TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

Advanced Information Engineering Services
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GENERAL DYNAMICS ON-SITE ADAPTIVE CONTROL VEHICLE

DEFECT INVESTIGATION

SCI 1 CASE NO: CA03-063

VEHICLE: 2000 DODGE GRAND CARAVAN SPORT

LOCATION: PENNSYLVANIA

CRASH DATE: OCTOBER, 2003

Contract No. DTNH22-01-C-17002

Prepared for:

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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 are 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.

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16. Abstract

This on-site investigation focused on an alleged open throttle issue in an adaptive control 2000 Dodge Grand Caravan Sport. The vehicle was operated by a 23-year old male with a C5 spinal cord injury that resulted in paralysis of the lower extremities and limited upper extremity mobility. The Caravan was adapted with remote electronic hand controls for the steering, brake, and throttle functions. The driver operated the vehicle from his motorized wheelchair that was restrained by a floor mounted EZ Lock electro-mechanical locking system. His body was essentially unrestrained by an improperly mounted and adjusted manual belt system. While traveling on a rural state route, the driver experienced an alleged throttle issue that resulted in constant acceleration. He attempted to control the Caravan by braking; however, the front brakes over-heated and became ineffective. The driver operated the Caravan for approximately 23 km (14 miles) in this condition. As he was ascending a steep hillcrest, he encountered a slower moving dump truck that was traveling ahead of his position. The driver steered rapidly in a clockwise direction into a farm field to avoid a front-to-rear crash with the dump truck. The driver traversed the cross slope of the field that had a changing grade and an overall negative grade from the road. Additionally, the field curved to the left, dictated by two wide rows of corn that bordered the field. The Caravan traveled a distance of 760 m (2,500') across the field. Located at the back left corner of the field was a row of six large 1.5 m (5.0') diameter round hay bales. The driver steered into the bales with the assumption that the bales would stop the vehicle. The Caravan experienced a full frontal impact with the bales. The impact displaced several of the bales and deflected the vehicle to its left. The Caravan travel 10 m (33') and impacted a 30 cm (12") diameter tree cluster located at the corner of a tree line. The vehicle came to rest against the struck tree. As a result of the frontal impact, the frontal air bag system deployed. The driver was displaced from his wheelchair onto the floor of the Caravan with his left shoulder and head resting on the leading edge of the chair cushion. He expired on the evening of the crash due to hypothermia. Prior to his death, the driver typed a brief chronology of the pre-crash events into a palm computer that was recovered by the investigating officer. Following a three-day air and land search for the driver, the crash site was located approximately 51 hours later, due to the remote location of the vehicle. The subsequent SCI inspection revealed a frayed throttle cable at the location of the servo motor unit for the adaptive throttle and brake controller. This frayed cable prevented closure of the throttle.

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TABLE OF CONTENTS

GENERAL DYNAMICS ON-SITE ADAPTIVE CONTROL VEHICLE DEFECT INVESTIGATION
SCI 1 CASE NO.: CA03-063
VEHICLE: 2000 DODGE GRAND CARAVAN SPORT
LOCATION: PENNSYLVANIA
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BACKGROUND

This on-site crash investigation focused on an alleged open throttle issue in an adaptive control **(Figure 1)** 2000 Dodge Grand Caravan Sport. The vehicle was operated by a 23-year old male with a C5 spinal cord injury that resulted in paralysis of the lower extremities and limited upper extremity mobility. The Caravan was adapted with remote electronic hand controls for the steering, brake, and throttle functions. The driver operated the vehicle from his motorized wheelchair that was restrained by a floor mounted EZ Lock electro-mechanical locking system. His body was essentially unrestrained by an improperly mounted and adjusted manual belt system. While traveling on a rural state route, the driver experienced an alleged throttle issue that resulted in constant acceleration. He attempted to control the Caravan by braking; however, the front brakes over-heated and became ineffective. The driver operated the Caravan for approximately 23 km (14 miles) in this condition. As he was ascending a steep hillcrest, he encountered a slower moving dump truck that was traveling ahead of his position. The driver steered rapidly in a clockwise direction into a farm field to avoid a front-to-rear crash with the dump truck. The driver traversed the cross slope of the field that had a changing grade and an overall negative grade from the road. Additionally, the field curved to the left, dictated by two wide rows of corn that bordered the field. The Caravan traveled a distance of 760 m (2,500') across the field. Located at the back left corner of the field was a row of six large 1.5 m (5.0') diameter round hay bales. The driver steered into the bales with the assumption that the bales would stop the vehicle. The Caravan experienced a full frontal impact with the bales. The impact displaced several of the bales and deflected the vehicle to its left. The Caravan travel 10 m (33') and impacted a 30 cm (12") diameter tree cluster located at the corner of a tree line. The vehicle came to rest against the struck tree. As a result of the frontal impact, the frontal air bag system deployed. The driver was displaced from his wheelchair onto the floor of the Caravan with his left shoulder and head resting on the leading edge of the chair cushion. He expired on the evening of the crash due to hypothermia. Prior to his death, the driver typed a brief chronology of the pre-crash events into a palm computer that was recovered by the investigating officer. Following a three-day air and land search for the driver, the crash site was located approximately 51 hours later, due to the remote location of the vehicle. The subsequent SCI inspection revealed a frayed throttle cable at the location of the servo motor unit for

Figure 1. Interior view of the adaptive controls.

the adaptive throttle and brake controller. This frayed cable prevented closure of the throttle.

The Pennsylvania State Police were summoned to search for the driver and the Dodge Caravan. Following the location of the vehicle and the discovery of the driver's body on October 5, 2003, the PA State Police initiated their investigation of the crash and the circumstances of the driver's death. The police were overwhelmed by the complexity of the adaptive control vehicle and contacted NHTSA assistance. The call was directed to the Office of Defects Investigation. The notification was forwarded to the Crash Investigation Division and subsequently assigned to the General Dynamics Special Crash Investigations team on October 29. Cooperation was established with the PA State Police and an on-site investigation was scheduled for November 5. Cooperating in this on-site investigation were two engineers from NHTSA's Vehicle Research and Test Center (VRTC), a hardware engineer from Electronic Mobility Controls (EMC), and a representative of the company that installed the EMC manufactured adaptive control equipment in the Dodge Caravan. In addition, this company provided extensive training to the driver prior to delivery of the vehicle.

SUMMARY

Crash Site

The events that precipitated this off-road crash occurred on a two lane state route in a rural area. The roadway consisted of an asphalt road surface with approximate 1 m (3') wide paved shoulders that were bordered by grassy road sides and occasional ditches. Local roads and private driveways intersected the roadway along this 23 km (14 mile) path of travel. The roadway followed the irregular terrain of northern Pennsylvania, consisting of curves, S-curves, grades, hillcrests, sags and narrow bridges. The posted speed limit was 89 km/h (55 mph).

On approach to the farm field where the crash occurred, the state route consisted of a positive grade for eastbound traffic that extended for a measured length of 1.0 km (0.6 miles). This positive grade terminated at a hillcrest **(Figure 2)**. The ascending grade immediately prior to the hillcrest averaged 6-7 percent.

Figure 2. Vehicle's ascent to hillcrest prior to road departure.

The off-road segment of this crash site occurred in a farm field. The field consisted of two wide rows of standing dry corn that were separated by a 60 m (200') wide cut section of alfalfa. The field followed the natural flow of the land which consisted of a cross slope that extended generally west to east. The field was planted with the wide rows curving approximately 90 degrees to the east, as viewed from a southeasterly direction from the south (right) road edge. The back section of the farm field was bordered by a treeline that formed a right angle. This field,

as viewed from the road, was downhill with a left curve. This downhill grade consisted of several hills and sags along the vehicle's path of travel. Located at the back left corner of the field was a stack of 1.5 m (5.0') diameter hay bales. These bales were approximately 112 cm (44") in depth and were positioned upright in two rows, three deep as reported by the investigating officer. The bales were positioned forward of the tree line.

The struck tree was a thorn apple cluster that measured 31 cm (12") at the base. The tree split into two branches at a point 61 cm (24") above the ground. The left branch was 14.0 cm (5.5") in diameter while the right branch was 17.8 cm (7.0"). A separate 10 cm (4") diameter trunk extended to the left of the primary trunk. Superficial bark damage was noted to the tree branches that extended 107 cm (42") above the ground.

At the time of the scene inspection that occurred one month following the crash, the stack of hay bales had been moved. Three bales were present near the struck tree. The officer who located the vehicle, observed two distinct rotating tire marks through the cut alfalfa field. These marks were no longer present at the time of the SCI inspection. The tire marks were masked by multiple road and farm vehicles that drove to the crash site. It should be noted that the estimated path of travel for the vehicle covered a measured distance of 763.4 m (2,504.6') across the field. At rest, the vehicle was not visible from the road due to the standing corn, the curvature of the field, and the distance from the road. Although an air search was launched, the canopy created by the leaves and branches of the tree obscured the vehicle from the air.

Vehicle Data – 2000 Dodge Grand Caravan

The involved vehicle was a 2000 Dodge Grand Caravan Sport. The vehicle was manufactured on 3/00 and was identified by Vehicle Identification Number (VIN) 1B4GP44G5YB (production number deleted). The vehicle's odometer reading at the time of the SCI inspection was approximately 58,000 km (36,000 miles). The Caravan (long wheelbase) was equipped with a 3.3 liter, V-6 transverse mounted gasoline engine linked to a four-speed automatic overdrive transmission. The braking system consisted of a power-assisted front disc/rear drum brakes with anti-lock (ABS). The exterior of the van was configured with two front hinge doors, two side sliding doors, and a rear liftgate. The glazing aft of the B-pillars was OEM tinted.

The Caravan was equipped with P215/65R16 Michelin MX4 all-season radial tires that were mounted on OEM alloy wheels. The recommended tire pressures were 241 kPa (35 PSI) at both axle positions. The specific tire data is identified in the following table:

Position	Tire Pressure	Tread Depth	Damage	DOT Number
LF	200 kPa (29 PSI)	6 mm (7/32")	None	M30D68AX0900
RF	200 kPa (29 PSI)	6 mm (7/32")	None	M30D68AXJ600
LR	207 kPa (30 PSI)	3 mm (4/32")	None	M30D68AX0900
RR	186 kPa (27 PSI)	3 mm (4/32")	None	M30D68AX0900

The driver purchased the 2000 Dodge Grand Caravan as a new vehicle from a dealership in August 2001. At the time of purchase, the Caravan had approximately 160 km (100 miles) on the odometer. Additionally, at the time of purchase, the vehicle had been modified with the drop floor, auto-kneel suspension, and the right side mounted bi-fold wheelchair ramp. In the lowered position, the height of the floor was 21.6 cm (8.5") above ground level. It should be noted that the drop floor design required the installation of a fabricated fuel tank that was mounted aft of the axle and the repositioning of the spare tire to a mounting bracket that was installed within the vehicle, rearward of the third seat. A contractor, identified on a label that was affixed to the lower left B-pillar, performed these modifications in March 2000. The label identified the contractor as the following:

The Braun Corporation
631 W 11th Street
P.O. Box 310
Winamac, IN 46996

The Interior of the Caravan was initially configured with seven-passenger seating. The third row, three-person passenger bench seat remained in the vehicle in its original position. The second row seating was removed to facilitate the wheelchair from the ramp position to the driver's position. The OEM front bucket seat was configured with a detachable extended base that could be used in both the front right and driver's position.

An occupational specialist evaluated the driver's driving requirements and a prescription for his adaptive equipment was prepared. The van was transported to a regional company that specialized in the installation of the required adaptive equipment and driver training. The installation of the adaptive equipment for this driver was completed in May 2002. This company was identified as the following:

Keller Wheelchair Lifts
197 Main Street
Luzerne, PA 18709

The OEM 3-point safety belt systems remained intact for the front and three rear seated positions. The four outboard positions were equipped with a 3-point continuous loop lap and shoulder belt webbing with lightweight locking latch plates and emergency locking retractors. The front safety belts were routed through adjustable D-rings. The center rear position was equipped with a fixed length adjustable lap belt that was equipped with a locking latch plate. The Caravan was equipped with OEM power windows and power, automatic locking (speed sensitive) door locks.

Adaptive Controls

The Dodge Caravan was initially modified with the drop floor that extended from the OEM toe pan to the forward aspect of the third seat. This drop floor lowered the full width of the floor approximately 25.4 cm (10.0"). Extension panels were added to the lower aspect of the rear sliding doors to accommodate the low drop floor design. In

addition to this drop floor design, the Caravan was equipped with a bi-fold wheelchair ramp. The electro-mechanical ramp folded upward from its deployed position to its stowed position within the vehicle. To facilitate a low ramp angle from ground level to interior floor level, the Caravan was equipped with an auto-kneel air suspension system that would lower the suspension height at the deployment of the ramp, and raise the suspension to a normal ride height upon stowage of the ramp. Entrance to the Caravan was controlled by a remote key-fob that would unlock the doors and deploy the ramp.

The EZ Lock wheelchair restraining device was identified by Model No. BL6290. This electro-mechanical locking device was centered between two aluminum guide ramps that were fastened longitudinally to the floor of the vehicle to guide the motorized wheelchair into the locking device. The EZ Lock was fastened to the drop floor via four Grade 5 9 mm (3/8") diameter bolts. A manual release lever was located at the forward right corner of the EZ Lock device. A secondary non-mechanical positioning device was located 19.1 cm (7.5") forward of the EZ Lock. The forward aspect of the wheelchair engaged this hook-shaped device that assisted in preventing forward displacement and rotation of the chair in the event of a crash.

A universal retrofit safety belt fastening guide was secured flush to the drop and extended from the aft edge of the B-pillar-to-B-pillar. This guide bar allowed for the installation of a retrofit safety belt system designed for wheelchair usage. The inboard anchorage of the retrofit safety belt system was secured to this guide bar at the mid point of the vehicle.

The Dodge Caravan was equipped with remote steering; a left hand operated remote throttle and brake controller, and a touch pad screen that controlled vehicle ignition, wiper, horn, power windows, power door locks, HVAC, and gear selection functions. These controls were manufactured by Electronic Mobility Controls (EMC) of Baton Rouge, Louisiana. The adaptive controls were monitored by the AEVIT system, which utilized two computers to monitor the steering and throttle/brake systems. The controls were installed by the above referenced contractor, Keller Wheelchair Lifts. The adaptive equipment installed in the 2000 Dodge Caravan was as follows:

Adaptive Throttle and Brake

The remote throttle and brake controller was an AEVIT DL-001, Serial No. 1199 **(Figure 3)**. The unit was mounted on a stalk to the left of the driver's position and consisted of a rectangular control unit that measured 24.1 cm (9.5") in length x 6.4 cm (2.5") in width by 9.5 cm (3.75") in height. A tri-pin hand device was mounted on the stalk of the unit. Fore and aft motion was programmed into the unit to control the throttle and brake functions. In this installation, the forward position controlled the throttle while the aft motion applied the vehicle's service brakes. It was stated during the investigation that the parking brake was activated when the controller was placed in the rear position with the ignition turned to the off-position. In addition to the throttle and brake functions, up to eight vehicle functions could be programmed into this unit. These functions included headlamp activation with highbeam, turn signals, four-way flashers, wiper/washer, etc. To activate these functions, a lateral input was required by the driver through the tri-pin device. A DigiTone audible signal confirmed the function selection.

Figure 3. Adaptive hand control for the throttle and brake functions.

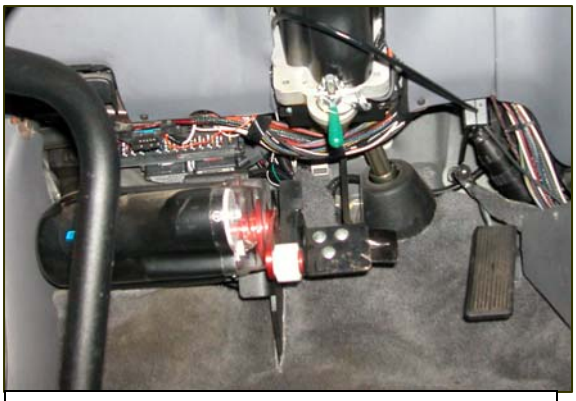


Figure 4. Servo motor and cable routed to the OEM accelerator pedal.

A servo motor control unit was mounted under the left side of the lower left instrument panel/knee bolster **(Figure 4)**. This unit provided the mechanical action to operate the throttle and brake systems following input from the hand controller (DL-001). The throttle was activated by a conventional steel sleeved cable that was routed from a cam arm on the left side of the servo motor unit. This cam arm was 7.6 cm (3.0") in length and was in a horizontal position when the throttle was closed. The arm rotated downward approximately 90 degrees to the full open throttle position. This arm motion pulled on the cable to open the throttle while the OEM throttle return spring closed the throttle unit. The steel sleeved cable was apparently cut to length by the contractor that installed the adaptive controls. The cut end of the cable sleeve was not equipped with an end treatment to prevent cable abrasion from contact with the cut edge of the steel coil sleeve.

The cable was mounted in a vertical position above the cam arm and was routed in a 90 degree loop rearward, crossing the aft aspect of the steering column below the knee bolster. The cable continued to a block clamp that was mounted on the right aspect of the lower instrument panel, above the position of the OEM accelerator pedal. The cable continued forward and was attached to the upper end of the OEM accelerator pedal linkage, above the mid pivot point **(Figure 4)**. Throttle input of the hand control would activate the servo, thus rotating the cam arm and pulling the cable. The cable would operate the OEM accelerator pedal that would then activate the throttle using the OEM cable system to the engine compartment.

Remote Steering

The vehicle steering system was configured with a low-effort remote system that was mounted on a stalk position at the right aspect of the driver's position, near the centerline of the vehicle. The unit was an EMC AEVIT DW-001, Serial No. 1154. The remote steering module consisted of a rectangular control unit with a 15.2 cm (6.0") diameter wheel positioned in a horizontal position. A tri-pin device was affixed to the 15.2 cm (6.0") diameter wheel for driver control/grip **(Figure 5)**. The steering module was hard-wired to a servo motor that was mounted to the aft aspect of the OEM steering column.

Driver input through the remote steering system would rotate the OEM steering assembly, thus activating the low-effort power-assisted rack and pinion steering system.

Figure 5. Remote steering assembly with tri-pin device.

Figure 6. DigiPad II control display with the AEVIT information system.

DigiPad II Control Panel

An electronic touch screen control panel was positioned on a stalk forward of the remote steering system. This unit was an EMC DigiPad II, Gold Edition that provided controls for the vehicle functions (ignition, lights, signals, cruise control, and horn), HVAC, and vehicle shifting. The overall dimensions of this unit were 16.5x19.1 cm (6.5x7.5") with a screen size of 11.4x14.0 cm (4.5x5.5"). On the perimeter of the unit were a series of buttons. The elongated bottoms were used to scroll through the selection guide while the small diameter buttons activated the selected feature. The AEVIT information system was mounted adjacent to the DigiPad II control panel. **Figure 6** is a view of the function touch pad controls.

Motorized Wheelchair

The driver operated the adaptive control Dodge Caravan from a motorized wheelchair. The wheelchair was identified as a Invacare Arrow Storm Series with a Serial No. of 99E61029 and a Model No. of 2GSTMARWR. The rear-wheel drive chair was equipped with a joystick control that was mounted on the left armrest. The chair was not damaged in the crash.

EZ Lock Wheelchair Restraint System

The wheelchair was secured to the vehicle by a floor mounted EZ Lock restraining device. This unit was identified by Model No. BL6290. The EZ Lock was an electro-mechanical device that was secured to the drop floor by four 9 mm (3/8") diameter Grade 5 bolts. A mechanical emergency release lever was located at the upper right aspect of the unit. The wheelchair was equipped with a 2.5 cm (1.0") bolt that was fastened to a plate on the bottom aspect of the chair. This bolt would engage the locking mechanism as the driver motored the wheelchair into his driving position. The system would automatically lock the wheelchair into the EZ Lock that properly engaged into the device.

A manually operated electric release would release the locking mechanism prior for exit from the vehicle.

Located 19.1 cm (7.5”) forward of the EZ Lock and mounted to the drop floor was a fixed position hook that engaged a front frame tube on the chair. This provided a two-point restraining system that would prevent forward excursion and/or rotation of the chair.

Adapted Manual Restraint System

The Dodge Caravan retained the OEM safety belt systems for the front seated positions. These were maintained for use by an able-bodied driver/front passenger if required.

The retrofitted safety belt system that was installed in the Caravan for this driver did not appear to properly restrain him. Although designed as a three-point lap and shoulder belt system, the system was installed as a two-point combination manual/passive restraint system. That is, the system was designed to remain buckled and positioned (when not in use) on the steering wheel. The driver was to position his wheelchair under the belt and place the belt across his body once locked into the EZ Lock system. He apparently did not have the upper arm strength/range of motion to adjust the belt slack. Therefore, the belt was simply placed across his lap and over the arms of the motorized wheelchair as a means of restraint. **Figure 7** is a view of the adjusted position of the retrofitted safety belt with respect to the driver’s position within his chair and the steering wheel rim.

Figure 3. Retrofitted safety belt system in the adjusted positioned worn by the driver.

The inboard aspect of the retrofitted belt system was attached to a stalk that was attached to the floor track that extended laterally across the drop floor at the aft aspect of the B-pillars. The stalk was a steel strap that measured 3.8 cm (1.5”) in width x 3.2 mm (0.125”) in thickness x 65.4 cm (25.75”) in length. A 9 mm (3/8”) diameter Grade 5 bolt secured the belt to the stalk. The belt webbing was attached to the upper end of the stalk with a plastic wire tie. This tie held the upright position of the webbing, which allowed the driver to reach the belt webbing from his wheelchair. The belt webbing length was 128.9 cm (50.75”) from the floor anchor point, terminating at a conventional sewn-on buckle. The outboard aspect of the belt system was attached to the outboard aspect of the left D-ring. This length of belt webbing contained a latch plate and a loop at the lower end to form a 3-point system. The lower loop was to be mounted to the track system adjacent to the left B-pillar. This loop was not attached and did not exhibit evidence that it was ever attached to the vehicle. The latch plate was fastened to the buckle and the free end of the lap belt was knotted around the buckle to fix the adjustment length. In addition to the knot, the inboard aspect of the belt webbing was twisted (three complete twists). In this configuration, this belt system formed a two-point, fixed length shoulder

belt. The overall length of the B-pillar mounted webbing was 102.9 cm (40.5") that formed a shoulder belt that was 231.8 cm (91.25") in length. It should be noted that during the removal of the driver's body, the shoulder belt webbing was cut 9.5 cm (3.75") below the D-ring attachment point.

Crash Sequence

Pre-Crash

The driver of the Dodge Caravan sustained a C5 level spinal cord injury on January 11, 1997, at the age of 16. This injury was related to a snowboard incident. The injury resulted in paralysis from the level of the mid chest and below. The driver did sustain weakness of the upper extremities with limited range of motion of the arms and hands. It should be noted that the driver did hold a valid PA driver's license for a period of approximately six months prior to his spinal injury.

On the day of the crash, the driver placed six bags of trash in the Caravan. He departed his residence at approximately 1230 hours, en route to a trash/recycling center located approximately 29-32 km (18-20) miles east of his residence. The driver entered the Caravan and initiated the procedures to start and operate the van. He proceeded in an easterly direction on the two-lane state route. This route is a rural road in a hilly environment with numerous curves and few straight segments.

As he traveled several miles from his residence, the driver experienced a throttle issue with the vehicle. He noted that his speed had reached 113 km (70 mph) and that he initially attributed it to downhill travel. He attempted to brake with the remote adaptive hand control; however, he could not stop the vehicle. He noted that the vehicle obtained a maximum speed of 137 km (85 mph) as he continued eastbound. The driver continued to ride the brakes while steering onto the roadside in an attempt to scrub off speed. He was traveling with the four-way flashers activated. The driver further noted that he deactivated the cruise control in an effort to control the vehicle's speed.

While traversing a long uphill grade, the driver encountered a slower moving dump truck that crested the hill. To avoid impacting the rear of the truck, the driver of the Caravan swerved to the right into a wide farm field. At this point, he had travel approximately 23 km (14 miles) since the on-set of the throttle issue. A mid thirties female driver of a non-contact minivan was following the Caravan over the last several kilometers and witnessed the erratic driving, the flashers, and the off-road steering maneuver **(Figure 8)**. As the Caravan entered the field, the driver of the non-contact minivan continued eastbound, following the dump truck.

The driver of the Caravan drove the vehicle through a cut section of alfalfa that was bordered by two wide rows of dry corn. The field curved left with a downhill grade. The terrain oscillated through a series of hills and sags with a cross slope. The Caravan traveled approximately 363 m (2,500') across this field, out of sight of passing motorists.

At this point, the driver had severely over-heated the front brakes. Refer to the *Front Brake Inspection* section of this report for further detail on the brake system. The driver

observed a stack of large diameter hay bales. He intentionally steered the Caravan into the bales in an attempt to stop, or slow the vehicle.

Figure 4. Intentional road turn-off trajectory of the Dodge Caravan into the cut alfalfa field.

Figure 5. Trajectory of the Caravan to impact with the hay bales and tree.

Crash

The full frontal area of the Caravan impacted the large round hay bales. The impact resulted in superficial damage to the hood face of the vehicle and displaced several of the bales. The bales redirected the van laterally left as it continued forward. The front left area of the Caravan impacted a tree cluster that was located at the edge of a tree line at the edge of the field. The struck tree was located 763.4 m (2,504.6') from the point of road departure. **Figure 9** is a view of the Caravan's trajectory to impact with the hay bales and tree cluster.

The overall deformation to the front bumper beam resulted from the impacts with the hay bales and tree. Due to the overlapping damage, the crush profiles could not be separated; therefore the entire damage was entered into the Damage Algorithm of the WinSMASH program to compute a maximum velocity change based on the residual damage. The 12 o'clock direction of force impacts resulted in a velocity change of 19 km/h (11.8 mph) with a longitudinal component of -19 km/h (-11.8 mph) and a 0 km/h lateral component. The redesigned frontal air bag system deployed as a result of the crash events, however, the specific event that triggered the deployment could not be determined.

Post-Crash

The Dodge Caravan came to rest against the struck tree. At rest, the vehicle was obscured from the road by the cornfield, the distance from the road, and the tree line. The canopy created by the tree braches and leaves obscured the Caravan from the air.

The driver, although improperly restrained by the poorly adjusted and configured safety belt system, initiated a forward trajectory and loaded the deployed driver's air bag. He subsequently submarined the steering assembly and safety belt system and came to rest on the front left floor of the Caravan with this left shoulder and head resting on the cushion of his wheelchair. At rest, he was facing the left door.

The driver sustained superficial abrasions of the upper and lower extremities. He did not sustain internal injury, as he remained alert and conscious post-crash. Due to his pre-crash condition, the driver did not have the arm strength to alter his position. He was able to retrieve a palm computer that was stored in a pocket on the right side of the wheelchair. He used this computer to type a chronology of the events that led up to the crash, indicating his speed, and inability to stop the vehicle which he attributed to the cruise control accelerate button on the right spoke of the steering wheel.

The driver expired due to hypothermia. His body was discovered approximately 51 hours following his departure from his residence following a report from the driver of the minivan who witnessed him drive off the road. The medical examiner estimated that the death occurred on the first night, as temperatures dropped to approximately 1 degree C (30 degrees F).

Vehicle Damage

The full frontal width of the Caravan sustained superficial abrasions from the initial impact with the large diameter hale bales. The hood face was dented full width from contact with the bales. This impact displaced several of the bales and deflected the Caravan laterally to its left. The right front fender and right door sideswiped the bales as the vehicle continued on a trajectory to impact with the tree. The left side engagement resulted in superficial abrasions and deformation of the sheet metal fender and door panel. The Collision Deformation Classification (CDC) for this impact was 12-FDEW-1.

Figure 10. Frontal damage to the Dodge Caravan.

Figure 11. Lateral view of the crush profile.

The front left area of the Caravan impacted a tree cluster that was located at the back corner of the field within the tree line. The impact resulted in 25 cm (9.75”) of maximum crush located on the bumper beam, 18 cm (7.0”) left of the centerline. The cluster

consisted of three branches that spread from a 31cm (12.0") diameter trunk. The direct contact damage began 15 cm (6.0") left of center and extended 68.6 cm (27.0") to the left corner **(Figure 10)**. The frontal impacts separated the fascia from the bumper beam. The tree impact deformed the full width of the bumper fascia resulting in a combined induced and direct damage (Field L) length of 131 cm (51.75"). Six crush measurements were documented at the level of the bumper beam **(Figure 11)** and were as follows: C1 = 11 cm (4.5"), C2 = 10 cm (4.1"), C3 = 15 cm (6.0"), C4 = 10 cm (3.875"), C5 = 4 cm (1.75"), C6 = 5 cm (2.0"). It should be noted that the bumper beam crush profile was the result of the tree and hay bale impacts. The CDC for this tree cluster impact was 12-FYEW-1.

Frontal Air Bag System

The 2000 Dodge Caravan was equipped with a redesigned frontal air bag system for the driver and front right occupant positions. The air bag system was not altered for this vehicle. The system did deploy as a result of the frontal crash from either the hale bale impact or the tree impact. The Caravan was not equipped with an Event Data Recorder (EDR).

There was no damage to the frontal air bag system or displacement of the adaptive controls from air bag expansion. Several small red dots (possibly blood) were noted to the backside of the driver's air bag.

Driver Demographics

Age/Sex:	23-year old/Male
Weight:	50 kg (110 lb), estimated by police
Seated Position:	Seated in motorized wheelchair
Restraint Usage:	Improper restrained by a retrofit two-point shoulder belt system
Usage Source:	Vehicle inspection
Medical Treatment:	None, expired at scene due to hypothermia

Driver Training

The driver received an extensive training program for this adaptive control vehicle that involved 28 hours of in-vehicle and road training. The training was provided by a certified instructor from Keller Wheelchair Lifts. The driver was deemed an excellent driver by Keller. Following his training, the driver successfully completed the requirements and passed the road test for the Pennsylvania driver's license on October 24, 2001. A representative from Keller noted that the state instructor rated the driver's driving skills as excellent. It should be noted that the driver did hold a valid PA driver's license for a period of approximately six months prior to his spinal injury.

The representative from Keller stated to the SCI investigator that the 28 hours of driver instruction did not cover emergency procedures in the event of system malfunction. He did obtain approximately 18 months of driver experience and was noted to have driven on several trips that covered approximately 800 km (500 miles) in each direction. His experience included both city and rural driving.

Driver Injuries

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
Death due to hypothermia	N/A, not coded under AIS90/Update 98	Exposure to the cold temperatures
0.7 cm abrasion with contusion of the dorsal left wrist and over the medial aspect of the left forearm	Minor (790202.1,2; 790402.1,2)	Remote adaptive tri-pin throttle and brake controller
0.6 cm round abrasion of the ventral proximal right forearm; 10 x.4.5 cm abraded contusion of the right distal forearm extending onto the right wrist and hand	Minor (790202.1,1; 790402.1,1)	Remote adaptive steering system
1.5 cm contusion of the dorsum of the left thumb over the distal interphalangeal joint	Minor (790402.1,1)	Left instrument panel
2.8 cm abrasion over the postero-lateral proximal right arm adjacent to the axially apex	Minor (790202.1,1)	Shoulder belt webbing
1.6 x 0.7 cm abrasion of the posterior-distal right arm with two closely spaced abrasions with contusions of the lateral and medial right elbow	Minor (790202.1,1; 790402.1,1)	Adaptive remote steering system
2.2 x 2 cm contusion with abrasion of the medial aspect of the distal left thigh with a 2.5 cm contusion of the left knee	Minor (890202.1,2; 890402.1,2)	Knee bolster
1.5 cm oval abrasion of the left anterior shin; two linear parallel abrasions of the left shin, and a 1.4 cm abrasion of the anterior left shin	Minor (890202.1,2; 890402.1,2)	Servo motor unit for throttle and brake functions
6 x5 cm abrasion with contusion over the right knee and a 3.5 x 0.4 cm abrasion over the antero-medial proximal right shin	Minor (890202.1,1; 890402.1,1)	Knee bolster

Injury	Injury Severity (AIS 90/Update 98)	Injury Mechanism
1.6 x 0.5 cm abraded contusion of the lateral aspect of the right hip over the lateral aspect of the anterior-superior iliac spine	Minor (890202.1,1; 890402.1,1)	Right arm/side panel of the motorized wheelchair

Source – Autopsy Report

Driver Kinematics

The driver of the adaptive control Dodge Caravan was seated in his motorized wheelchair that was secured to the drop floor of the vehicle by the electro-mechanical EZ Lock restraint device. He was not restrained by the OEM manual 3-point lap and shoulder belt system. The driver was improperly restrained by the adapted two-point shoulder belt that was attached to the floor track at the inboard aspect and to the left B-pillar D-ring attachment point. The adjusted length of this belt was 231.8 cm (91.25") between the two mounting points, therefore creating approximately 50 cm (20") of slack between the driver's torso and the webbing. Supplemental restraint was provided by the deployment of the redesigned frontal air bag system. The driver was seated in a presumed upright posture in his wheelchair with his hands positioned in the adaptive tri-pin devices on the hand controls for the throttle and brake and remote steering system. His upper extremities were not in the path of the deploying driver's air bag.

At impact with the hay bales, the driver was displaced forward. He was displaced further forward following the tree impact. The redesigned frontal air bag system deployed during the crash sequence. Due to the lack of an onboard Event Data Recorder (EDR), the specific impact event that produced the air bag deployment could not be determined with certainty. The hale bales had been moved prior to this on-site SCI investigation; therefore the specific placement and impact with the bales could not be determined.

Figure 12. Driver's seated position and the adjusted position of the retrofitted safety belt.

Due to the lack of proper restraint **(Figure 12)**, the driver responded to the frontal crash forces and moved forward. His torso and face loaded the deployed air bag as his pelvic region began to submarine the steering column and the retrofit shoulder belt system. There was no contact evidence on the deployed air bag and no deformation of the steering wheel rim and/or energy absorbing column. The driver sustained multiple abrasions and contusions from probable contact with the adaptive hand controls and instrument panel. He sustained an abrasion of the postero-lateral aspect of the right arm adjacent to the axially apex from contact with the retrofitted shoulder belt as he submarined the steering assembly. The driver sustained

an abraded contusion of the lateral aspect of his right hip that probably resulted from contact with the right side panel and armrest of the motorized wheelchair.

His left knee/lower leg contacted the left aspect of the knee bolster. This contact scuffed the bolster panel 48.3-54.6 cm (19.0-21.5") left of center and 10.2-19.1 cm (4.0-7.5") below the upper instrument panel. An additional scuff mark was noted to the throttle and brake servo motor unit that was mounted below the left aspect of the bolster panel. The driver sustained a 2.5 cm contusion of the left knee and a 2.2 x 2 cm contusion with abrasion of the medial aspect of the distal left thigh from the bolster contact. The servo motor contact resulted in abrasions of the left shin. Although there was no contact evidence to the right aspect of the bolster panel, the driver sustained a large abrasion with contusion of the right knee with an abrasion over the proximal right shin.

The driver continued forward as his lower extremities buckled due to his paralysis. He came to rest in a slumped position on the front left floor of the Dodge Caravan with his left shoulder and head resting on the leading edge of the wheelchair seat cushion. At rest, he was facing the left front door panel.

Post-Crash Driver Activities

The driver of the Dodge Caravan remained conscious and alert following the crash. He retrieved a palm computer that he stored in a pocket on the right side of the motorized wheelchair and entered a brief chronology of the sequence of events that preceded the crash. In these notes, he identified a throttle issue that he related to the cruise control accelerate button on the steering wheel. He further noted that he attempted to control the vehicle by braking; however, he could not stop the Caravan as he overheated the brakes. He entered this statement approximately 3-3.5 hours following the crash.

The driver was dressed in a white T-shirt with a long sleeve pullover shirt, khaki cargo pants, socks and sneakers. Additionally, he was wearing a circumferential elbow pad on his right arm that extended from the distal left arm to the proximal forearm. The temperature dropped to approximately 1 degree C (30 degrees F) on the night of the crash. This temperature was officially recorded at a location that was located approximately 29 km (18 miles) north of the crash site.

The driver's body was discovered approximately 51 hours following his initial departure from his residence, following a report from the driver who observed him depart the roadway and steer into the field as he avoided the dump truck. He was pronounced deceased at the crash site. His body was transported to the regional Medical Examiner's office where an autopsy was performed. The Medical Examiner concluded that the caused of death was due to hypothermia. He further concluded that the death probably occurred during the night of the crash. The autopsy did not reveal any internal injury other than soft tissue abrasions and contusions.

It should be noted that this crash occurred in a rural area of Pennsylvania with minimal cellular telephone coverage. The Pennsylvania State Police noted that the area of the crash was within the cellular blackout area.

Defect Investigation Results

A Pennsylvania State Trooper with expertise in vehicle mechanical systems was summoned to the scene of the crash to provide an initial assessment of the vehicle. He opened the hood of the Dodge Caravan and observed the throttle plate was opened approximately 1.3 cm (0.5") from its closed position. He further noted that the battery was ajar from its OEM position, resting against the air intake duct. As he attempted to reposition the battery, the throttle plate retracted to the closed position. He did not pursue further investigation of the throttle system due to the complexity of the adaptive controls.

Figure 13. Open throttle position resulting from the frayed cable.

During the on-site SCI investigation that was coupled with an inspection by engineers from NHTSA's VRTC, the mechanical throttle system was initially investigated for potential defects. Upon throttle application of the OEM accelerator pedal, the engine throttle plate opened and returned to within 9 mm (0.375") of its closed position **(Figure 13)**. The OEM throttle cable extended full length and operated freely during this inspection step. This process was repeated and again the throttle fully opened and returned to the partially closed position. The throttle cables within the engine compartment appeared to be free of defect.

The passenger compartment components of the throttle assembly were inspected. These components included the OEM pedal, pivot, and cable; the servo motor assembly and the cable that translated the hand control inputs from the servo motor unit to the OEM gas pedal.

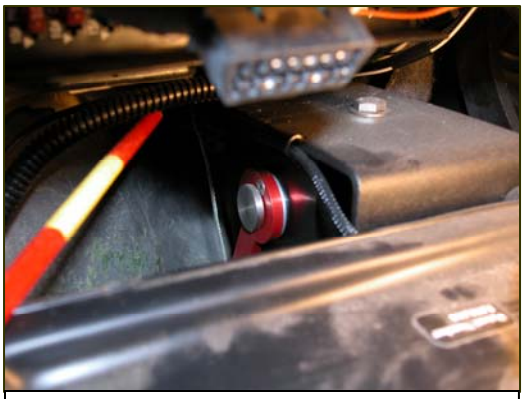


Figure 14. Cable and servo motor cam arm centered in image.

Figure 15. Frayed adaptive control throttle cable.

The retro fitted steel sleeved cable that connected the cam arm on the servo unit to the OEM gas pedal was looped at the downstream end, between the sleeve and the cam arm. The cam arm was rotated downward to extend the cable **(Figure 14)** and open the throttle. As this step was initiated, the loop was straightened and the cable extended from the sleeve. Upon release of the cam arm, the cable failed to retract within the sleeve. It was observed that the cable was frayed **(Figure 15)** over a 1.3 cm (0.5") length. The frayed segment of cable partially engaged within the sleeve, but snagged at the cut end of the sleeve, which prevented the throttle from fully closing. This process was repeated several tines during this investigation with the same results. All other components associated with the throttle system appeared to be fully operational. It should be noted that there were no attempts to start the engine of the Caravan during this investigation.

Front Brake Inspection

The driver noted that he applied the brakes and could smell the brakes burning prior to his intentional road departure. The mechanical inspector for the PA State Police removed the front wheels during his inspection of the vehicle and noted the front brakes had overheated to a point where the backer plate for the inboard disc brake pad had deformed. He further noted heat-related damage to the lower ball joint boots and to the ABS wheel sensors.

The front wheels were removed and the SCI investigator dismantled the brakes during this on-site investigation. The initial observation revealed severe scoring of the brake rotors and deformation to the backer plate of the inboard brake pads. The heat generated by the brakes resulted in a bluish discoloration to the rotors and to the top surface of the brake calipers.

The 10 mm bolts were removed that fastened the calipers to the steering spindle castings. Due to the extreme heat that was generated during the prolonged braking, the calipers were seized to the mounting brackets. A long pry-bar was used to free the calipers from the spindle assemblies.

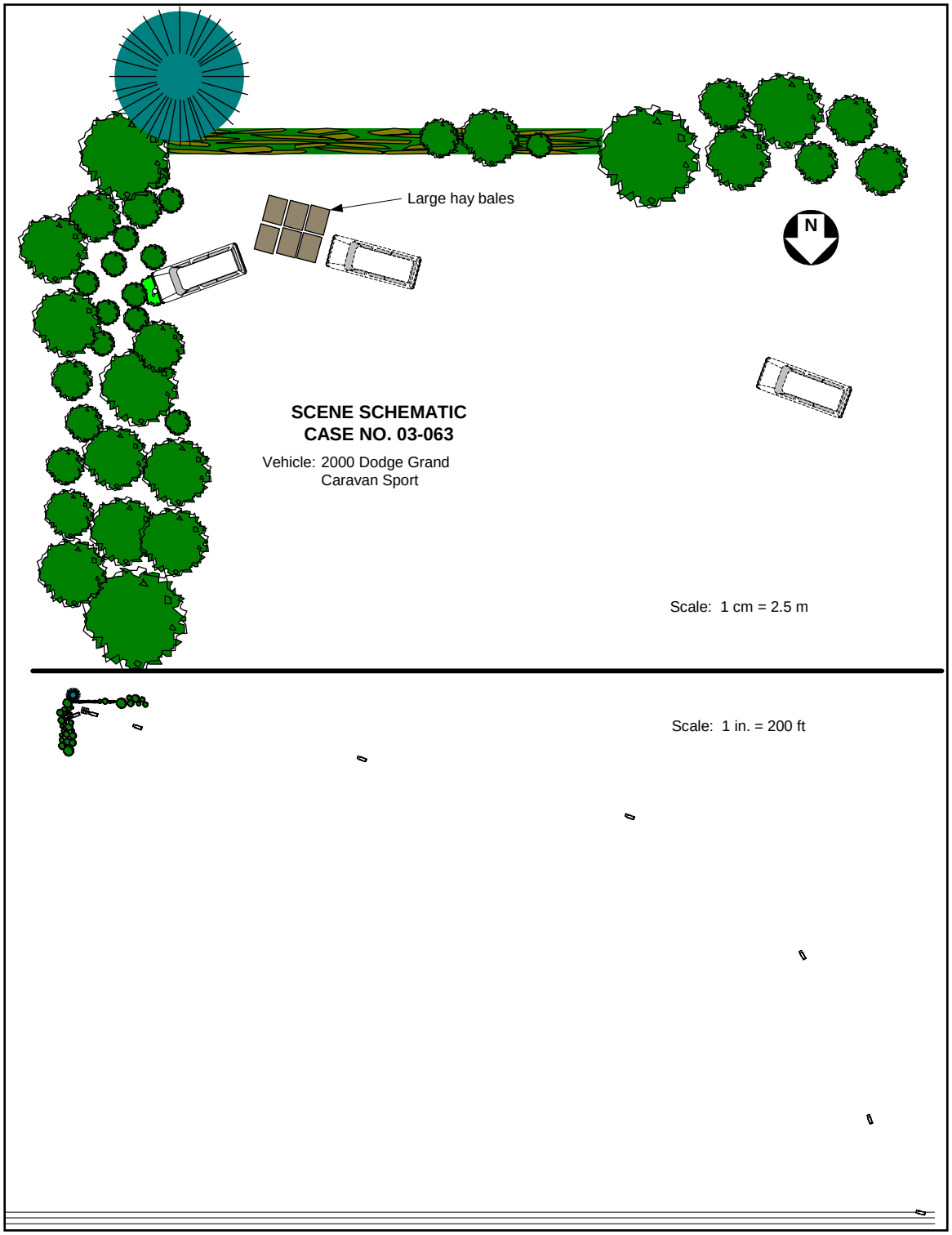
As the front calipers were removed, the riveted brakes pads were inspected and removed from the calipers. The outboard pads were worn to the rivet heads and sustained severe degradation due to heat. The riveted linings and rivet heads in the area of the caliper pistons were completely worn away to the backer plate **(Figure 16)**. The backer plates were bowed inboard with brake lining remaining on the winged sections of the plates. The piston side of the backer plates were eroded from engagement with the piston. The alloy caliper pistons were melted **(Figure 17)** at the engagement points with the brake pad. The heat that was generate by this prolonged braking melted the caliper piston boot (seal), the boots for the caliper slides, the lower ball joint boots, the outer tie rod boots, with minimal burn evidence visible on the ABS wheel sensors. Due to the piston boot damage, brake fluid was leaking from the calipers during this inspection process.

Figure 16. Left front disc brake pads. Note deflection of lower (piston side) backer plate.

Figure 17. Deteriorated left front brake caliper piston and boot seal.

Conclusion

Based of the observations of the frayed throttle cable that extended from the adaptive throttle servo motor unit, this frayed cable prevented the throttle from closing during vehicle operation. The driver experienced an open throttle issue and attempted to override the open throttle by prolonged application of the service brakes. He could not stop the vehicle as the brakes became over-heated. He intentionally steered off-road to avoid an impact with the dump truck and traveled 0.8 km (0.5 mile) off-road to the impacts with the hay bales and the tree. He ultimately succumbed to the elements due to his remote final rest position. Furthermore, the driver did not receive emergency driving training for this vehicle as he continued to drive the adaptive Caravan with a stuck throttle for a distance of 22+ km (14+ miles).



Scene Schematic