Virginia Commonwealth University
Transportation Safety Training Center

Crash Investigation Team

Special Report Number 19 - June, 2005

ABSTRACT

This special report entitled "School Bus Crash Evaluation Study" examines the safety aspects of full size school buses involved in traffic crashes occurring within the Commonwealth. In two cases studies, crashes were investigated in-depth, illustrating the crash dynamics and occupant kinematics. In addition, the two most recent fatal school bus crashes, which occurred in early 2005, are outlined. Past investigations completed by the Team are summarized as to the circumstances, severity, and type of school bus involved. A table listing the number and severity of all reported school bus crashes reported in Virginia for the last twenty years is included. Specific information concerning belt use in school buses is also cited.

The Crash Investigation Team, based on its findings in the real world and from numerous research studies and actual crash testing of buses equipped with belts and without belts, still strongly opposes a requirement for lap belts on full size school buses. This issue was addressed in 1985 in House Joint Resolution 288 in which the General Assembly directed the Department of Education to study (in part) the need for equipping new and old school buses with seatbelts. The resolution concluded, as do most other studies since that time, that lap belts are not warranted and they should not be used on large school buses. The use of combined lap/shoulder belts on newer bus designs looks promising in certain instances and should be studied by Virginia authorities.

Recipients of this Special Report are encouraged to consider its contents and become more aware of the issues of combination lap/shoulder belt use in school buses. The debate over the installation and use of safety belts on school buses has ensued for the past 30 years and is likely to continue for the next decade.

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INTRODUCTION

School buses are the safest form of surface transportation and their overall safety record is excellent. According to national figures, school buses are about 170 times safer than passenger cars, 34 times safer than rail transportation and 4 times safer than air transportation in terms of injury and death rates. In a May 2002 report to Congress, the National Highway Traffic Safety Administration said that the fatality rate for school buses is 0.2 fatalities per 100 million vehicle miles traveled, compared with 1.5 fatalities per 100 million miles traveled for all vehicles. Crash statistics both nationwide and in Virginia indicate that when school buses are involved in traffic crashes, the results are generally minor. Nearly all fatalities involving school buses occur in other vehicles striking the bus and/or with children positioned outside the school bus. In most collisions when a student fatality and/or serious injury occurs inside the bus, the bus has been impacted by a larger vehicle such as a truck or train and/or the bus experiences a rollover with an ejection. However, these occurrences are rare.

Over the past 20 years, the Commonwealth averaged nearly 600 reported traffic crashes involving school buses (1984 through 2003, see Table 1). This represents about 0.5% of all reported crashes involving motor vehicles. In these crashes, an average of three each year were fatal, and nearly all the deaths were occupants riding in vehicles other than the school bus. In the past 20 years, six occupants inside school buses were killed in collisions and of these deaths, only one was a student (in March 1994, the left rear side of a bus struck a tree. A 12-year-old boy was thrown from his seat, striking the bus window and tree, killing him instantly). The remaining five fatalities were school bus drivers. The number of occupants injured per year in school bus crashes has averaged nearly 370 in the last 20 years. Of these injuries, the overwhelming majority were minor, consisting of bruises, cuts and scrapes. For comparison purposes, the Commonwealth averages about 957 fatalities and 78,549 injuries annually in all traffic crashes (see table 2). When considering that over 20,000 public school buses are registered in Virginia, transporting hundreds of thousands of students and traveling millions of vehicle miles annually, the crash history of school bus transportation is excellent.

Why are school buses so safe? The reasons are multiple. One is the excellent training received and practiced by many conscientious school bus drivers. Two is increased safety

awareness by the motoring public regarding school bus transportation, and three is the numerous safety features incorporated into school bus construction. Beginning in the 1978 model year and continuing through the present, new school buses have been designed to offer safer occupant protection for the students (and drivers). These design improvements can be divided into two main categories – *crash avoidance* factors and *crashworthiness* factors. Crash avoidance factors include better braking systems, designed to stop quicker and in a straight line. Brighter yellow color paint schemes with available highly reflective tape and roof mounted flashing strobe lights add to the conspicuity of the school buses. The addition of front and rear high intensity amber flashing lamps which are activated during the stopping process compliment the familiar large, bright front and rear top-mounted red flashing lamps that are illuminated once the bus stops. The presence of a side-mounted stop sign/signal arm gives further visibility and warning to motorists. The front-mounted crossing control arm helps direct entering and exiting children away from the front of the bus, improving the driver's ability to visually track someone crossing in front of them. The use of large convex mirrors and larger windshields increases the driver's field of vision. Design changes in the school bus body, with newer transit style buses and snub nose shapes, bring drivers closer to the front of the bus, also improving their vision. These are marked improvements from the older style buses, where the driver's seat was located about 6 to 7 feet behind the front bumper. The older type of bus required the driver to look out over a long hood, resulting in a large blind spot immediately in front of the bus.

In the crashworthiness area, many improvements have also been made since 1977. Improvements include better fuel tank integrity, school bus body joint strength and rollover protection (roof, side walls and flooring), the addition of roof-mounted escape hatches and exit windows that easily and quickly push out in the event of an emergency, user friendly emergency doors, the use of shatterproof glass in windows and non-flammable materials for the interior. Seat frames today are sturdier and more securely fastened to the flooring to reduce their movement during a collision. However, the one crashworthiness improvement, which has made perhaps the biggest impact on school bus safety, is "compartmentalization." Compartmentalization refers to upgraded design and placement of the seat cushions and interior barriers for the purpose of occupant protection. The seat and back cushions are thicker, heavier and taller with added padding. They are placed closer together than the pre-DOT 1977 buses. This design shortens the travel distance of the students and helps reduce the energy forces exerted on them during a frontal collision. The design dissipates the impact forces over a larger

portion of the occupant's body as the student strikes the padded seat cushions in front of them. The seat cushions no longer have metal tubing around their frames and no unprotected vertical or horizontal stanchions are located inside the bus. (Students are prohibited from standing up in the bus while it is in motion. This certainly reduces the chances of being tossed about and/or ejected from the bus during a collision or sudden braking action). The inclusion of a padded barrier cushion at the front of the bus better separates the passengers from the driver area and the front service door. This added protection helps to reduce the potential of ejections during rapid crash rotations and/or rollovers. The large size of the school bus and higher seated positions of the occupants also assists in energy dissipation when a bus collides with other vehicles, which are usually smaller and lower than the school bus.

The debate for safety belts on buses continues despite the numerous safety improvements on post 1977 school buses. Also despite the many research studies and dynamic/computer simulation tests indicating that lap belts are not needed on buses with compartmentalization. At present, the overwhelming evidence clearly indicates that school buses should not be equipped with lap belts. This is primarily due to the incompatibility of belt use with compartmentalization. Also, in some instances, the energy loads exerted on students wearing lap belts are greater in frontal crashes than when the students are not belted. Since these loads are greater, the risk of injury to the student increases. Likewise, the probability of belted children striking their heads on the seat cushions and incurring serious neck injury is greater than for non-belted students in frontal collisions.

Other concerns associated with lap belts on school buses relate to proper belt use and whether riders would wear them. Non-use, misuse, and abuse, including using the belts as "weapons" or other non-intended purposes, along with the high costs of required installation are all valid concerns. The primary purpose of lap belts is to keep occupants in their seat and in the vehicle during a crash. Therefore, in certain mishaps, properly worn lap belts could lessen the risk of student's injuries. However, these occurrences (rollovers, side impact with large vehicle and rapid rotations after a significant collision) have historically been infrequent.

The debate over lap belt use on large school buses has shifted over the past 30 years from the installation and use of lap belts only to combination lap/shoulder belts. Most recent studies and opinions from safety officials indicate that lap/shoulder belts are not yet compatible with compartmentalization and thus they are not recommended.

However new school buses are now available with lap/shoulder belts integrated into the school bus seat backs. The costs associated with this option are high. According to a major school bus distributor in Virginia the approximate cost for a standard post 1997 school bus 3 position seat is $80.00. In contrast, the cost of a 3 position lap/shoulder belt equipped seat is $500.00, and the seat must be 45 inches wide. But the most significant factor cited by safety officials not yet recommending that lap/shoulder belts be installed on large school buses is the reduction of seating capacity due to the extra space required for the lap/shoulder belts. Some estimates are as high as 20% loss of capacity.

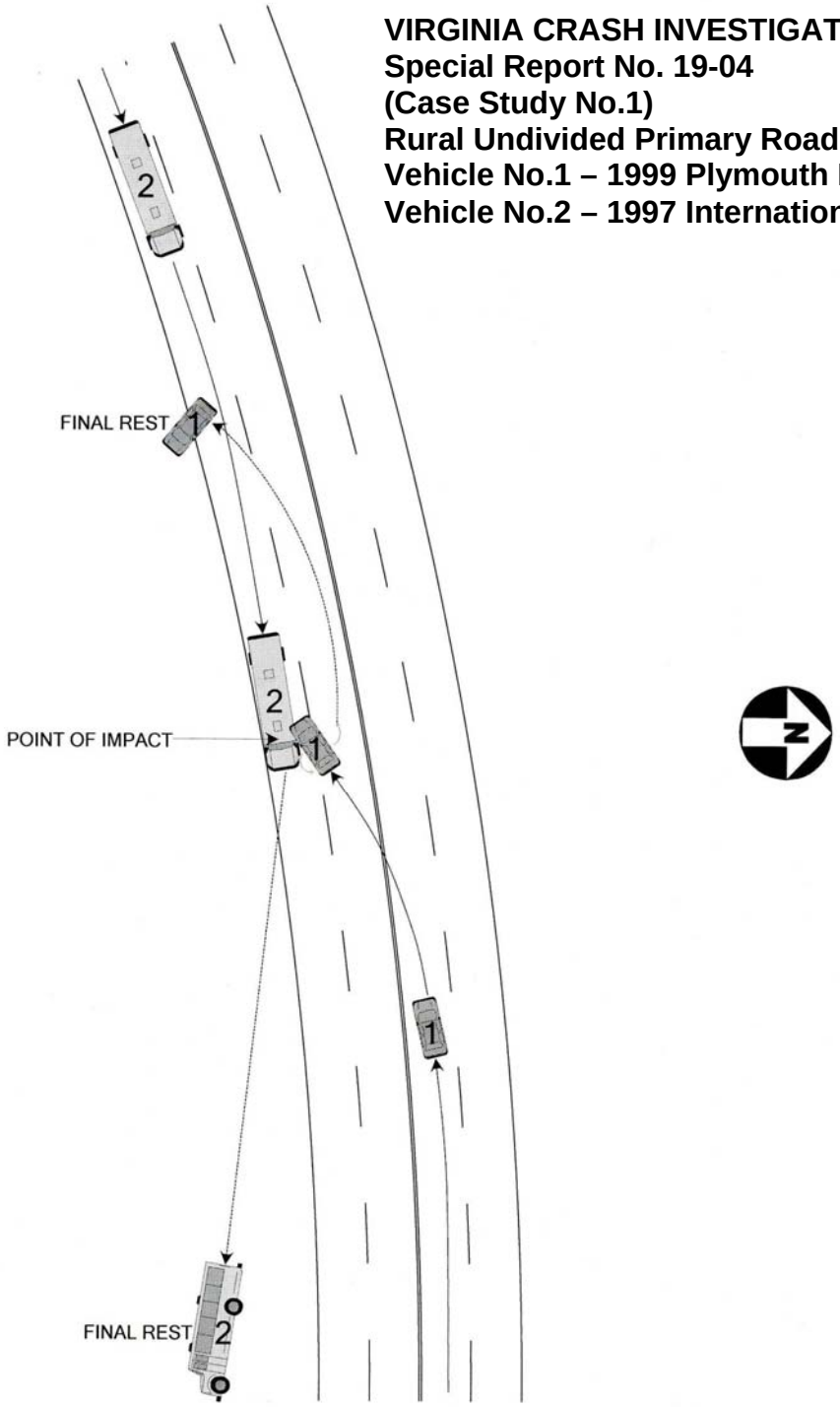
In order to fully equip newer school buses with the combination lap/shoulder belts, more school buses would have to be purchased and put on the roads to accommodate the loss of student capacity and at higher price. Some argue the increased exposure risk associated with more school buses in the traffic mix may offset the added benefits of combination lap/shoulder belts.

The primary shift in the partial acceptance of combination lap/shoulder belts in large school buses is that they ensure that students are not thrown out of their seats (when worn) and they prevent ejection. They are especially beneficial in frontal type collisions (which are frequent) and in rollovers (which are infrequent). However, the use of combination belts (when used) are not beneficial to the safety of the children when the bus is struck broadside by a large vehicle and/or when the passenger compartment is compromised by intrusion. Fortunately, these occurrences are infrequent. Interestingly, a pilot program conducted in 2002 on lap/shoulder belt systems installed within large buses indicated that nearly all students ages 6-10 years old used belts each time they rode the bus; among riders 11-15 years old the belt use rate dropped to about 50%.

In a special highway investigation report by the National Transportation Safety Board (NTSB/SIR-99/04) where selected school bus crashes were analyzed nationwide, several important conclusions and recommendations were made concerning the safety of school bus transportation. Among them, it was noted that school bus passengers are safer now than they were before 1977 because of compartmentalization. However, current compartmentalization is incomplete in that it does not protect school bus passengers during lateral impacts with larger vehicles or in rollovers. This assessment was based on the fact that passengers do not always remain completely within the seating compartment in such crashes. The NTSB stopped short of recommending the mandatory installation of combined lap/shoulder belts for new school buses.

While the Crash Investigation Team was completing this Special Report, two fatal school bus crashes occurred within the Commonwealth. Both were reported in early 2005 and resulted in the deaths of three student occupants. At this writing, the investigations and legal procedures are still pending. However, the factual circumstances surrounding them are noted at the end of this report in the addendum section.

VIRGINIA CRASH INVESTIGATION TEAM
Special Report No. 19-04
(Case Study No.1)
Rural Undivided Primary Road
Vehicle No.1 – 1999 Plymouth Breeze
Vehicle No.2 – 1997 International School Bus



CASE STUDY NUMBER 1

Type of Crash:	Head-on collision and rollover
Day, Time, Season:	Monday, 10:08 a.m., Summer
Vehicles Involved:	1997 International full size school bus 1999 Plymouth Breeze automobile
Roadway:	Primary highway
Occupants:	40 occupants on school bus Lone auto driver
Severity:	11 students and 1 adult from bus treated for minor injuries and released at local hospital. Car driver was seriously injured.

SUMMARY:

On a clear, dry Monday morning, a yellow, 71 passenger 1997 International school bus was eastbound on a rural, four lane undivided highway. The occupant compartment was a Thomas-built design and incorporated all the latest safety design features required for school buses. The bus was owned by a nearby city public school board and was being driven by a 48-year-old male. The driver was a professional school bus driver employed by the city school system. He was properly wearing his combination lap/shoulder safety belt. He was accompanied by another adult, who was seated just behind the driver, and 38 children ranging in ages from 10 to 14 years. All of the passengers in the bus were seated on the bench style seats and were unrestrained due to the bus not being equipped with safety belts. This school bus was the lead bus of three that were traveling from their city location to a recreational camp for the week. All three school buses had been on the road for about 30 minutes and were about 1 hour away from their destination. The second school bus, carrying about 30 passengers, was traveling about 300 feet behind the first bus. All of the school buses were eastbound and positioned in the right lane, traveling at speeds of about 45 mph. As the first bus was exiting a long, flat, moderately sharp curve to the right, while traveling in a heavily wooded terrain through a swamp, it suddenly encountered an approaching car heading directly toward it. The bus driver seeing that a head-on collision was imminent braked and steered to his right in an unsuccessful attempt to avoid the errant vehicle.

Photo No.1: Final rest of school bus lying on its right side at the foot of the highway embankment/shoulder.

The westbound car, a red 1999, four-door Plymouth Breeze, midsize automobile was being driven by its' lone 18-year-old owner. The belted female driver, employed as a nurse's aid, was returning home from visiting friends in the area. She had been on the asphalt-paved road, which was in excellent condition and properly signed and marked, for about one hour and was about 50 minutes away from her destination. The car had just traversed a slight hill and a long straight highway section as it entered the heavily wooded, swampy area. No other vehicles were in the immediate vicinity between the westbound car and the eastbound bus. At a point approximately 150 feet before the road curves to the left for the car driver, the automobile gradually exited its westbound left lane and crossed the double solid yellow centerlines. The car remained on this diagonal path of travel as it first crossed the inside eastbound lane. With no apparent evasive action by its young driver, the car entered the right outside eastbound lane where its left front collided with the school bus' left front wheel and tire. Since the vehicles were on an offset, head-on position to each other, the car continued colliding with the school bus as the bus was traveling forward. Due to the relatively small size and lower profile of the car, the auto struck the left side undercarriage of the bus, including the battery box, and frame member with its left front bumper, fender, hood and "A"-post. After sliding 21 feet along side and

underneath the left side of the bus, the car's left front corner collided with the left rear dual wheels of the bus. This impact caused the bus to partially mount the car's front as the car's forward movement was abruptly halted. The larger and higher bus continued traveling forward as the car disengaged and rotated rapidly in a counter-clockwise direction while still in the eastbound lanes. The second school bus driver, seeing what was occurring in front of him, shouted at his students to "hold on" as he was braking abruptly in an evasive attempt to avoid colliding with the spinning automobile. Just as the second bus was stopping in the right lane, the car's right rear bumper and tail light struck its front bumper. This minor collision helped stop the movement of the Plymouth and the car came to rest in the right eastbound lane, facing east with the second school bus nearly against the car's rear. No injuries occurred to the students or driver in this second collision.

Photo No.2: Final rest of the school bus taken from the point of impact in the right, eastbound lane. Note the gouge marks, tire scuffmarks and debris denoting the point of impact. The furrow marks on the shoulder indicate where the bus began to roll over after the collision with the auto.

The struck bus, after separating from the auto, began to roll over as it continued traveling forward. Due to the ramping effect between the bus and car, combined with the steep, grassy shoulder bordering the eastbound lanes that the bus now traveled, the school bus tipped over onto its right side and slid, furrowing through the moist sod and light brush. The bus did not strike any

of the large hardwood trees located intermittently along the shoulder. From the point of impact, the bus traveled a total distance of 200 feet, including 110 feet along the shoulder. It slid on its side approximately 75 feet until it came to rest facing southeast about 15 feet from the pavement edge. It was resting against several bushes on the grassy shoulder; about five feet lower than the highway surface. The car came to rest about 70 feet west of the impact point, still in the right, eastbound lane.

Photo No.3: Final rest of the automobile. After collision with the first school bus, it rotated and lightly struck the second bus shown in the photo. Note damage to the auto.

Almost immediately after the crash, passing motorists began stopping. Using cell phones, they called for emergency medical and police services and help arrived within moments. The school bus driver remained seated behind the steering wheel. His safety belt prevented him from being thrown to his right, down into the stairwell during the collision and roll over. He unbuckled his safety belt and gently lowered himself into the door area. He then stood up inside the bus to check on the condition of his passengers. The 39 passengers on board the bus were originally seated throughout its interior, on both sides of the bus, front and rear. The children seated on the left side behind the driver were lifted off their seats and slid to their right and down onto the right side of the bus during the rollover. These students struck the padded seats, seat frames and sidewall of the bus, as well as other students, during the crash sequence. Because the rollover was only a one-quarter roll and not onto the bus' top, and because it was not a

particularly hard roll, the energy forces experienced in the collision were minimized. None of the passengers sustained serious or even moderately serious injuries. The students were able to climb over the seats and work their way to the back of the bus to exit. The right service door was inoperative due to the bus resting on its' right side, so the driver assisted the passengers through the rear emergency door. With assistance from the other bus drivers traveling in the convoy and motorists at the scene, all of the bus occupants were able to exit in an orderly and timely manner with no difficulty. The bus interior was not damaged or compromised in any way and the threat of fire was minimal. None of the windows or side glass on the bus was broken and all seat frames, attachment points on the floor and seat cushions remained intact. The students were kept on the grassy shoulder and out of harm's way until the six local rescue squads arrived, within 15 minutes. While the children were being treated for minor bumps, bruises and scrapes, medics determined that 11 children should be taken to the hospital for observation. In total, 8 children were taken to the closest hospital and 3 were taken to a second hospital. Within an hour after their arrival and after being examined and treated, all the children were released with no problems. The school bus driver was also examined and released from the hospital later in the afternoon. The car driver was hospitalized for several days due to multiple serious head and body injuries. She advised the investigating Trooper that she did not remember what had happened to cause her to lose control of her vehicle. An opened purse with a cell phone was found on the car seat beside the driver just after the crash. An unopened soda and pack of crackers were also discovered inside the car. No vehicle defects were found on the car. The Plymouth driver was later charged with reckless driving.

Photo No. 4: Closer view of the left side and undercarriage of the school bus struck by the auto. Note damage is below the seated positions of the students on the bus.

DISCUSSION:

This collision between a full size, conventional style school bus and a mid-size passenger car is an excellent example of two common situations involving school bus transportation safety. First, it illustrates the type of offset, head-on collisions especially common with narrow, rural roadways where buses typically meet errant vehicles. Second, it exemplifies the life-saving and injury-reducing features of school buses that are involved in collisions with smaller vehicles. But, to better understand these features, it's important to detail the vehicle dynamics and occupant kinematics associated with this particular crash type.

Frontal collisions are one of the safest types of crashes for occupants riding in large school buses because they produce forces that cause the students to move forward during the collision. Rotation or post crash movement of the large bus is minimal reducing the likelihood of multiple secondary collisions inside the bus. This forward movement, if the collision is severe enough, will cause the children to strike the heavily padded seat cushions directly in front of them. These tall and relatively soft seat cushions help to absorb the energy forces from the collision. The large cushions, absent of any metal railings, also help to spread out or distribute the impact loads over a larger part of the child's body, as opposed to a narrow, blunt and

unpadded object being struck by the child. After impact with the struck cushions, the child is then re-directed, as designed, back into his or her seat.

The post 1977 life-saving components inside the bus proved beneficial in this frontal collision because the seat frames remained securely fastened to the floor and because of structural integrity intrusion inside the bus was kept to a minimum.

In any collision where a larger vehicle encounters a smaller vehicle, the occupants of the smaller vehicle usually experience the higher energy force levels and these smaller vehicles incur the most damage. Such crash circumstances invariably offer more protection to the occupants riding in the larger vehicle. In this particular case, the larger and taller school bus, weighing about 35,000 pounds and having a floor height about 38 inches above the road, was struck by the smaller and lower Plymouth automobile, weighing about 2800 pounds and its center of mass being only about 20 inches high. Since the school bus possessed the greater momentum at impact, its huge mass difference stopped the automobile's forward movement almost instantly at impact. At the same time, the amount of energy forces exerted on the school bus striking such a small vehicle which possessed much less momentum, caused only a minimum change in velocity or delta V for the bus during the collision. The small delta V on the large bus was hardly felt by the children at the time of the collision.

For the driver of the car, however, the forces were major and produced injury. Also increasing the margin of safety for the children on the bus was the fact that the car struck the bus at a point below where the children were seated. Instead of the impact forces being directly aimed at the student's bodies and heads, they were centered below the flooring of the bus, near the children's feet. At the same time, the body and frame of the bus was not compromised in the collision; no intrusion was found within the occupant compartment where the children were seated.

In this head-on/rollover crash, the school bus was actually exposed to three collisions with varying degrees of impact forces. The initial impact to its left front wheel, left side and undercarriage from the opposite moving auto generated the lowest delta V for the bus and its occupants. This is because the car did not strike the bus directly but at an angle and slid under the bus as both vehicles moved forward against each other. The second impact, occurring milliseconds later, generated the next higher energy loads and a greater delta V. This impact was between the car's left front corner and the left rear dual wheels on the bus. This collision, which was a more direct impact with a substantial part of the bus, instantly stopped the forward

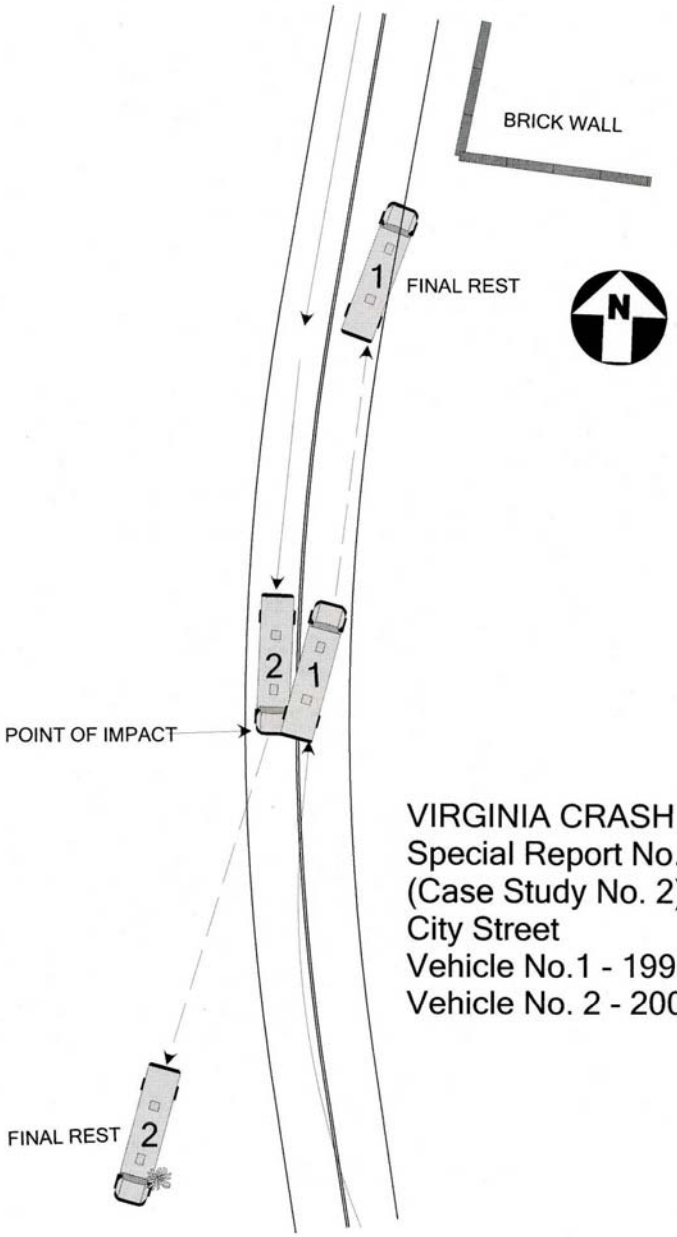
movement of the car while jamming the wheel assembly on the bus backwards into the wheel well. This impact would have been more obvious to the occupants on the bus compared to the first impact and probably caused the children to move forward in their seats and strike the padded seat cushions. Also simultaneously, the bus mounted the car with its left side and began the rollover process. Within a few more milliseconds, the left side of the school bus because airborne as it continued traveling forward off the road and down the shoulder's embankment. The third and final impact occurred when the bus struck the ground and halted the rollover. This impact, since it occurred on a relatively soft and moist grassy shoulder while the bus was moving and decelerating, probably generated a similar delta V to the one that was experienced in the second collision. However, as is typical in a rollover crash, the occupants seated on the trailing side of the roll (the left side of the bus), experienced greater energy forces than the occupants on the leading side of the rollover (the right side of the bus). This phenomenon occurs because the children seated on the left travel a further distance and are accelerated downward during the roll. When the right side of the bus touched down, the children on the left then fell onto the right side, striking the padded components of the bus as well as their fellow students on the right side. Conversely, the occupants on the right side were not thrown around inside the bus, but rather they slid against the right sidewall and windows as the bus completed its one-quarter roll to the right. Once completely on its right side, the bus then slid to an uneventful stop on the grassy shoulder. Because the bus did not strike any of the large trees nearby, this movement generated very low energy loads on the bus and its occupants.

During the entire collision and rollover process, the most likely times students would have sustained injury-producing forces was during the rollover phase, when they were thrown to their right and collided with the other students and/or the bus interior. However, no serious or moderately serious injuries occurred. This was due to the padding on the seat cushions and the relatively low speed when the bus rolled over. The exact seating arrangement and how many students were seated on the left and right sides of the bus and to the front or rear of the bus is unknown. No formal seating chart was required or prepared by the driver. So, the number of children thrown to the right when the bus rolled over is not known, but is estimated at one half the load or about 20 children. The bus interior showed no signs of occupant impacts. No dents, blood, hair or tissue from the children were found on the seats, sidewall or windows. Likewise, no one was ejected in this collision.

Photo No.5: Photo showing the interior of the school bus looking from the rear forward. The collision occurred on the left side of the bus. Note the lack of damage to the bus interior; the seat/back cushions, sidewalls, windows and roof on both sides of the aisle displayed no contact damage by the pupils.

Although speculative, had this bus been equipped with lap/shoulder belts, it is doubtful that there would have been any fewer injuries among the students. It is quite possible, considering the crash dynamics of the bus and kinematics of the occupants (particularly during the rollover), that wearing belts may have produced abdominal injuries on some of the students or possibly led to neck injuries when the bus "jerked" them during the touch down. However, one thing is certain in this crash: of the 38 student passengers on the school bus, eleven received only minor injuries requiring treatment at a hospital. These injuries consisted of cuts, bruises, scrapes and emotional trauma. In this particular crash, the safety design of the school bus interior (referred to as "compartmentalization") functioned properly and reduced the injury risk for its passengers. These safety components, adopted as requirements since 1977 by the United States Department of Transportation (DOT) -- which parents and students take for granted and don't particularly recognize -- are numerous. The specific features that functioned well in this case were: the high back and thick padded seat and back cushions (to soften impact forces and reduce travel distance of the students); the closeness of the seat placement (less than two feet apart to reduce the travel distance and impact velocity of the students when they strike the seats and to help restrict travel distance of the students); the strong anchoring of the bench seats, which

prevented them from coming loose in the crash; and the sturdy construction of the bus side walls and flooring which did not rupture in the collision. The Crash Team concludes that clear evidence illustrates this school bus was built in a proper and safe manner and that it functioned remarkably well, as designed, during the crash. The students had the maximum safety protection available.



VIRGINIA CRASH INVESTIGATION TEAM
Special Report No. 19-04
(Case Study No. 2)
City Street
Vehicle No.1 - 1996 International School Bus
Vehicle No. 2 - 2001 International School Bus

CASE STUDY NUMBER 2

Type of Crash:	Partial head-on/sideswipe opposite direction collision
Day, Time, Season:	Tuesday, 2:56 p.m., Spring
Vehicles Involved:	1996 International full size school bus 2001 International full size school bus
Roadway:	City street
Occupants:	Lone bus driver on 1996 bus 28 occupants on 2001 bus
Severity:	21 students and 2 adults were transported to hospital, treated for minor injuries and released.

SUMMARY:

On a cloudy and damp Tuesday afternoon in March, a 71 passenger yellow 1996 International school bus was northbound on a rural, two lane undivided city street. The conventional, snub nose bus had an occupant compartment built by Thomas which incorporated the latest safety design features required for school buses at the time of construction. The weather was light-to-moderate snow showers; however, the snow was not sticking to the ground or pavement. The school bus was driven by its 53-year-old female driver who was properly wearing her combination lap/shoulder safety belt. The driver had 10 years driving experience with the city school system that owned the bus. At the time of the crash, the lone driver was returning to a public middle school for her routine afternoon pickup of students. The school destination was about 4 miles away. The driver was very familiar with her bus and the roadway; as this was the assigned bus that she had operated for the past year. After turning at an intersection located about .3 mile away, the northbound bus began to climb a slight roadway grade while negotiating a moderately sharp left hand curve. The asphalt-paved roadway had a total width that varied between 20 and 22 feet. The pavement was in deteriorating condition and the yellow centerlines were faded and almost invisible, especially when the pavement was damp. No white edge lines were painted. The roadway, posted for 25 mph, was bordered by numerous trees, ditch lines, utility poles and a brick wall, all in close proximity to the road's edge. The pavement had bleeding tar patches at various places that make the surface slick. After negotiating the first curve and traveling several hundred feet on a straight, tangent section, the

school bus entered a moderately sharp curve to the right. Due to the design of the curve and the placement of a 10-foot tall, brick wall bordering the inside of the curve only inches from the pavement, sight distance looking at approaching traffic was limited to approximately 150 feet. At a point when the northbound bus was near the apex of the curve, with its left side tires on the centerlines, its driver noticed a southbound school bus approaching the same curve from the opposite direction. In an attempt to get further in her lane, the northbound driver steered abruptly to her right while braking hard. Due to a combination of the damp road, the bus being steered sharply in the curve and the abrupt braking action, the rear wheels began to lock up and the tires skidded on the pavement. The rear of the bus then began to rotate clockwise and "fish-tail" across the centerlines. It then traveled about four feet into the southbound lane where it was now on a collision course with the approaching bus. The right front tire of the northbound school bus ran off the pavement and began to furrow on the unimproved, sod shoulder.

Photo No.6: View looking north, showing the curve where collision occurred between the two school buses. Photo taken approximately 100 feet before impact. Note roadway surroundings and sight distance restrictions.

The southbound school bus, owned by the same city, was a transit or coach style, yellow 2001, full size International bus. Its occupant compartment was also a Thomas built design and it had all the current passenger safety standards required by DOT. It was being driven by a 49-year-old female who worked for the city as a full time bus driver. She had 10 years school bus driving experience and was familiar with both the roadway and her bus. The school bus was occupied by

27 students, ranging in ages from 11 to 15 years old. The bus was not at its full capacity, and the children were seated throughout its interior on both sides, front-to-rear. The students were on their way home from being picked up at the same middle school where the northbound bus was heading. The southbound bus driver saw the approaching bus fishtail partially in her lane and immediately yelled for the children to "hold on" for fear of an impending collision. She braked and steered to her right as far as she could go without colliding with a telephone pole and ditch line located about 12 inches away from the edge of the southbound lane. These driving actions caused her bus to skid briefly, traveling forward in a straight line as it collided with the northbound bus.

Photo No.7: Closer view of the impact point. Note faint skid mark from the left front tire diagonally crossing the northbound lane and the abrupt direction change at the northern end of the skid mark. This denotes point of impact and locates where the left front tire was positioned at the instant of collision. Note furrow marks on the right shoulder made from the right front tire that was skidding before and during collision.

The two school buses were at an approximate 20-degree angle to each other when the left front corner of the southbound bus struck and raked along the left rear side of the northbound bus. The entire left rear side, from top to bottom, including the two rear-most windows on the northbound bus was impacted. The damage extended nearly 6-½ feet and included the left rear bumper, which was pulled away from its attachment point. The left front corner of the southbound bus incurred contact damage along its edge just above the bumper and extending to

its roof. This included damage to the headlamp assembly, mirrors, sidewall, windshield and driver side windows. The contact point measured 6 feet 2 inches high and two feet wide.

Photo No.8: View looking south, taken approximately 100 feet before impact. Note roadway design and surroundings. The southbound school bus ran off the road on the right and traveled through the brush and tree lined shoulder after impact in the southbound lane.

The southbound bus possessed the most forward momentum at impact and the impact occurred behind the center of mass on the northbound bus. These factors, compounded by the damp roadway surface, which allowed the bus to spin more easily, knocked the northbound bus clockwise while its right front was traveling off the road. It came to rest diagonally across the northbound lane about 18 feet northeast of the impact point. It remained facing northward. Its right front tire was about 36 inches from the pavement edge on the sod shoulder and its right rear tires remained at the edge of the pavement's lane. Its left front tire, which skidded both before and after the impact, came to rest near the center of the northbound lane, about 40 inches from the edge of the road. The left rear dual tires came to rest about two feet from the centerlines in the northbound lane. The left rear of the bus extended several inches into the southbound lane. Even though the pavement was damp, clear discernable skid marks were evident. The bus driver, since she was belted by the lap and shoulder restraints, remained in the bus and was not tossed about inside. Because the impact occurred about 22 feet behind her, she was not in the direct path of the collision forces. She came to rest upright in her seat without striking any of the interior components inside the bus. This bus, originally traveling about 30 mph, had decelerated

prior to impact by skidding on the damp road surface about 32 feet. It is estimated that the northbound bus was traveling about 20 mph at the collision point.

Photo No.9: Damage to the southbound bus from impact with the side of the northbound bus. This bus sustained no interior damage in the collisions with the northern bus, the several small trees and brush after it was off the road and/or from the students inside the bus striking the interior components.

The southbound school bus, also skidding and decelerating prior to and during the collision, had decelerated to about 25 mph at impact. Its forward trajectory was altered in the collision, causing the bus to be knocked westward several feet as it skidded off the road. The bus traveled about 95 feet from the collision point and entered the grassy, brush-lined shoulder where it stopped against several decaying trees. Its left side had missed a large hardwood tree by mere inches. At final rest, its rear was about 10 feet from the edge of the southbound lane. The belted driver remained upright behind the steering wheel and did not strike the bus interior during the collision. Within seconds after stopping, she turned the bus off and immediately took an inventory of herself and the situation. She then went to the assistance of the students. All of the students remained in their seats during the collision and post collision sequences. None were knocked to the floor, although seven reported striking the backs of the high, heavily padded seat cushions directly in front of them. None of the passengers struck each other and none struck the interior sidewalls of the bus. Several of the students were “shaken up”, with most being scared and some were crying.

With assistance from the other bus driver and motorists who had stopped within minutes of the crash, the southbound bus driver began evacuating the bus. Since the right front service door was in the brush and against several small trees, she decided to have the students exit through the rear emergency exit. The bus did not sustain any structural or frame damage to its rear, and the emergency door opened easily. The children who wanted off the bus exited while others, due to the inclement weather and no risk of fire, decided to stay on the bus until emergency personnel arrived. Four local rescue squads, police/fire services and school officials responded shortly after the crash. They treated the children at the scene for only minor injuries: bruises, scrapes and scratches. However, it was decided that 21 students and the 2 drivers would be taken to two different hospitals for further treatment and/or observation. Within five hours after the crash, all the occupants were released. Only one student, a 14-year-old female, received a moderately severe injury, that of a sprain to her left wrist. It was believed that she tried to brace herself just before the collision and her wrist was injured against the seatback cushion. In the immediate days following the crash, several of the students involved in the collision did not report to school due to soreness and emotional trauma. Both drivers, who were put on extended medical leave, advised the investigating officer that each bus appeared to be "speeding" and in the other's lane just before the crash occurred.

DISCUSSION:

This collision between two full size school buses is a fine example demonstrating the impact forces involved in a near head-on collision between two large vehicles and the excellent crash worthiness of the safety design of the buses. The southbound school bus was struck in its left front corner, directly in front of and beside the driver. The amount of intrusion was measured at 8 inches. It did not collapse inward more because the impact occurred to one of the strongest points on the bus, its corner. Also, this bus struck the side wall of the other bus, which was a relatively soft contact point. The children seated in the southbound bus were all located several feet away from and behind the point of contact. Their positioning helped reduce the collision forces on the students. The change in velocity or delta V in the collision with the other bus was likely less than 15 mph. After this, the bus then ran off the road and through the soft sod, where it struck several small trees and brush. The deceleration forces acting on the southbound bus while it was slowing through the brush were less than during the collision with the northbound bus. This is because its speed had reduced and the deceleration occurred over a longer time and

distance than at impact with the other bus. The students likely experienced these last deceleration and impact forces with a lesser degree of severity, at a level not likely to produce injuries. Because of the high back cushions and their padding, the students did not strike any hostile interior objects and hence, no serious injuries occurred. Since the bus experienced no lateral or rotational forces in this crash, the movement of the students during the collisions would have been forward. In this instance the presence of lap/shoulder belts, had they been installed and worn, would not have provided the students any more protection than was already offered by the compartmentalization of the bus.

Photo No.10: Damage to the left rear side of the northbound bus.

The northbound bus incurred more structural damage than did its counterpart. This was because its side, a relatively soft component on the bus, was struck. The left rear area at the two rear-most windows incurred six inches of inward penetration or damage, caused by the left front of the southbound bus. The interior sidewall was likewise pushed into the occupant compartment; however, no buckling or tearing of the metal interior occurred. The top half of one of the two windows was shattered and both halves of the rearmost window were broken. This caused pieces of tempered glass to be thrown inside the bus. Both seat frames and anchors remained fixed to the flooring and were not compromised. The left side of the rear-most seat was against the damaged interior sidewall, but it was not contorted. None of the rivets connecting the sheet metal failed. This damage, located high on the sidewall, is typical of a larger vehicle

colliding with the bus. Had this bus been occupied at the time of the crash and had students been seated in the last two left-side seats, they would have experienced the highest energy forces compared to the other seated positions on the bus. These students would have probably struck the interior of the sidewall as it was intruding in on them. Such an impact would have produced the highest risk for injuries. It is speculative as to the degree of potential injuries, but it's doubtful that they would have been life-threatening. The Crash Team asserts, however, that if students were seated at this location and belted, the belts would not have reduced the amount of energy forces exerted them. This is because the striking forces were introduced broadside and not from the front or rear. Under the circumstances of this crash, both the school buses performed well when considering the momentum and energy generated by two large vehicles colliding with each other and their probable speeds at impact.

Photo No.11: Interior damage to the left side of the northbound school bus. Two windows were shattered and the sidewall was pushed inward several inches. The seat cushions, frames and flooring were not damage.

Table 1
Virginia Traffic Crashes Involving School Buses

Year	# of school bus reported crashes	% of all crashes	# of fatal crashes	# of school bus occupants killed	# of school bus occupants injured
2003	724	0.5%	1	1 (driver)	314
2002	700	0.5%	4	0	411
2001	677	0.5%	2	0	374
2000	696	0.5%	3	0	662
1999	596	0.4%	4	1 (driver)	356
1998	395	0.3%	2	0	282
1997	427	0.3%	4	0	284
1996	538	0.4%	5	0	399
1995	539	0.4%	3	0	367
1994	565	0.4%	2	1 (student)	403
1993	523	0.4%	3	0	449
1992	510	0.4%	2	0	279
1991	560	0.5%	3	1 (driver)	239
1990	627	0.5%	2	0	255
1989	659	0.5%	3	0	433
1988	714	0.6%	2	0	425
1987	637	0.5%	4	0	504
1986	609	0.5%	4	0	334
1985	590	0.5%	5	2 (drivers)	256
1984	606	0.5%	4	2	N/A
Totals	**11,892**	**-**	**62**	**6**	**7,026**
(Yearly Averages)	(595)	(0.5%)	(3.1)	(.3)	(370)

Sources: Virginia Traffic Crash Facts, Department of Motor Vehicles (1984-2003).
Virginia Department of Education, Pupil Transportation statistics.

Table 2

Virginia Traffic Crashes Involving All Motor Vehicles

Year	Fatalities	Injuries
2003	942	78,842
2002	913	78,896
2001	935	80,187
2000	930	79,806
1999	877	81,204
1998	934	81,221
1997	981	81,866
1996	869	82,363
1995	900	82,400
1994	925	82,146
1993	875	77,852
1992	839	76,615
1991	938	70,899
1990	1,071	76,436
1989	999	79,310
1988	1,069	77,735
1987	1,022	80,114
1986	1,118	79,188
1985	980	74,585
1984	1,014	69,306
Totals	**19,131**	**1,570,971**
(Yearly Averages)	(957)	(78,549)

Source: Virginia Traffic Crash Facts, Department of Motor Vehicles (1984-2003).

TABLE 3

SYNOPSIS of PAST CIT Investigations of full size School Bus Crashes when occupied with students.

REPORT#	YEAR Investigated	VEHICLES/LOCATION	SEVERITY	CIRCUMSTANCES
1. No.190	2003	1997 International School bus 1998 Acura Integra Bedford County	8 students injured (minor). 35 students not injured. 1 car passenger killed.	Head-on collision between car and slowing/stopping school bus. Combined impact closing speed estimated at 30mph.
2. Special Report #14	2001	1998 International School Bus 1992 Saab Sedan Henrico County	1 student injured (minor). Two car occupants killed.	Moving school bus was struck broadside by car. Bus then rotated clockwise, nearly tipping over. Impact speed estimated at 55mph.
3. No.179	1997	1994 International School Bus 1985 GMC truck Louisa County	16 students injured (1 serious). 23 students not injured. Bus driver received near-fatal injuries.	Partial head-on collision between front of bus and left side of large tanker truck. School bus then ran off the road and struck several trees. Combined closing impact speed estimated at 40mph.
4. No. 155	1985	1975 Ford School Bus 1978 International Tractor-trailer Northampton County	13 students injured (1 serious). 16 students not injured.	School bus was slowing and was rear-ended by a tractor-trailer. Bus then ran off the road and struck a tree as it rolled over onto its left side. Impact speed estimated at 50mph.

TABLE 3 cont.

SYNOPSIS of PAST CIT Investigations of full size School Bus Crashes when occupied with students.

Report#	Year Investigated	INVOLVED VEHICLES	SEVERITY	CIRCUMSTANCES
5. NTSB HAR-85/02*	1984	1980 Ford School Bus Train Isle of Wight County	Bus driver died five days after crash. Of the 26 students on the bus two were seriously injured, one had moderate injuries and 23 sustained minor injuries.	School bus was struck in its right front side by a train at a railroad grade crossing. The body of this bus separated from its chassis and was thrown 80 feet from the impact point and rolled over. The estimated speed of the train at impact was 45mph against the stopped school bus.
** This crash was investigated by the Team while lending assistance to the NTSB. The Board concluded that the presence and use of lap belts by the students would have reduced the amount of injuries for two students but would have had little or no effect on the severity of injuries to the remaining 24 students. None of the students were ejected. The Board did not recommend the installation of safety belts for school buses.*				
6. Memo No.59	1983	1978 Ford School Bus 1973 VW Beetle Amherst County	14 students injured (all minor). 19 students not injured. 3 car occupants killed.	Head-on collision between car and school bus. Bus then ran off the road and into ditch. Combined impact closing speed estimated at 45mph.
7. No. 136**	1981	1980 Ford School Bus 1971 Mack Tractor-trailer Nelson County	13 students injured (all minor). 40 students not injured.	Sideswipe, same-direction collision. Bus then ran off the road and struck embankment. Impact speed estimated at 50mph.
*** This was the first school bus crash investigated by the team, which incorporated the new DOT safety design requirements called, "Compartmentalization". The Team concluded, "Due to the newer construction of this school bus thus making it more forgiving – Post 1977 design- the degree of injuries sustained to the students during the collisions were kept at a minimum. Had this school bus incorporated the older design, more student injuries and more severe injuries would have occurred in this crash".*				
8. No. 124	1980	1973 Ford School Bus 1971 Mack Tractor-trailer Appomattox County	1 student killed, 2 students seriously injured, 4 students with minor injuries and 6 students received no injuries.	Stopped school bus was rear-ended by the tractor-trailer. Bus then ran off the road and struck embankment. Impact speed estimated at 45mph.

TABLE 3 cont.

SYNOPSIS of PAST CIT Investigations of full size School Bus Crashes when occupied with students.

Report #	YEAR Investigated	INVOLVED VEHICLES	SEVERITY	CIRCUMSTANCES
9. No. 92***	1977	1972 International School bus 1975 Peterbilt Tractor-trailer Campbell County	3 students killed, (one ejected), 17 students seriously injured, 8 students received minor injuries and 4 not injured.	Stopped school bus was rear ended by tractor-trailer. Bus then ran off the road and rolled over onto right side. Impact speed estimated at 60mph.
**** This investigation was also conducted by the National Transportation Safety Board (No.NTSB-HAR-78-1) during the time when new Federal Motor Vehicle Safety design standards for school buses were being developed – Compartmentalization. The NTSB concluded that, "The availability of occupant restraints and the presence of an adequate restraining barrier would have prevented the ejection of the fatally injured student". The NTSB also noted that, "Contributing to the fatalities and injuries was the lack of occupant restraints in the school bus which allowed the student to be ejected, resulting in fatal injuries and others to be propelled into sharp or unyielding interior components". The NTSB did not recommend that future school buses should be equipped with safety belts or that existing school buses be refitted with restraints.*				
10. No. 88	1976	1970 Chevrolet School Bus 1973 Ford Maverick New Kent County	20 Students injured (minor). 25 students not injured. 2 car occupants killed.	Slowing school bus was struck by the car's right side after car skidded in front of bus. Combined impact closing speed estimated at 50mph.
11. No. 61	1975	1962 International School Bus Roanoke County	All 7 students were injured; 2 serious and 5 minor. The belted driver sustained critical injuries.	School bus, while descending a steep grade, lost its brakes and subsequently ran off the road. It struck a rock wall, culvert, embankment and several trees while rolling over onto its right side, roof and left side. Estimated speed at impact was 40mph.

Addendum to Crash Investigation Team Special Report Number 19- June 2005:

While the Team was completing this Special Report, two separate fatal school bus crashes occurred in the Commonwealth in early 2005. The Team, as well as other local, state and national investigative authorities, examined the two crashes. Although the findings are still pending as of this writing, some preliminary factual information is noted below. Once the investigations and legal proceedings are complete, a more in-depth analysis may be issued.

Date: February 9, 2005 7:10 a.m.

Location: A rural two lane undivided secondary highway.

Involved vehicle: 1996 International-Navistar 3800, full size, snub nose, yellow, 71-passenger school bus. Body built by Bluebird.

Driver: 33-year-old female, belted with combination lap/shoulder belts, with 5 years school bus driving experience.

School bus Passengers: 18 students, ranging in ages between 12 and 18 years, seated throughout the bus. None were belted because the school bus was not equipped with lap/shoulder belts. Because this bus was used occasionally for transporting special needs children, the first passenger seat behind the driver was equipped with an after-market single lap belt. The 16-year-old occupying the seat was not using the belt.

Severity: One student (16-year-old male, seated in the first row behind the driver) incurred a fatal closed head injury. Seven students received varying degrees of injuries, three of which were serious.

Crash Circumstances: While westbound and en route on her normal morning run to a local high school and middle school, the school bus driver allowed her vehicle to run off the right side of the road. The narrow straight and level roadway was marked by double solid centerlines and was posted with a 45 mph speed limit sign (although the maximum legal speed for this school bus was 35 mph). Once the right side tires were off the road, they traveled down into a three feet deep ditch line directly adjacent to the pavement edge. The bus continued traveling forward and struck a large tree with its right front corner and side, causing significant damage to the right front, hood, service door, roof and side. The bus then struck a raised embankment and several smaller trees/brush before stopping partially in the right ditch line and pavement. During the collision with the ditch line, trees and embankment, 9 of the 18 passengers were thrown from

their original seated positions. The fatally injured passenger struck his head on the emergency brake lever and lower dashboard and came to rest lying in the aisle near the top of the right front stairwell. The driver alleges that she was avoiding an oncoming car that had encroached into her lane. She was charged with reckless driving which was later reduced to improper driving by the court.

Causal Factors: The narrow width of the road, the deep ditch line drop off and the close proximity of the tree line/embankment to the pavement's edge made this roadway an unforgiving environment. The possible presence of an errant vehicle and/or the driving actions of the school bus driver caused her to run off the road. The injury risk of the students was increased by their being tossed around inside the bus. Remarkably, the extensive intrusion of the collapsing roof in the right front half of the bus did not injure the six students seated in this area. This is because the effected students took defensive actions to avoid flying glass and collapsing roofline.

Photo A: Front view of the 1996 International full size school bus. NOTE deformed roof damage over the right front side from collision with struck tree.

Photo B: Closer view showing damage to right, front side. NOTE damage to service door, roof and top side in area of the windows. Fatally injured 16-year-old student was originally seated in the first left passenger seat, directly behind the driver.

Photo C: Showing interior damage to front of school bus. The right front area was crushed downward onto the tops of the seats for the first four rows. Although extensive intrusion in this area, none of the children seated in this area were seriously injured.

Date: April 18, 2005 8:40 a.m.

Location: An urban four lane undivided primary highway.

Involved vehicles: 1999 Thomas built; full size, yellow, 76-passenger transit style school bus. Body built by Thomas.

2003 Mack, four axle, single unit Trash Truck

Drivers: 37-year-old female bus driver belted with combination lap/shoulder belts, with 11 years of school bus driving experience.

41-year-old male truck driver, unbelted, with 3 years truck driving experience.

School bus Passengers: 15 students, ranging in age between 6 and 12 years, seated throughout the bus. The school bus was not equipped with lap/shoulder belts.

Severity: Two students were fatally injured. The first fatality, a 9-year-old girl originally seated two seats behind the driver, died instantly in the crash. The second fatality, a 7-year-old boy originally seated in the first passenger seat behind the driver, received multiple body and extremity injuries, and died nearly 40 hours after the crash. Both children were positioned directly in the impact area and died as a result of severe body and head injuries. The remaining 13 students received varying degrees of non-fatal injuries. Both drivers received critical head and body injuries. This investigation is still underway, and possible charges and causual factors are still pending.

Crash Circumstances: The truck and bus were traveling in opposite directions on this four lane street. The crash occurred close to an intersection located at the top of a hillcrest. The truck was in the left travel lane and had already passed through the intersection. The bus was in the left turn lane approaching the intersection. The left lift arm and cab of the truck struck the left front corner of the bus. The heavily constructed truck components tore into the thinner wall of the bus, ripping open the metal siding at the level of the seats through the first five seats, exposing the interior. The window frames collapsed. The high backs of the first four seats were bent rearward and the roof buckled down to the top of the seats. The bus was pushed backward from impact and came to rest in the left turn lane. After impact, the truck veered across both lanes and departed the roadway to the right where it jumped a curb, struck a stop sign and came to rest with its front wheels in a grassy yard. One count of reckless driving and one count of failure to pay full time and attention were charged against the bus driver. The truck driver was charged with a single count of reckless driving.

Causal Factors: Still under investigation.

Photo D: A front view of the 1999 Thomas built, full size transit, style school bus. Note extensive damage to the left front corner and side caused by the collision with the large trash truck. This photo was taken at final rest of the bus, still in the roadway's left turn lane.

Photo E: Closer view showing damage to the left front side of the bus. NOTE extensive intrusion, roof collapse and seat displacement caused by left front corner of trash truck.

Photo F: Shows different view of damage to left front and side of school bus while it was being lifted by a wrecker. The two children that received fatal injuries caused when they were struck by the intruding "lift arm" on the trash truck were originally positioned in the first two outboard seats, directly behind the driver.

TABLE 4 (Addendum)

All reported school bus fatal crashes occurring in Virginia (student occupants)

School Year	No. of Fatal Crashes	No. of Fatalities	Crash Circumstances
1950-'51	1	5	Train/school bus collision- Prince Edward Co.
1959-'60	1	2	Truck rear-ends stopped school bus- Frederick Co.
1968-'69	2	3	(1) Truck rear-ends stopped school bus- King George Co. Killing two students. (2) School bus runs-off-road and down an embankment- Page Co. Killing one student.
1970-'71	1	2	Truck broadsides school bus- Montgomery Co.
1976-'77	1	3	Truck rear-ends stopped school bus- Campbell Co.
1980-'81	1	1	Truck rear-ends stopped school bus- Appomattox Co.
1993-'94	1	1	School bus strikes rock ledge, then tree inside- Pulaski Co.
2004-'05	2	3	(1) School bus run-off-road strikes embankment and tree- Louisa Co. Killing one student. (2) School bus struck head-on/opposite direction, sideswipe collision (intrusion) - Arlington Co. Killing two students.

Source: VA Crash Investigation Team
VA Department of Education, Pupil Transportation