvises of several occupants who were visible during the crash sequence, in addition to qualitatively describing the occupant kinematics throughout the event. As expected, based on the vehicle dynamics causing the bus to rotate approximately 180 degrees, head velocities and accelerations were greater for occupants seated toward the back of the bus than for those seated in the front. Pelvic velocities and accelerations were also higher toward the back of the bus, but lap belts provided pelvic restraint and reduced overall lower body motion.

The continuous video system on the Port St. Lucie school bus provided unique data on restrained passenger kinematics, occupant-to-occupant interactions, occupant-to-interior contacts, short-term injury outcomes, and sequencing of emergency response. Schools buses, motorcoaches, transit buses, and large trucks provide a particularly beneficial environment for video recordings, which can provide invaluable information about pediatric and adult trauma in a crash. The continued investigation of crashes with video recordings is essential to improve bus occupant protection and also to increase our knowledge of biomechanics, injury causation, and short- and long-term injury outcomes. Ultimately, this knowledge will lead to improvements in the lifelike quality of crash test dummies.

For example, the detailed head injury documentation in the Port St. Lucie investigation quantifies actual occupant motion and head contact with the school bus interior—data which are not possible to collect by traditional research. Such documentation can be coupled with existing biomechanical data to help researchers understand when certain crash forces result in traumatic head injuries to children. Further, in some cases, the video recordings documented movement of the body through large ranges of motion without injury. Such ranges of motion are beyond the physical capability of current crash test dummies, and forces causing this movement would likely be assessed as injurious. Using these data, the lifelike quality of pediatric crash test dummies can be improved, as can computer simulations that strive to use more realistic models of human beings. The NTSB concludes that the use of continuous video systems data from school buses—including occupant kinematics, restraint usage and design, and detailed injury documentation—can serve as the foundation for a multidisciplinary approach to improving transportation safety.

Furthermore, the NTSB concludes that collecting and documenting onboard video recordings, including crash information; developing the information into a useable form; and distributing these critical data are essential to the process of improving occupant protection systems. To support improvements in design, installation, maintenance, and management—and to encourage the proper use of existing lap and lap/shoulder belts in large buses—these data should include the nature and severity of injuries and the crash circumstances in which occupants were injured.

## 4.2 NHTSA Crash Data

NHTSA currently collects and maintains a large amount of real-world data concerning motor vehicle crashes, including some school bus crashes, in an effort to meet its mission of saving lives and preventing injuries. To document traffic crash data on a nationally representative scale, NHTSA uses eight primary database systems—which encompass a combination of census, sample-based, and state data files (NHTSA 2010).[26]

Since 1975, NHTSA has collected data on 1 million motor vehicle fatalities through the Fatality Analysis Reporting System (FARS). Another system, the Special Crash Investigations (SCI) program, focuses on special crash circumstances or outcomes from an engineering perspective. SCI staff often investigate school bus crashes in which the vehicles were equipped with new technology. In 2012, NHTSA initiated a review of a third system, the National

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[26] These databases consist of the Fatality Analysis Reporting System (FARS), the National Automotive Sampling System (NASS) General Estimates System, the NASS Crashworthiness Data System, the National Motor Vehicle Crash Causation Survey, the Special Crash Investigations (SCI) program, the Crash Injury Research (CIREN) program, the State Data System, and the Crash Outcome Data Evaluation System.

Automotive Sampling System (NASS), by requesting input from users on the utility of the collected data, on the electronic formats for crash data available to the public, and on improving data collection methods and quality control procedures (NHTSA 2012). A goal of the NASS modernization effort is to collect data in support of emerging technologies and evolving policy needs; this new data collection will begin in 2016. The other five databases focus on motor vehicle fatalities, injuries, and property-damage-only crashes. Much of the detailed crash and injury information (including photographs of accident scenes and vehicles) in all of the database systems is available to the public through NHTSA's electronic data system.

Although these motor vehicle crash databases are extremely valuable both to NHTSA and to the safety community at large, many aspects of each crash are still unknown. In the Crash Injury Research (CIREN) program, for example, teams of experts use forensics to collectively evaluate and decide how injuries may have been caused and the likely source of injury. The team then assigns a probable level of certainty to each injury and source.

The continuous video system from the Port St. Lucie crash investigation provided visibility of the event as it was happening and eliminated the need for the forensics work traditionally required to quantify occupant motion and document injury causation. In the videos, initial positions, trajectories, and full occupant motion were quantified relative to the vehicle interior. Contacts between individual occupants and between occupants and the surrounding interior were visible, and these contacts could be directly correlated to sustained injuries or, in some cases, to the lack of injury. The video evaluation revealed many of the traditionally unknown aspects of vehicle motion, occupant motion, and injury causation. If maintained on a larger scale, such video evidence would provide a wealth of recorded crash and injury data to the safety community.

NHTSA is the primary source for real-world motor vehicle crash data in the United States, but it currently does not have a method to collect and store video or rules to permit access to video recordings. For the benefit of these recordings to be realized by the safety community, NHTSA should address their sensitivity and privacy concerns. Therefore, the NTSB recommends that NHTSA incorporate into its existing crash database systems, with appropriate access controls, standardized procedures for collecting and using pertinent video recordings, injury information, and crash data from video-equipped buses, consistent with privacy regulations and policies.

# 5 Conclusions

1. The continuous video system in the Port St. Lucie school bus provided valuable kinematics data on the complexity and duration of motion for occupants involved in a severe collision.

2. Although the continuous video system in the Port St. Lucie school bus documented critical postcrash information regarding passenger evacuation and loss of consciousness, it provided inadequate visibility of all passenger seating positions.

3. Improper camera positions and the lack of low-light recording capabilities on the Kearney motorcoach resulted in inadequate capture of occupant precrash position and restraint usage video data.

4. Onboard video systems, both continuous and event-based, can provide valuable information for evaluating the circumstances leading to a crash, as well as critical vehicle dynamics and occupant kinematics data for assessing crash survivability.

5. Both continuous and event-based onboard video systems, along with a driver feedback program, may provide a long-term safety benefit for equipped vehicles.

6. The use of continuous video systems data from school buses—including occupant kinematics, restraint usage and design, and detailed injury documentation—can serve as the foundation for a multidisciplinary approach to improving transportation safety.

7. Collecting and documenting onboard video recordings, including crash information; developing the information into a useable form; and distributing these critical data are essential to the process of improving occupant protection systems.

# 6 Recommendations

The National Transportation Safety Board makes the following new safety recommendations.

**To the National Highway Traffic Safety Administration**:

> Incorporate into your existing crash database systems, with appropriate access controls, standardized procedures for collecting and using pertinent video recordings, injury information, and crash data from video-equipped buses, consistent with privacy regulations and policies. (H-15-1)

**To the American Bus Association, United Motorcoach Association, American Trucking Associations, American Public Transportation Association, National Association for Pupil Transportation, National Association of State Directors of Pupil Transportation Services, and National School Transportation Association**:

> Encourage your members to ensure that any onboard video system in their vehicles provides visibility of the driver and of each occupant seating location, visibility forward of the vehicle, optimized frame rate, and low-light recording capability. (H-15-2)

**To AngelTrax Bus Video, Apollo Video Technology, Eye3Data, Fortress Systems International Inc., Idrive Inc., Lytx Inc. (DriveCam), MobilEye Inc., Planet Halo Inc., Pro-Vision Video Systems, Radio Engineering Industries Inc., Rosco Vision Systems, Safety Vision LLC, Seon Design Inc., SmartDrive Systems Inc., and 247 Security Inc.:**

> Develop written guidance for the initial installation and long-term maintenance of onboard video systems, and publish that guidance on your websites and in future owner's manuals. (H-15-3)

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**Adopted: March 3, 2015**

# Appendix A: Occupant Evacuation Summary

The Port St. Lucie, Florida, onboard video recordings included additional information on the evacuation of the school bus. Some occupants were able to evacuate, some were assisted off the bus, and others remained on the bus at the end of the video recording—which occurred about 15 minutes after the bus came to final rest. Table A-1 shows the times taken to evacuate the Port St. Lucie bus and the evacuation locations. (See also figure 8, school bus passenger seating chart, in the main report.) The evacuation times are measured from when the bus reached its final rest position until the occupants exited the bus. Occupants in seats 8C, 8D, 9C, and 10D were evacuated from the bus with assistance. Occupants in seats 3E, 6D, 7C, 7D, 8F, 10C, and 10F are not represented below because they remained on the bus at the end of the video recording.

**Table A-1.** Evacuation times and locations from Port St. Lucie school bus by occupant.

| Occupant | Time (sec) | Location |
|---|---|---|
| 10D | 20 | Rear emergency exit |
| 1D | 30 | Front loading door |
| 1F | 32 | Front loading door |
| 1A | 34 | Front loading door |
| 1C | 35 | Front loading door |
| 5A | 35 | Front loading door |
| 3D | 36 | Front loading door |
| 5C | 37 | Front loading door |
| 4D | 38 | Front loading door |
| 2C | 39 | Front loading door |
| 3C | 40 | Front loading door |
| 3A | 42 | Front loading door |
| 2D | 45 | Front loading door |
| 5D | 46 | Front loading door |
| 5F | 47 | Front loading door |
| 4F | 48 | Front loading door |
| 2E | 50 | Front loading door |
| 2F | 54 | Front loading door |
| 9F | 60 | Front loading door |
| 9C | 113 | Rear emergency exit |
| 8D | 135 | Rear emergency exit |
| 7A | 179 | Front loading door |
| 8C | 206 | Rear emergency exit |

# Appendix B: Loss of Consciousness Summary

The video recordings from the Port St. Lucie, Florida, investigation contained a large amount of postcrash data, including the state of consciousness of school bus occupants. Most occupants were largely visible after the bus reached its final rest position. Table B-1 summarizes the loss of consciousness (LOC) of each occupant and the confidence of that evaluation based on observations and visibility of the occupant's final rest position in the videos. In addition, for occupants with a possibility of LOC, the first visible voluntary motion is documented. Only a brief summary is provided in this report to highlight data from the video recordings. Details on visible voluntary motions, interactions with responders, and associated times are documented in the school bus video documentation group factual report.[27]

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[27] See the NTSB public docket for this crash (HWY12FH008).

**Table B-1.** Occupant loss of consciousness as indicated by Port St. Lucie video postcrash.

| Occupant | Loss of Consciousness, Confidence[a] | Time of Visible Voluntary Movement (hr:min:sec) |
|---|---|---|
| 1A, 1C, 1D, 1F | No, certain | Not applicable |
| 2C, 2D, 2E, 2F | No, certain | Not applicable |
| 3A, 3C, 3D | No, certain | Not applicable |
| 3E | Yes, probable | 15:55:23 |
| 4D, 4F | No, certain | Not applicable |
| 5A, 5C, 5D, 5F | No, certain | Not applicable |
| 6D | Yes, certain | 16:09:24 |
| 7A | No, possible | 15:55:18 |
| 7C | Yes, certain | 16:01:24 |
| 7D | Yes, probable | 15:56:01 |
| 8C | No, probable | 15:55:16 |
| 8D | Yes, certain | 15:57:02 |
| 8F | Yes, probable | 15:57:15 |
| 9C | Unknown | 15:55:27 |
| 9F | No, certain | Not applicable |
| 10C | Yes, certain | Not applicable, fatality |
| 10D | Unknown[b] | Not visible |
| 10F | Unknown | 16:04:05 |

[a] "Certain," "probable," "possible," and "unknown" are the four terms used to classify the confidence of the group members in assessing LOC. "Certain" indicates clear evidence that LOC occurred or did not occur. "Probable" indicates that LOC likely occurred or likely did not occur, but that either the visibility of the occupant was limited or the camera view was not clear. "Possible" indicates that LOC may have occurred or may not have occurred, but there was no clear evidence to prove the state. "Unknown" indicates that the occupant was not visible.

[b] Although investigators were unable to visualize state of consciousness on the video, the occupant was noted to have LOC and change in mental status by medical personnel, and was given an abbreviated injury scale diagnosis of concussion with LOC in the injury coding factual report in the NTSB public docket for this crash (HWY12FH008).

# Appendix C: NTSB Safety Alert

See the following two pages.

NTSB
SAFETY ALERT
National Transportation Safety Board

# Commercial Vehicle Onboard Video Systems

## *Tips for Improving the Utility of Onboard Videos*

### *The problem*

Commercial vehicles such as school buses and motorcoaches are equipped with onboard video systems for a variety of reasons. Video systems can be used (1) to monitor passenger behavior and dissuade negative actions, such as bullying or theft; (2) to monitor traffic surrounding the vehicle and assist in recording the observance of traffic laws; and (3) to enhance driver safety through feedback programs that correct potentially unsafe behaviors. The NTSB has also used onboard video systems in its accident investigations.

In some cases, however, commercial vehicle onboard video systems lack the capability to record useful video in certain conditions, or are not properly installed or well maintained. Characteristically, the following shortcomings are common among current video systems:

- No view of what is happening in front of the vehicle.
- No view of all seating positions, including the driver.
- Lack of low-light recording capability (no night vision).
- Low frame rates, such that videos are jumpy or skip over events.
- Poorly positioned cameras.
- Improperly maintained cameras.

### *Selected NTSB accident investigations*

On March 26, 2012, about 3:45 p.m., in Port St. Lucie, Florida, a truck-tractor semitrailer traveling 63 mph on State Road 70 struck a school bus preparing to make a left turn, resulting in a severe lateral impact collision. The bus was occupied by the driver and 30 elementary school students. It was equipped with lap belts at all passenger seating positions and a continuous audio and video system, which recorded useful precrash, crash, and postcrash information. However, of the four camera views, none recorded the one occupant who was fatally injured.

A three-event crash began about 2:00 a.m. on October 6, 2011, in Kearney, Nebraska, when a truck-tractor semitrailer overturned and came to rest across both lanes of

Interstate 80. A short time later, two commercial vehicles—another truck-tractor semitrailer and a motorcoach—came upon the overturned truck. The truck-tractor semitrailer was able to move onto the right shoulder, where its left side sideswiped the overturned truck's front bumper. The motorcoach driver applied the brakes but was unable to avoid colliding with the overturned truck, and the motorcoach came to rest in the median. The motorcoach was equipped with lap/shoulder belts and with a continuous audio and video system, which recorded precrash information from a forward-facing camera. However, due to poorly oriented interior cameras and a lack of low-light recording capability, the system did not capture any information concerning the driver or the motorcoach interior.

## To ensure optimum use of video systems

School districts and bus operators can take the following steps to improve the utility of onboard videos:

- Check to see that current or newly purchased equipment has the following features:
    - ✓ Provides visibility of the driver.
    - ✓ Provides visibility of each occupant seating location.
    - ✓ Provides visibility forward of the vehicle.
    - ✓ Ensures optimized frame rate.
    - ✓ Allows low-light recording capability (night vision).
- Properly install and maintain onboard video systems.

## For more information

On March 3, 2015, the NTSB adopted safety report NTSB/SR-15/01, *Commercial Vehicle Onboard Video Systems*. The report provides additional details on the strengths and limitations of onboard video systems in capturing precrash, crash, and postcrash information; on the Port St. Lucie and Kearney accidents specifically, among other NTSB investigations; and on the kinematics of occupant injury.

# Appendix D: Individual Occupant Injuries

The Port St. Lucie, Florida, school bus passenger injury information was categorized as follows:

- By the International Civil Aviation Organization (ICAO) injury code, which is the same as the 49 *Code of Federal Regulations* (CFR) 830.2 injury categories of uninjured, minor, serious, or fatal.
- By the total injury severity score (ISS), ranging from 0 to 75.

Table D-1 lists individual injuries by ISS body region and abbreviated injury scale (AIS) code for each school bus occupant who received treatment and for the fatally injured occupant.

**Table D-1.** Individual ISS, AIS, and injury descriptions for Port St. Lucie school bus occupants.

| | ISS Body Region | AIS Code | Description |
|---|---|---|---|
| **Driver**<br>**ICAO: minor**<br>**ISS-3** | *Head or neck* | 640278.1 | Cervical spine sprain (whiplash) |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | 640678.1 | Lumbo-sacral spine sprain |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 910000.1 | Soft tissue hemorrhage |
| | | | |
| **Occupant 2C**<br>**ICAO: minor**<br>**ISS-1** | *Head or neck* | None | None |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 410402.1 | Chest wall contusion |
| | | 710402.1 | Upper arm contusion, left |
| | | 710402.1 | Wrist contusion, right |
| | | | |
| **Occupant 2F**<br>**ICAO: minor**<br>**ISS-1** | *Head or neck* | 1000099.9 | Head injury (unspecified) |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 110202.1 | Scalp abrasion, occipital area |
| | | 210402.1 | Forehead hematoma, right middle |
| | | 110402.1 | Scalp contusion |
| | | | |
| **Occupant 3D**<br>**ICAO: minor**<br>**ISS-2** | *Head or neck* | 640278.1 | Cervical spine sprain (whiplash) |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 410402.1 | Chest wall contusion |
| | | | |
| **Occupant 3E**<br>**ICAO: minor**<br>**ISS-6** | *Head or neck* | 161002.2 | Concussion with brief LOC[a] |
| | *Face* | 251404.1 | Teeth fracture |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |

| | | | |
|---|---|---|---|
| | *External* | 810402.1 | Lower leg contusion, right |
| | | 210600.1 | Lip laceration |
| | | 210402.1 | Lip hematoma, upper |
| | | 810202.1 | Leg abrasion, right lower |
| | | 110202.1 | Head abrasions |
| | | 210202.1 | Face abrasions |
| | | | |
| **Occupant 4F<br>ICAO: serious<br>ISS-5** | *Head or neck* | None | None |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | 772410.1 | Wrist (carpal) sprain, left |
| | | 874010.1 | Knee sprain, left |
| | | 852002.2 | Ankle closed fracture, left |
| | | 800099.9 | Hip and thigh injury |
| | | 700099.9 | Elbow/forearm/wrist injury, left |
| | *External* | 210402.1 | Face contusion, right |
| | | 910400.1 | Skin/subcutaneous/muscle contusion, unspecified |
| | | 110402.1 | Scalp contusion |
| | | 210202.1 | Face abrasions |
| | | 210202.1 | Neck contusion |
| | | | |
| **Occupant 6D<br>ICAO: serious<br>ISS-10** | *Head or neck* | 140602.3 | Cerebral contusion, right |
| | | 140602.3 | Cerebral contusion, left temporal lobe |
| | | 140602.3 | Cerebral contusion, left frontal |
| | | 140638.3 | Cerebral hematoma, left |
| | | 140650.3 | Subdural hemorrhage, right frontal |
| | | 140450.3 | Cerebral edema (loss of differentiation) |
| | | 140642.3 | Cerebral shearing injury, left |
| | | 150200.3 | Mastoid fracture, unspecified |
| | | 150402.2 | Skull fracture (nondepressed), right parietal |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 110600.1 | Scalp laceration, right parieto-occipital |
| | | | |
| **Occupant 7A<br>ICAO: minor** | *Head or neck* | 161001.1 | Concussion without LOC |
| | *Face* | None | None |

| | | | |
|---|---|---|---|
| **ISS-2** | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 210202.1 | Forehead abrasion, right |
| | | 210602.1 | Forehead abrasion (superficial), unspecified |
| | | 510202.1 | Abdomen abrasions, left lower |
| | | 510402.1 | Abdomen contusion, left iliac crest |
| | | 910400.1 | Skin/subcutaneous/muscle hematoma (multiple), unspecified |
| | | | |
| **Occupant 7C**<br>**ICAO: serious**<br>**ISS-17** | *Head or neck* | 140694.2 | Cerebral subarachnoid hemorrhage, without coma >6 hours |
| | | 140678.2 | Intraventricular hemorrhage, left |
| | | 140678.2 | Intraventricular hemorrhage, right |
| | *Face* | None | None |
| | *Chest* | 441402.3 | Lung contusion, unspecified |
| | *Abdominal or pelvic contents* | 543800.2 | Retroperitoneum hemorrhage, right |
| | *Extremities or pelvic girdle* | 856151.2 | Pubic fracture, right |
| | *External* | 210202.1 | Face abrasions, unspecified |
| | | | |
| **Occupant 7D**<br>**ICAO: serious**<br>**ISS-29** | *Head or neck* | 161002.2 | Concussion with LOC |
| | | 150206.4 | Basilar skull fracture, right, comminuted |
| | | 150206.4 | Basilar skull fracture, left, comminuted |
| | | 150402.2 | Temporal bone fracture, left |
| | | 131699.2 | Cranial nerve VII palsy, right |
| | | 131499.2 | Cranial nerve VI palsy, right |
| | *Face* | 240499.1 | Eye hematoma, right |
| | *Chest* | 441402.3 | Pulmonary contusions, unspecified |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | 856151.2 | Pelvic ring fracture, anterior iliac spine |
| | *External* | 210402.1 | Face hematoma, unspecified |
| | | 810402.1 | Abdomen/pelvic hematoma, right |
| | | 810402.1 | Pelvic abrasions, anterior |
| | | 710202.1 | Forearm abrasion, left |
| | | 210600.1 | Ear laceration, right |
| | | | |
| **Occupant 8C**<br>**ICAO: minor**<br>**ISS-2** | *Head or neck* | None | None |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | 545699.1 | Labia (vulva) abrasion, bilateral |

| | | | |
|---|---|---|---|
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 210202.1 | Ear abrasion, left |
| | | 510402.1 | Abdomen contusion, unspecified |
| | | 510202.1 | Abdomen abrasion, bilateral |
| | | 810402.1 | Upper leg hematoma, left |
| | | 810202.1 | Upper leg abrasion, unspecified |
| | | | |
| **Occupant 8D<br>ICAO: minor<br>ISS-5** | *Head or neck* | 161002.2 | Concussion with LOC |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 110600.1 | Forehead laceration, right |
| | | 110600.1 | Scalp laceration, right |
| | | | |
| **Occupant 8F<br>ICAO: serious<br>ISS-17** | *Head or neck* | 161002.2 | Concussion with LOC |
| | | 251235.2 | Orbital fracture, right |
| | *Face* | 251404.1 | Teeth fracture, incisor |
| | | 240416.1 | Conjunctiva hemorrhage, right |
| | *Chest* | 441408.3 | Lung contusion, right middle and lower lobes |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | 877110.1 | Ankle sprain, right |
| | | 857200.2 | Talus fracture, right talar neck |
| | *External* | 710600.1 | Forearm laceration, right |
| | | 810600.1 | Cheek laceration, right |
| | | 210402.1 | Face hematoma, right |
| | | 410202.1 | Chest abrasions, multiple |
| | | 810402.1 | Lower leg, ankle, foot hematoma, right |
| | | | |
| **Occupant 9C<br>ICAO: serious<br>ISS-6** | *Head or neck* | 161000.1 | Concussion without LOC |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | 856151.2 | Pelvic fracture, sacral spine |
| | | 856151.2 | Pelvic fracture, R ramus through pubic symphysis |
| | *External* | 210202.1 | Face abrasions, unspecified |
| | | 210600.1 | Face lacerations, unspecified |
| | | 510402.1 | Abdomen contusion, inferior to the iliac crest |

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|---|---|---|---|
| | | 510202.1 | Pelvic abrasions, unspecified |
| | | 110600.1 | Head lacerations, right |
| | | 110600.1 | Head laceration, right temple |
| | | 810202.1 | Leg abrasions, right |
| | | 810402.1 | Upper leg hematoma, right obturator muscle |
| | | | |
| **Occupant 9F**<br>**ICAO: minor**<br>**ISS-1** | *Head or neck* | None | None |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 810402.1 | Leg contusion, right |
| | | 810202.1 | Leg abrasion, right |
| | | | |
| **Occupant 10C**<br>**ICAO: fatal**<br>**ISS-57** | *Head or neck* | 140660.3 | Cerebral edema, bilateral |
| | | 140693.2 | Cerebral subarachnoid hemorrhage, right frontoparietal |
| | | 140693.2 | Cerebral subarachnoid hemorrhage, left frontoparietal |
| | | 140693.2 | Cerebral subarachnoid hemorrhage, superior hemispheres |
| | | 150402.2 | Skull fracture, left temporal and parietal bones |
| | | 640250.5 | Cord laceration and dislocation, vertebrae C7-T1 |
| | *Face* | None | None |
| | *Chest* | 441412.4 | Lung contusion, bilateral, 1 lobe per lung |
| | *Abdominal or pelvic contents* | 540810.2 | Colon hematoma, proximal ascending |
| | | 542026.4 | Mesentery lacerations, complex |
| | | 541424.3 | Small bowel laceration, near transection |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 210202.1 | Forehead abrasion, central |
| | | 210402.1 | Face contusion, left cheek |
| | | 210202.1 | Face abrasion, left chin |
| | | 210202.1 | Face abrasion, right cheek |
| | | 210202.1 | Face abrasions, left cheek |
| | | 710402.1 | Arm contusion, right lateral |
| | | 710402.1 | Forearm hematoma, right |
| | | 710402.1 | Wrist hematoma, right |
| | | 710202.1 | Hand abrasion, left |
| | | 810402.1 | Leg contusion, right upper |

| | | | |
|---|---|---|---|
| | | 810402.1 | Foot contusion, right |
| | | 510202.1 | Abdomen/back abrasions, bilateral |
| | | 510202.1 | Back contusion, right upper |
| | | 110402.1 | Scalp contusion, left parietal and temporal |
| | | 110402.1 | Scalp hematoma, right temporalis muscle |
| | | 110402.1 | Scalp hematoma, left and middle frontal area |
| | | | |
| **Occupant 10D<br>ICAO: serious<br>ISS-5** | *Head or neck* | 161002.2 | Concussion with LOC |
| | *Face* | None | None |
| | *Chest* | None | None |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | None | None |
| | *External* | 210402.1 | Ear contusion, left |
| | | 110402.1 | Scalp hematoma, right frontal |
| | | 910400.1 | Skin hematoma, unspecified |
| | | 210402.1 | Face contusion, right |
| | | | |
| **Occupant 10F<br>ICAO: serious<br>ISS-29** | *Head or neck* | 140651.3 | Cerebral subdural hematoma, right temporal and parietal |
| | *Face* | None | None |
| | *Chest* | 441412.4 | Lung contusion, bilateral, at least 1 lobe |
| | *Abdominal or pelvic contents* | None | None |
| | *Extremities or pelvic girdle* | 750621.2 | Clavicle fracture, medial |
| | | 770530.2 | Sternoclavicular joint separation, right |
| | *External* | 210202.1 | Face abrasion, right |
| | | 210402.1 | Face hematoma, right |
| | | 710202.1 | Shoulder abrasion, right |
| | | 710402.1 | Shoulder, hematoma, right |
| | | 110402.1 | Temporal scalp hematoma, right |
| | | 810202.1 | Ankle hematoma, right |
| | | 110202.1 | Temporal scalp abrasion, right |
| | | 510202.1 | Lower back abrasion, right |
| | | 810402.1 | Ankle hematoma, left |
| | | 710202.1 | Hand/wrist abrasion, left |
| | | 710402.1 | Hand hematoma, left |

[a] LOC = loss of consciousness.

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