INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER
School of Public and Environmental Affairs
501 South Morton Street Suite 105
Bloomington, Indiana 47403-2452
(812) 855-3908 Fax: (812) 855-3537

ON-SITE CHARTER BUS ROLLOVER INVESTIGATION

CASE NUMBER - IN10005
LOCATION - FLORIDA
VEHICLE - 2001 KRYSTAL ENTERPRISES
BUS BODY ON A FORD F550 CHASSIS
CRASH DATE - February 2010

Submitted:
August 9, 2010

Contract Number: DTNH22-07-C-00044

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
National Center for Statistics and Analysis
Washington, D.C. 20590-0003

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

Technical Report Documentation Page

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15. *Supplementary Notes* On-site motor coach rollover investigation involving a 2001 Krystal Enterprises bus and a 2010 Mercury Milan Premier.			
16. *Abstract* The focus of this investigation was the rollover of a 2001 Krystal Enterprises bus, which was being used for charter service. Eight passengers were ejected during the rollover and there were five fatalities. The bus was driven by a restrained 68-year-old male. It was occupied by a restrained 62-year-old female front right passenger and 30 unrestrained passengers located within the bus body rearward of the driver. Their ages ranged from 65 years to 86 years. The bus was traveling north on a divided U.S. highway in the outside through lane. The crash occurred when the 81-year-old driver of a 2010 Mercury Milan proceeded east from a rural roadway through the median opening and executed a left turn into the path of the bus. The right fender of the Mercury impacted the left side of the bus. The bus rotated clockwise and rolled over left side leading as it departed the east side of the road. The vehicle rolled over 6 quarter turns and came to final rest on its top. In addition to the five fatally injured bus occupants, the remaining bus occupants with the exception of the front right passenger sustained police reported A (incapacitating) injuries and were transported to a hospital. The front right passenger sustained a C (possible) injury. The driver of the Mercury was not injured. Both vehicles were towed from the crash scene due to damage.			
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The focus of this investigation was the rollover of a 2001 Krystal Enterprises bus (**Figure 1**), which was being used for charter service. Eight passengers were ejected during the rollover and there were five fatalities. This crash was brought to our attention by the National Highway Traffic Safety Administration (NHTSA) on February 22, 2010. The investigation was assigned on February 24, 2010. This crash involved the Krystal bus and a 2010 Mercury Milan Premier. The crash occurred in February, 2010, at 2216 hours, in Florida and was investigated by the Florida Highway Patrol. Both vehicles and the crash scene were inspected on February 26-27, 2010. This report is based on the police crash report, police traffic homicide investigation report, scene and vehicle inspections, occupant kinematic principles, and evaluation of the evidence.

Figure 1: The damaged 2001 Krystal Enterprises bus

CRASH CIRCUMSTANCES

Crash Environment: The bus was traveling north on a curved, 6-lane, divided, U.S. highway that traversed in a general north-south direction. The bus was approaching a 4-leg intersection. On the south leg of the intersection, the northbound roadway had 2 through lanes, a left turn lane, and a right turn lane. Each lane was approximately 3.6 m (11.8 ft) in width. The roadway was bordered by a 1.7 m (5.6 ft) wide bituminous shoulder on the right and a 7.5 m (24.6 ft) wide grass median on the left. The grade on the approach of the bus was positive 2.5%. The roadway also had a positive 4.2 % grade across the roadway to the east. The Mercury was traveling on a level, 2-lane, undivided rural roadway that traversed in an east-west direction. The roadway had one through lane in each direction and the Mercury was approaching the same 4-leg intersection. The Mercury's roadway was controlled by a stop sign at the intersection and a yield sign within the median crossover. The speed limit on the U.S. highway was 105 km/h (65 mph). At the time of the crash, the light condition was daylight and the weather was clear. The roadway surface was dry bituminous. The Crash Diagram is on page 12 of this report.

Pre-Crash: The bus was driven by an restrained 68-year-old male. It was occupied by a restrained 62-year-old female front right passenger and 30 unrestrained passengers located within the bus body rearward of the driver. Their ages ranged from 65 years to 86 years. The Mercury was driven by a restrained 81-year-old female. The driver of the bus was an employee of a local tour company. Based on the police traffic homicide investigation report, he was familiar with the bus and had operated it for approximately four years. The driver held a valid Class C Florida driver's license with passenger endorsement, which allowed him to operate any vehicle whose Gross Vehicle Weight Rating (GVWR) was less than 11,794 kg (26,001 lbs). He had a license restriction that required him to wear corrective lenses, which he was wearing at the time of the crash. He had never been cited for any traffic violations. The driver had nine hours of sleep the

night prior to the crash. He was taking blood pressure and cholesterol medication. On the day of the crash, the driver was returning the group to their hotel following a local tour. He had conducted the tour on previous occasions and was familiar with the roadway. The bus was traveling north on the U.S. highway in the outside through lane (**Figure 2**). The driver was negotiating a left curve as he approached the 4-leg intersection. The Mercury was traveling east on the rural roadway. According to the police crash report, the driver of the Mercury stopped at the intersection and proceeded through the median opening (**Figure 3**) and executed a left turn into the path of the bus.

Crash: The right fender of the Mercury (**Figure 4**) impacted the left side of the bus (**Figure 5**). The sideswiping type engagement continued down the left side of the bus and the right front wheel of the Mercury (**Figure 6**) engaged the left rear wheel of the bus (**Figure 7**). The bus rotated clockwise approximately 50 degrees from its original heading on the roadway and began to roll over left side leading as it departed the east side of the road (**Figure 8**). The vehicle rolled over 6 quarter turns resulting in the ejection of 8 occupants. The bus came to final rest on its top plane on the east side of the road heading southeast (**Figure 9**). The Mercury came to final rest in the outside acceleration lane heading north.

Figure 2: Approach of the bus to impact; photo taken 60 m (197 ft) from center of intersection; arrow shows approach of the Mercury

Figure 3: Approach of the Mercury from the median opening to the area of impact

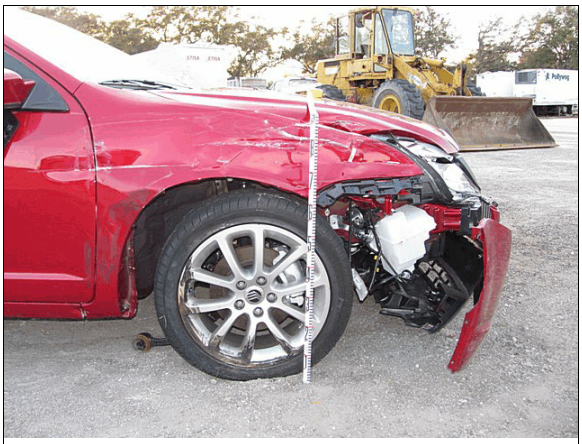

Figure 4: Damage on right side of the Mercury from impact with the left side of the Ford; vertical scale in 10th of meter

Figure 5: Arrows shows area of contact on left side of the bus from the impact with the Mercury; arrow on right shows extent of red paint transfer

Figure 6: Black rubber transfer on the Mercury's right front wheel from engagement with the left rear wheel of the Ford

Figure 7: Arrows show black rubber transfer on the rim and contact on the left rear tire of the Ford from engagement with the right front wheel of the Mercury

Figure 8: Approach of bus to rollover; tire mark on left is left rear, tire mark on right is left front

Figure 9: View northeast to path of rollover of the Ford; arrows show area of final rest position of the Ford

Post-Crash: The police were notified of the crash at 1422 hours. Emergency rescue and medical services also responded to the crash scene. The occupants of the bus were transported by either ground or air ambulance to area hospitals. Five occupants sustained fatal injuries. The driver of the Mercury was not injured. Both vehicles were towed due to damage.

ROLLOVER DISCUSSION

The Krystal bus was not equipped with any rollover mitigation features. Following the impact with the Mercury, the bus rotated clockwise as it traveled toward the east side of the roadway. As the vehicle rotated the left rear and left front tires created yaw marks on the roadway (**Figure 8**). The yaw mark from the left rear tires began 36 cm (14.2 in) west of the left lane line of the acceleration lane and extended 32 m (105 ft) northeast where it ended at the outside edge of the shoulder. The tire mark from the inside left rear tire ended approximately in the center of the acceleration lane as the tire began to lift off the pavement (**Figure 10**) indicating the area where

the vehicle was beginning to rollover. The yaw mark from the left front tire began in the approximate center of the acceleration lane (**Figure 10**) and extended 14.4 m (47.2 ft) northeast to the outside edge of the shoulder. At this point the vehicle had rotated clockwise approximately 50 degrees from its original heading on the roadway. The left front tire mark continued an additional 3.3 m (10.8 ft) through the grass and broadened into an irregular shaped furrow that joined with a large ground disturbance. The ground disturbance (**Figure 9**) indicated the area where the left side of vehicle touched down during the first quarter turn of the rollover. The rear portion of the vehicle also contacted the pavement surface during the first quarter turn, which produced scratch marks on the pavement and abraded the vehicle's left roof side rail and roof (**Figure 11**). At this point, the vehicle had rotated clockwise approximately 100 degrees from its original heading on the roadway. The vehicle continued to rollover a total of 6 quarter turns along the negative 16.7% grade of the embankment and came to final rest on its roof heading southeast. The distance traversed during the rollover was approximately 27 m (88.6 ft).

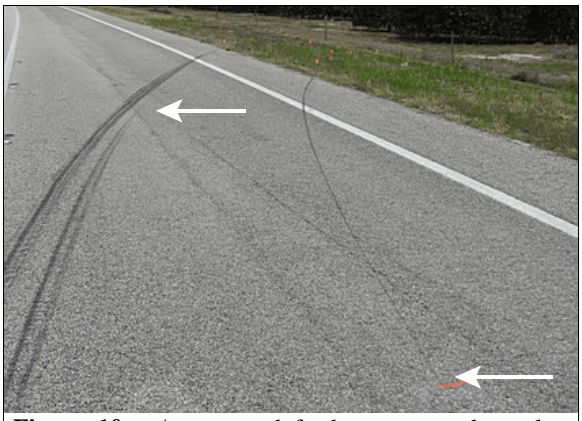

Figure 10: Arrow on left shows area where the inside left rear tire of the bus began to lift off the pavement and the bus began to rollover; arrow on right shows beginning of the yaw mark from the left front tire

Figure 11: Arrows show location of pavement abrasions on the left roof side rail and roof; grass and dirt were entrapped in the roof side rail forward of this area

CASE VEHICLE

The Krystal bus consisted of a 2001 Ford F550 chassis (VIN: 1FDAF56F21E------) with a 2-door cab. The bus was equipped with a 7.3-liter, 8-cylinder diesel engine, automatic transmission, rear wheel drive, and 4-wheel anti-lock brakes. The vehicle's GVWR was 8618 kg (19,000 lbs). The Krystal certification label and Ford incomplete vehicle label are presented in **Figures 12** and **13**. The front row was equipped with bucket seats, integral head restraints, lap-and-shoulder safety belts, and driver and passenger frontal air bags. The bus body was equipped with 33 seating positions in 8 seating rows. A rear-facing bench seat with a folding seat cushion was located in the second row, while the remaining seats were bench seats with folding backs and integral head restraints. None of the seats within the bus body were equipped with restraints.

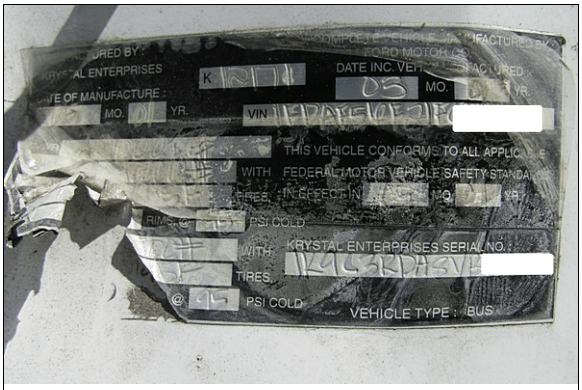

Figure 12: The Krystal Enterprises' vehicle certification label

Exterior Damage: The bus sustained left side damage during the impact with the Mercury. The direct damage began 405 cm (159.4 in) rear of the bus's left front axle and extended rearward 387 cm (152.4 in). The direct damage resided on the fiberglass lower side panel. The damage consisted of scuffs, red paint transfer, and a piece of the side panel 222 cm (87.4 in) in length was broken off the vehicle. The left rear wheel of the bus also engaged the right front wheel of the Mercury. The rim cover was bent and a black rubber transfer approximately 38 cm (15 in) in length was present on the rim cover. The left rear wheel of the bus was displaced rearward 21 cm (8.3 in).

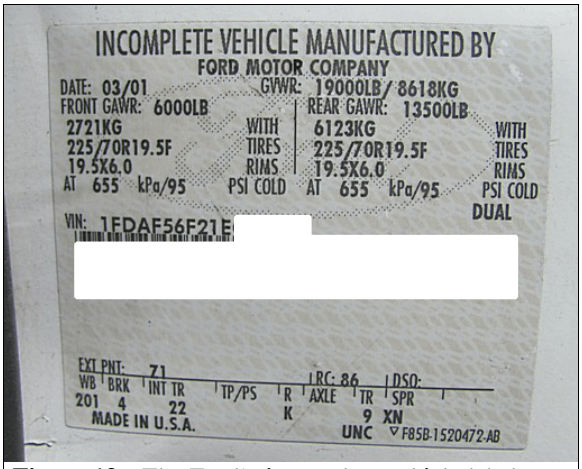

Figure 13: The Ford's incomplete vehicle label

The damage from the rollover involved primarily the left side and top of the Bus. The direct damage on the left side began 48 cm (18.9 in) forward of the left front axle and extended the full length and height of the vehicle. Grass and dirt were entrapped in the roof side rail. The abrasions from the contact with the roadway surface began 79 cm (30.7 in) rear of the left rear axle and extended rearward along the edge of the roof and left roof side rail. The left side of the roof was crushed vertically 42 cm (16.5 in) and shifted to the right (**Figure 14**) 85 cm (33.5 in) as measured at the left roof side rail. The damage on the right side consisted of a dent in the rim cover of the right front wheel with dirt and grass in the rim, and a separated bead on the outboard right rear tire with dirt in the bead. The condition of the right front and right rear wheels indicated that they impacted the ground during rollover.

Figure 14: Front to rear view of the right shift of the roof and status of the outboard seats

The vehicle manufacturer's recommended tire size was 225/70R19.5. The bus was equipped with 245/70R19.5 size tires. The vehicle's tire data are shown in the table below.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	621	90	655	95	3	4	None	No	No
LR Outside	Unk	Unk[1]	655	95	8	10	None	No	No
LR Inside	Unk	Unk[1]	655	95	8	10	None	No	No
RR Inside	565	82	655	95	13	16	None	No	No
RR Outside	Flat	Flat	655	95	14	18	Bead separated[2]	No	Yes
RF	579	84	655	95	10	13	None	No	No

Vehicle Interior: The left front and right front doors of the cab of the bus remained closed during the rollover. Both doors had been opened at some point following the crash and would not close due to the deformation on the door frames. The front portion of the right front door was deformed where it had been forced open against the right fender. The passenger loading door was located on the right side directly behind the front right passenger seat and was separated from the vehicle. The door on the back of the vehicle was open and the door frame was deformed. The latch and striker were damaged and separated. The last seating row consisting of 5 seats was configured across the back of the bus. There was no direct aisle access to the back door.

There was an open fiberglass package compartment located on the roof above the left and right side seating rows. The end structures of both package compartments remained intact but all the vertical supports on both package compartments were broken. Both package compartments remained attached to the roof structure. The left package compartment was shifted inboard over aisle from the rightward lateral displacement of the roof. The left front and right front window glazings of the cab were closed prior to the crash. The left front window glazing was disintegrated from impact forces, while the right front window glazing was undamaged. The windshield glazing was cracked from impact forces. It had separated from the frame along the windshield header and right A-pillar and fallen inside the front row. There were eight window glazings on the left side of the bus body and seven on the right side. Each window was 100 cm (39.4 in) in height and 73 cm (28.7 in) in width. All the side window glazings on the left side of the bus body were either closed or fixed and all were disintegrated from impact forces. The majority of the glass fragments were displaced outside of the bus with some glass fragments randomly distributed inside the bus.

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[1] The valve stem was not accessible.

[2] There was dirt present in the bead indicating the wheel impacted the ground during the rollover.

On the right side of the bus body, the 7th window glazing was disintegrated. Window 6 was separated from the vehicle and window 2 was found open. The remaining glazings were undamaged.

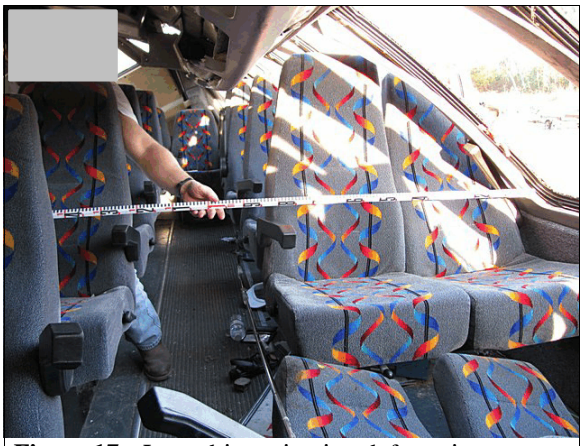


Figure 17: Lateral intrusion into left seating rows

Figure 18: Vertical intrusion into left seating rows

Intrusion: The bus sustained multiple intrusions. The most severe intrusions on the body of the bus involved all the seating rows on the left side of the vehicle. The most severe intrusions into the left seating rows are as follows: (seating rows are numbered front to rear with row 1 residing in the cab of the bus and rows 2-9 residing within the body of the bus)

- Top of window frames and window frame pillars (**Figures 17** and **18**): 94 cm (37 in) lateral and 35 cm (13.7 in) vertical intrusion in rows 2-9.
- Overhead open package compartment: displaced laterally 45 cm (17.7 in) and intruded vertically 41 cm (16.1 in) to 53 cm (20.9 in) in rows 2-6, and 49 cm (19.3 in) to 32 cm (12.6 in) in rows 7-9
- Roof inboard of the package compartment: 38 cm (15 in) to 24 cm (9.4 in) vertical intrusion in rows 2-9
- Side panel below windows: 11 cm (4.3 in) lateral intrusion in rows 2-9.

As a result of the approximate uniform lateral displacement of the roof and left side of the bus body, the available seating space was similarly reduced in all the left seating rows. The resultant seating space dimensions are as follows:

- Lateral distance across the seat cushion from the side of the bus to the inboard edge of the seat cushion (**Figure 17**): 88 cm (34.6 in)
- Lateral distance from the window frame to the inboard edge of the seat back at the top of the seat (**Figure 17**): 0 cm
- Vertical distance from the inboard seat cushion to the top of the window frame (**Figure 18**): 82 cm (32.3 in)
- Vertical distance from the outboard seat cushion to the window frame pillar (**Figure 18**): 30 cm (11.8 in)

Seats Within the Bus Body: There were eight rows of seats within the bus body designed to accommodate 33 passengers. A rear-facing 2-person bench seat with a folding cushion was located at the passenger loading door. A row of five seats was configured across the back of the bus. The left two seats in the back row had folding backs, while the other three were fixed. The

remaining seat rows were configured with 2-person bench seats on each side. These seats were equipped with integral head restraints, folding backs, and arm rests. A figure depicting the seat positions within the bus is presented at the end of this report on page 13.

Figure 19: Separated floor anchor on left row 2 seat

The seats that were located along the sides of the bus were anchored to the floor in a metal channel on the inboard side and to the side of the bus on the outboard side. The seats in rows 3-8 on the left side of the bus were all displaced to the right approximately 6 cm (2.4 in) from the deformation on the left side. All the side anchors on the left side seats remained intact as did all the floor anchors with the exception of seat row 2, where the back anchor was separated from the floor 3 cm (1.2 in) (**Figure 19**). The front floor anchor remained attached. For the seats located along the right side of the bus, the right shift of the bus body deformed the side anchor plate for each seat (**Figure 20**) and it pulled away from the side surface 2-3 cm (0.8 in-1.2 in) in each row. All the side and floor anchors for the right side seats remained attached as did the floor anchors for the seats located across the back of the bus.

Figure 20: Top view of deformed side anchor plate on right row 8 seat

Emergency Exits: The vehicle was equipped with one marked emergency exit, which was located on the roof above seating row 6. The exit dimensions were 57 cm (22.4 in) x 57 cm (22.4 in). The exit door was found in the latched position and was opened to the ventilation position. Windows 1, 4, and 7 on the left side of the bus and 2 and 6 on the right side were equipped with red latch handles and hinged at the top, but they were not marked as emergency exits. Access to the door at the back of the bus was obstructed by the back row of seats.

AUTOMATIC RESTRAINT SYSTEM

The bus was equipped with a driver and front right passenger frontal air bag system. The driver's air bag was located within the steering wheel hub and the front passenger's air bag was located within the middle instrument panel. Neither the driver nor front passenger air bags deployed in this crash.

The bus was equipped with an Event Data Recorder (EDR). The EDR was imaged by the police and there was no recorded data. This model EDR records air bag deployment related information once and air bag deploys. Since the frontal air bags did not deploy in this crash, no data was recorded. This model EDR does not record pre-crash data.

MANUAL RESTRAINT SYSTEM

The bus was equipped with lap-and-shoulder belts for the driver and front passenger seating positions. The seating positions within the bus body were not equipped with restraints. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), sliding latch plate, and an adjustable upper anchor. The adjustment of the upper anchor could not be determined due to the damage on the B-pillar. The front right safety belt was similarly equipped and the adjustable upper anchor was located approximately in the middle position.

The inspection of the driver's safety belt assembly revealed that the retractor was jammed with the safety belt in the retracted position. The driver told police that he was restrained at the time of the crash.

Inspection of the front passenger safety belt assembly revealed a lateral load mark on the belt webbing consistent with loading on the D-ring. The retractor was partially jammed with a length of safety belt extended out of the retractor consistent with usage. This evidence indicated that the front right passenger was probably restrained at the time of the crash.

KINEMATICS ANALYSIS

The initial impact with the Mercury probably resulted in some forward displacement of the bus occupants within their seats. As the bus rotated clockwise following the impact, the occupants were displaced to the left. As the bus rolled over left side leading the occupants continued to be displaced to the left in addition to being redirected toward the roof. During the rollover, eight occupants were ejected and four of them sustained fatal injuries. A fifth occupant sustained fatal injuries but was not ejected. The ejections probably occurred through a window adjacent to their seat positions with the exception of the passenger seated in the window seat of left seating row 2. It was reported that she was ejected through the loading door. The figure[3] on page 13 at the end of this report presents the seat positions, age, sex, injury status, and ejection status of the 32 bus occupants. Evidence of occupant contact within the body of the bus consisted of the following:

- Blood transfer on top outside edge of seat back on inboard seat of row 2, left side
- Arm rest bent to left on inboard seat of row 4, right side
- Arm rest bent to left on inboard seat of row 6, left side
- Hair in top of window frame in row 6, left side
- Abrasions on the window frame in row 6, left side

[3] Information provided by the National Transportation Safety Board investigation team and the Florida Highway Patrol

- Abrasions on window frame in row 8, left side
- Arm rest bent to left on inboard seat of row 8, right side
- Blood transfer on the roof and/or package compartment above all of the left side seating rows except row 9

OTHER VEHICLE

The 2010 Mercury Milan Premier was a front wheel drive, 4-door, sedan (VIN: 3MEHM0JAXAR-------) equipped with a 2.5-liter, I4 engine, automatic transmission, and 4-wheel anti-lock brakes. The vehicle was certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The vehicle was equipped with dual stage frontal air bags, front seat-mounted side impact air bags, and side impact inflatable curtain air bags. None of the air bags deployed in this crash.

Exterior Damage: The Mercury sustained right side damage during the impact with the bus. The right fender, right front wheel, and front portion of the right front door were directly damaged (**Figure 21**). The right front wheel of the Mercury engaged the left rear wheel of the bus during the impact, which displaced the Mercury's right front wheel forward 6 cm (2.4 in) and separated the control arm. The direct damage on the left side plane of the Mercury began 71 cm (28 in) rear of the right front axle and extended 143 cm (56.3 in) forward along the right side. The crush measurements were taken at the upper door level and the residual maximum crush was 12 cm (4.8 in) occurring at C_5 (**Figure 22**). The table below presents the right side crush profile.

Figure 21: Damage on the right fender and right front wheel of the Mercury from the impact with the left side plane of the Ford

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	143	12	143	0	1	5	10	12	0	140	140
in		56.3	4.7	56.3	0.0	0.4	2.0	3.9	4.7	0.0	55.1	55.1

Damage Classification: The CDC for the right side impact 06RYES2 (170 degrees). The WinSMASH program could not be used to calculate a Delta-V for the Mercury since sideswipe impacts and impacts with a bus are out of scope for the program.

The vehicle manufacturer's recommended tire size was P225/45R18. The Mercury was equipped with tires of the recommended size. The vehicle's tire data are shown in the table below.

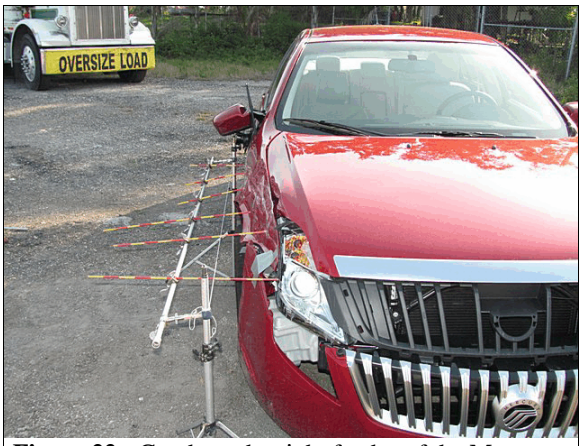
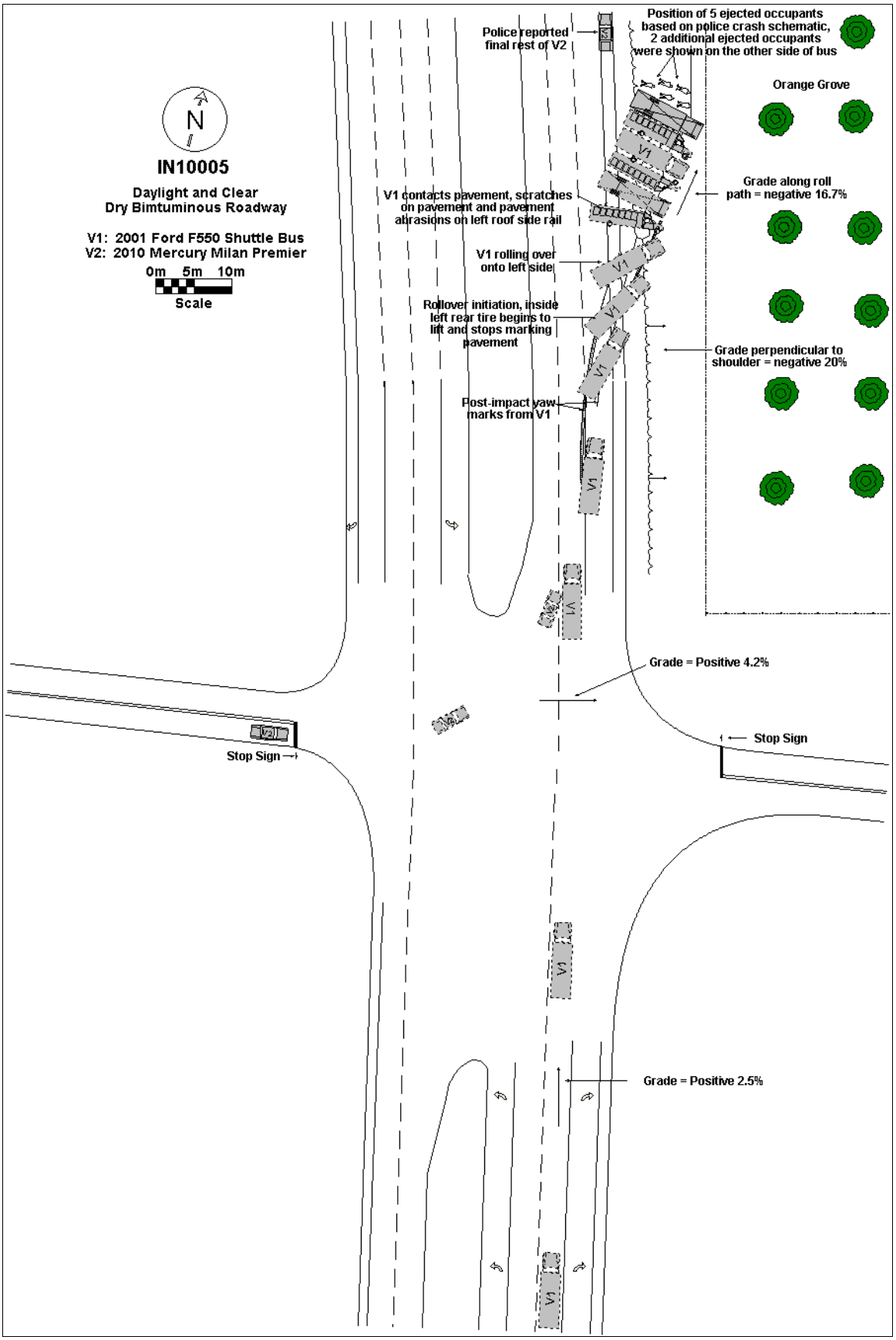
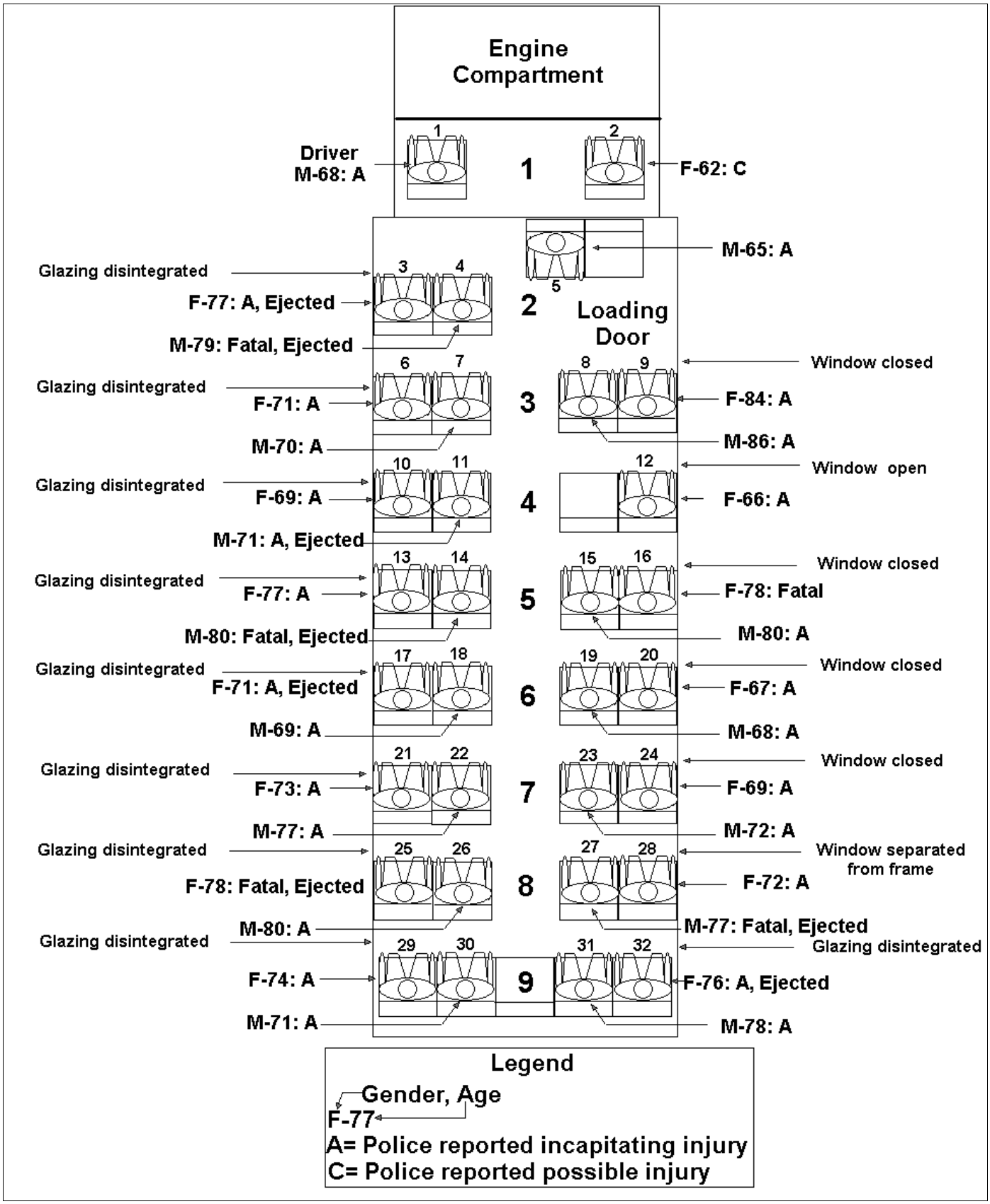


Figure 22: Crush on the right fender of the Mercury

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Cold Tire Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	228	33	241	35	10	12	None	No	No
LR	228	33	241	35	10	12	None	No	No
RR	221	32	241	35	10	12	None	No	No
RF	221	32	241	35	10	12	None	No	No

Other Vehicle's Driver: The police crash report indicated that the driver of the Mercury (81-year-old, female) was restrained by the lap-and-shoulder safety belt and sustained no injury.


N
IN10005
Daylight and Clear
Dry Bimtuminous Roadway
V1: 2001 Ford F550 Shuttle Bus
V2: 2010 Mercury Milan Premier
0m 5m 10m
Scale
Police reported final rest of V2
Position of 5 ejected occupants based on police crash schematic, 2 additional ejected occupants were shown on the other side of bus
Orange Grove
V1 contacts pavement, scratches on pavement and pavement abrasions on left roof side rail
Grade along roll path = negative 16.7%
V1 rolling over onto left side
Rollover initiation, inside left rear tire begins to lift and stops marking pavement
Grade perpendicular to shoulder = negative 20%
Post-impact yaw marks from V1
Grade = Positive 4.2%
Stop Sign
Stop Sign
Grade = Positive 2.5%


Engine Compartment
1
2
Driver
M-68: A
F-62: C
M-65: A
5
Glazing disintegrated
3
4
F-77: A, Ejected
2
Loading Door
M-79: Fatal, Ejected
Glazing disintegrated
6
7
8
9
Window closed
F-71: A
3
F-84: A
M-70: A
M-86: A
Glazing disintegrated
10
11
12
Window open
F-69: A
4
F-66: A
M-71: A, Ejected
Glazing disintegrated
13
14
15
16
Window closed
F-77: A
5
F-78: Fatal
M-80: Fatal, Ejected
M-80: A
Glazing disintegrated
17
18
19
20
Window closed
F-71: A, Ejected
6
F-67: A
M-69: A
M-68: A
Glazing disintegrated
21
22
23
24
Window closed
F-73: A
7
F-69: A
M-77: A
M-72: A
Glazing disintegrated
25
26
27
28
Window separated from frame
F-78: Fatal, Ejected
8
F-72: A
M-80: A
M-77: Fatal, Ejected
Glazing disintegrated
29
30
31
32
Glazing disintegrated
F-74: A
9
F-76: A, Ejected
M-71: A
M-78: A
Legend
Gender, Age
F-77
A= Police reported incapitating injury
C= Police reported possible injury