Collision Warning Systems
Supplemental Information Report

HWY-09-MH-015
Miami, OK

(12 pages)

NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF HIGHWAY SAFETY
WASHINGTON, D.C. 20594

SUPPLEMENTAL INFORMATION REPORT

A. ACCIDENT

Location:	Interstate 44 (I-44) East, Will Rogers Turnpike, at Milepost 321.5, in Ottawa County, Oklahoma, approximately 8 miles northeast of Miami, Oklahoma
Vehicle 1:	2008 Volvo Truck Tractor and 2009 Great Dane Refrigerated Semi-Trailer Combination Unit Operated by: Associated Wholesale Grocers Inc. of Springfield, MO
Vehicle 2:	2003 Land Rover SUV
Vehicle 3:	2003 Hyundai Sonata Passenger Car
Vehicle 4:	2004 Kia Spectra Passenger Car
Vehicle 5:	2000 Ford Windstar Minivan
Vehicle 6:	2004 Ford F350 Pickup Truck and 16-foot Livestock Trailer
Vehicle 7:	2008 Chevrolet Tahoe SUV
Date:	June 26, 2009
Time:	Approximately 1:22 p.m. CDT

NTSB # - HWY-09-MH-09

B. ACCIDENT SUMMARY

About 1:13 p.m. CDT on Friday June 26, 2009 an 18-year-old driver operating a 2001 Ford Focus passenger car eastbound on I-44 Will Rogers Turnpike near milepost 321.76 drifted into a parked truck tractor semi-trailer on the right-hand shoulder. After the Ford side-swiped the semi-trailer wheels the driver overcorrected, lost control and struck the concrete median barrier twice, before coming to rest in the roadway and blocking the dual eastbound lanes. Traffic began stopping and a queue developed before passing motorists could push the disabled vehicle to the right-hand shoulder. The queue of stopped and slowing vehicles extended back approximately 1500 feet to milepost 321.5.

Meanwhile, a 76-year-old truck driver operating a 2008 Volvo truck tractor and a 2009 Great Dane refrigerated semi-trailer was traveling eastbound in the outside lane. The combination unit had crested a vertical curve down a 2.75 percent grade toward the stopped traffic, approximately 1,735 feet away. Witnesses stated the combination unit was traveling about 70 mph in the posted 75 mph zone, did not brake to slow down and collided into the rear of the stopped and slow moving traffic. This accident occurred at 1:16 p.m. CDT or about three minutes after the first accident.

At initial impact, the combination unit struck a 2003 Land Rover SUV, pushing it forward into a 2003 Hyundai Sonata passenger car; the Land Rover continued off to the right where it came to rest on the right-hand grassy right-of-way. The combination unit continued forward approximately 42 feet and collided into the Hyundai, overriding it and pushing it forward about 29 feet to where the combination unit then struck and overrode a 2004 Kia Spectra passenger car. The combination unit and the two passenger vehicle continued forward into the rear of a 2000 Ford Windstar minivan, which was also partially overridden by the combination unit. The Ford minivan was pushed forward into the rear of a 16-foot livestock trailer (loaded with 10 head of sheep) being towed by a 2004 F350 pickup truck. The F350 pickup truck was then pushed forward into a 2008 Chevrolet Tahoe. The combination unit came to final rest on top of the Hyundai, Kia, and a portion of the Ford minivan. From the initial impact to final rest, the combination unit traveled approximately 270 feet, leaving gouges and friction tire marks on the pavement.

At the time of the accident the weather was clear and the pavement was dry.

As a result of the collision, 10 occupants in the passenger vehicles were fatally injured; nine passengers were fatally injured at the crash site and one passenger died at an area hospital and four passengers received minor to serious injuries. The driver of the combination unit received serious injuries. Four of the passenger cars were destroyed from impact. The Ford F350, livestock trailer, and Chevy Tahoe had moderate damage. The Volvo truck tractor sustained extensive damage, and the Great Dane semi-trailer was undamaged.

C. INTRODUCTION

The impacting vehicle in this accident was a 2008 Volvo truck tractor, and although it was a late model vehicle equipped with an anti-locking braking system and electronic stability control, it was not equipped with a collision warning system, nor was it required to be according to current federal motor vehicle safety regulations.[1] Information on collision warning systems (CWS), also known as collision avoidance systems (CAS), or forward collision warning systems (FCW or FCWS) is presented in this report for the purpose of providing an informational basis for recommendations on these safety technology systems.

[1] For further details such as specifications and equipment on the 2008 Volvo truck tractor see the Vehicle Group Chairman's Factual Report

The Federal Motor Carrier Safety Administration (FMCSA), whose goal it is to reduce the number and severity of large truck fatalities and crashes, has not proposed any regulations for the use of CWS on commercial motor vehicles at this time. In the last several years, FMCSA has collaborated with the trucking industry to test and evaluate these systems, has defined voluntary operational requirements, and is now promoting voluntary adoption of these systems within the trucking industry.

Although there are many developments involving various CWS in the passenger car arena, CWS for commercial motor vehicles will be the focus of this report. This report will first provide a history of CWS and explain the technology behind the systems by listing some of the commercially available CWS for heavy truck applications. Details regarding the market for these systems, sales, and cost will then be covered followed by a discussion of some of the research that has been completed, and that is currently underway, involving field operational tests, fleet experience, and accident reduction rates.

D. HISTORY OF CWS

Collision warning systems are vehicle-based electronic systems that monitor the roadway in front, and in some applications to the side, of the host vehicle and warn the driver when a potential collision risk exists. Most systems utilize radar technology mounted discretely to the vehicle, typically within the front bumper assembly. When other vehicles or stationary objects are within predefined distances or closing speeds in the forward path of the host vehicle, audible and visual alerts are communicated to the driver from an in-cab display unit. An add-on to this system is Adaptive Cruise Control (ACC) which uses the same technology to adjust or disengage conventional cruise control when it is in use at the time when a collision risk is detected. Some collision warning systems can also engage the foundation brakes of the vehicle when an imminent hazard is detected, this is called *active braking*, and when combined with CWS, the system is often called a Collision Mitigation System (CMS).

The use of radar technology as an automotive safety system dates back to the 1950's.[2] Collision warning systems began to appear as safety devices on large trucks on the 1990's.[3] Since then CWS have matured into a sophisticated technology utilizing advanced algorithms and logic to detect collision risks while filtering out roadway objects such as guardrails and sign posts and operating under various weather and lighting conditions.

i. NTSB Recommendations

In May of 2001 the NTSB made recommendations H-01-6 and H-01-7 to the National Highway Traffic Safety Administration (NHTSA) in the 2001 Special Investigation Report on Vehicle and Infrastructure-based Technology for the Prevention of Rear-end Collisions:[4]

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[2] George Rashid Sr. patented a collision avoidance radar technology for use in motor vehicles in 1953.
[3] The VORAD system, previously owned by Eaton and now owned by Bendix, was introduced in 1995.
[4] National Transportation Safety Board, *Vehicle- and Infrastructure-based Technology for the Prevention of Rear-End Collisions*, Special Investigation Report NTSB/SIR-01/01 (Washington, DC: NTSB, 2001).

H-01-6, Status: Open – Acceptable Action
Complete rulemaking on adaptive cruise control and collision warning system performance standards for new commercial vehicles. At a minimum, these standards should address obstacle detection distance, timing of alerts, and human factors guidelines, such as the mode and type of warning.

H-01-7, Status: Open – Acceptable Action
After promulgating performance standards for collision warning systems for commercial vehicles, require that all new commercial vehicles be equipped with a collision warning system.

Following the investigation of an October 2005 accident where five people were killed when a motorcoach collided with an overturned truck tractor semi-trailer combination unit on Interstate 94 near Osseo, Wisconsin the NTSB issued recommendation H-08-15 to NHTSA in September 2008 regarding a requirement for CWS on commercial vehicles:[5]

H-08-15, Status: Open – Await Response
Determine whether equipping commercial vehicles with collision warning systems with active braking and electronic stability control systems will reduce commercial vehicle accidents. If these technologies are determined to be effective in reducing accidents, require their use on commercial vehicles.

Recommendation H-01-006 to NHTSA is currently on the NTSB Most Wanted List of Transportation Safety Improvements under the area titled "*Prevent Collisions by Using Enhanced Vehicle Safety Technology*." Deployment of vehicle collision avoidance technology has been on the Most Wanted List since November 2007.

ii. Voluntary Operational Requirements

In July 2005 FMCSA published "*Concept of Operations and Voluntary Operational Requirements for Forward Collision Warning Systems and Adaptive Cruise Control Systems On-board Commercial Motor Vehicles*." This document established voluntary requirements that describe the features and functions of CWS and ACC. Sections covered are Functional Requirements, Data, Hardware and Software Requirements, Driver Vehicle Interface Requirements, and Maintenance and Support Requirements.

The among the items included in FMCSA's Voluntary Operational Requirements are that CWS should detect, track, and issue warnings for potential pre-collision conditions based on following interval thresholds when the host vehicle is closing on a vehicle that is accelerating, decelerating, has a constant velocity, has just changed lanes, or that is stopped. Also noted is that CWS and ACC systems should be capable of detecting a vehicle with the same lane of travel at a distance of up to 328 feet on straight roads and on curves with radius greater than 1640 feet.

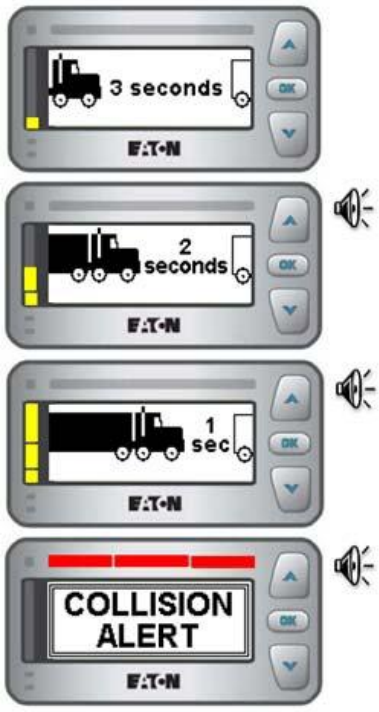
[5] HWY-05-MH-003 Osseo, WI accident report adopted 9/16/2008, report number HAR-08/02

At the time that the Voluntary Operational Requirements were written CWS and ACC systems did not take any automatic actions, such as active braking, to control the vehicle.

E. COMMERCIALLY AVAILABLE CWS FOR HEAVY TRUCKS

i. Bendix VORAD

Formerly known as the Eaton VORAD, Bendix Commercial Vehicle Systems LLC purchased the VORAD system from the Eaton Corporation in January 2009. The latest version of this system, the VORAD VS-400, is in its fourth generation. This CWS uses a forward looking radar sensor that employs both pulsed and Doppler radar along with an in-vehicle processor to detect and provide warnings. The forward looking radar tracks all vehicles that are in front of the host vehicle, as well as those that are in the left and right adjacent lanes ahead of the host vehicle. This system also uses a yaw sensor to calculate turn radius and track the vehicles in the same lane when entering curves.



If a vehicle is detected in the same lane within 350 feet from the radar, but greater than a three second following distance, the driver interface unit will display "Object Detected" in the LCD screen. The driver is alerted with a series of yellow LED indicator lamps at three, two, and one second following distances with the text and warnings displayed on the LCD screen. Audible tones are also introduced when following distance closes to less than two seconds or if the following distance is closing in, warning the driver that the situation is becoming unsafe. If the headway following distance closes to less than 0.5 second, or the radar detects slow moving or stopped traffic within 350 feet of the vehicle, the driver will be alerted with three red LED indicators along with an audible tone. The LCD screen will display "Collision Alert", warning that a collision may occur if the driver does not take immediate action.[6]

The Bendix VORAD also offers an ACC system called SmartCruise, which attempts to maintain a default following distance of approximately 3.25 seconds.[7] When approaching slower moving traffic, or if the traffic ahead suddenly slows down, SmartCruise maintains the following distance by defueling the engine, engaging the engine compression brake, and allowing vehicles equipped with automatic transmissions to downshift.

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[6] Eaton VORAD VS-400 Driver Instructions Publication VODR0100, February 2009.

[7] Some systems allow the driver to adjust the following distance by changing the range setting in the driver interface menu options. The user can adjust the following distance from a maximum of 3.25 seconds down to 2.25 seconds.

Bendix has also introduced a product called Wingman ACB (Active Cruise with Braking). Wingman ACB has many of the same features as the VORAD system; however Wingman ACB enables the foundation brakes to be applied to avoid collisions. Wingman ACB also requires that the vehicle be equipped with an electronic stability system for even braking performance.

ii. Meritor WABCO OnGuard

Meritor WABCO introduced OnGuard in February 2008 as the first commercial vehicle CWS with active braking. OnGuard uses forward-looking radar sensor technology to monitor the distance to a moving vehicle ahead. OnGuard is integrated with Meritor WABCO's anti-locking braking system as well as it electronic, roll stability, and automatic traction control systems.

The OnGuard system is capable of detecting and tracking vehicles up to 500 feet in front of the host vehicle. OnGuard does not detect or track stationary vehicles for objects. OnGuard will only detect and track vehicles traveling above 10 mph, however once a vehicle has been detected OnGuard will continue to track and provide alerts on that vehicle even if it slows down to below 10 mph, or becomes stationary. OnGuard delivers an audible and visible distance warning when the following interval to the vehicle ahead becomes less than 1.5 seconds.

The in-cab display shows the driver the speed of, and distance to, the vehicle in front on them, when detected. The cruise control set speed is also displayed when cruise control is in use. When ACC is on (cruise control is set by the driver) OnGuard attempts to maintain a 3.6 second following distance to the vehicle ahead.

When OnGuard detects that a potential collision is developing, it sends progressive audible and visual warnings through an in-cab dash display so the driver is alerted to take appropriate corrective action. Haptic warnings of one half second .25g brake pulses at one second intervals are also used to gain the attention of the driver. If a potential rear-end collision is developing without the driver taking corrective action to decelerate the vehicle, OnGuard's active braking automatically de-throttles the engine, and applies the engine and foundation brakes to provide up to .35gs deceleration.[8] The driver can override the system at any time by taking the appropriate braking action.

[8] Meritor WABCO Technical Bulletin TP-08122, OnGuard™ Display Operating Instructions, September 2009.

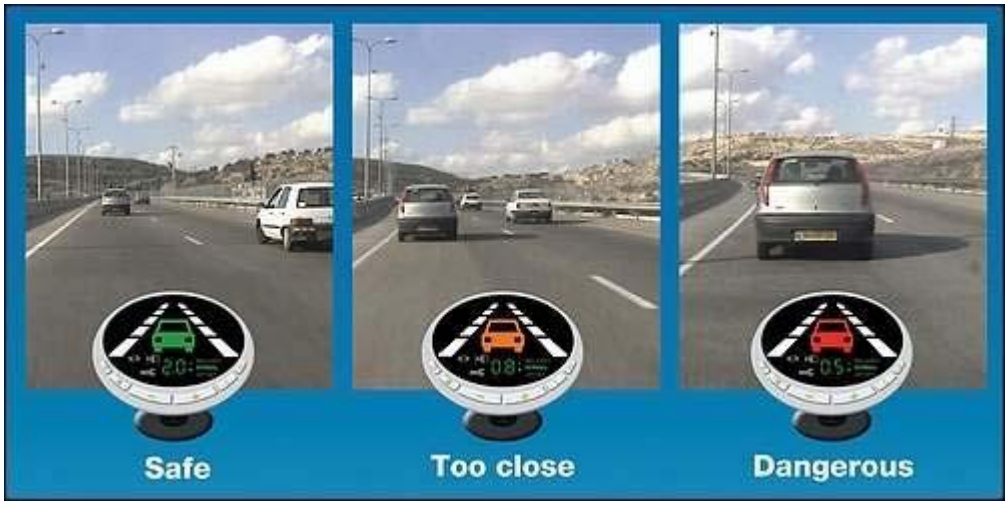
iii. Mobileye

Mobileye is a European system that is predominately on passenger vehicles in the United States and in 2008 was introduced to the American commercial vehicle market.[9] Mobileye is a camera based system that uses vehicle detection algorithms to recognize images of motorized vehicles such as cars, motorcycles and trucks, in the forward path of the host vehicle. Mobileye provides an audible and visible Forward Collision Warning (FCW) to the driver within up to 3.0 seconds in critical closure rates where a collision is imminent. The FCW system detects whether a crash is imminent by computing the 'Time-To-Contact', taking into account host vehicle speed, relative speed, and relative acceleration. Relative speed and acceleration are measured using target image size changes. Images come into the detection range within approximately 100 - 120 meters (328 - 394 feet) of the host vehicle.

The Mobileye FCW algorithm takes into account scenarios where the system is expected to have different sensitivity. Such scenarios include when a vehicle ahead of the host vehicle is standing still since the vision sensor does not require the target to be moving in order to be acquired. Mobileye is advertised to work well in most weather in lighting conditions, however since the camera based system relies solely on vision, objects that cannot been seen (if obscured by fog, snow, etc) cannot be detected. Night vision of this camera based system works by detecting taillights and brake lights of the surrounding traffic.

The Mobileye system also offers a Lane Departure Warning (LDW) system that detects and tracks the lane markings on the roadway. Another feature offered by Mobileye is a Headway Monitoring and Warning (HMW) system that recognizes vehicles in the host vehicle's lane and adjacent lanes and provides headway estimations in seconds to the driver along with an incremental green, yellow, red indicator. The Mobileye's Advanced Warning System (AWS) packages three features: FCW, LDW, and HMW systems. Mobileye also has the capability to communicate with telematic fleet management systems to relay data on driver warnings back to the motor carrier for review.

[9] Mobileye was launched to the commercial vehicle industry in Europe and the Middle East in 2007.



F. CWS MARKET

Volvo Trucks of North America, the manufacturer of the truck tractor in this accident, currently offers the Bendix VORAD system as an available CWS option for factory installation. According to Volvo the estimated cost for this factory option is between $500 and $1,000. Staff found varying cost estimations for VORAD, Wingman, and OnGuard collision warning systems. The estimations varied between $500 and $4,000, but most were around $2,500, depending on what options and features were included. As a comparison, the overall cost of a newly manufactured truck is in the neighborhood of $100,000. According to Volvo, 6.3% of the truck tractors that they have manufactured from 2007 to present have been equipped with an optional CWS.

The Bendix VORAD system is a currently available factory installation option on all major heavy trucks, including Volvo, Freightliner, International, Peterbilt, and Kenworth, with the exception of Mack.[10] The VORAD is also available for aftermarket installation. Bendix estimates that approximately 80,000 systems have been installed as a factory option or aftermarket installation on commercial vehicles since the product was introduced in 1995. According to Bendix the estimated cost of the VORAD system is about $2,000.00 per vehicle.[11] The VORAD system is currently being used by industry fleets including L.J. Kennedy Trucking[12], Hoffman Transportation[13], and Pohl Transportation[14].

The Bendix Wingman ACB system is a currently available option on Volvo, Mack, and International Trucks, and will be an available option on Peterbilt and Kenworth trucks in August 2010.

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[10] Mack is incorporated within Volvo Trucks of North America, and although the VORAD system is not option on this brand, a system by Bendix called Mack Road Stability Advantage is available and offers an ACC feature.
[11] This cost estimate includes all features, SmartCruise, and BlindSpotter.
[12] L.J. Kennedy is a building materials hauler based in New Jersey whose fleet size is approximately 400 tractors, 800 trailers, and 350 drivers.
[13] Hoffman Transportation is a multifaceted hauler based in Illinois with a fleet of 379 Peterbilt tractors.
[14] Pohl Transportation is a dry commodities hauler based in Ohio with a fleet of approximately 130 tractors.

The Meritor WABCO OnGuard system is a currently available factory installation option for International and Freightliner trucks. According to Meritor WABCO the estimated cost for OnGuard is about $2,700. Meritor WABCO estimates that approximately 8,000 units have been sold to date. OnGuard is not available as an aftermarket installation. Fleets currently using the OnGuard system include Crete Carrier Corporation[15], and Maverick Transportation LLC[16].

Mobileye is not a factory installation option for any of the commercial vehicle manufacturers at this time, and is mainly being sold for aftermarket installation in commercial vehicle industry.[17] Mobileye estimates that 35 to 50 thousand of their systems have been installed on commercial vehicles worldwide. The cost for Mobileye's AWS package with fleet management system is about $1,000 for a single application. Volume discounts exist for fleets purchasing a large number of units. Mobileye is currently installed on over 1,200 units in the C.R. England fleet and scheduled to the installed on every truck in their fleet.[18]

G. RESEARCH

In February 2005 a Study titled "*Volvo Trucks Field Operational Tests: Evaluation of Advanced Safety Systems for Heavy Truck Tractors*" was published by Volvo Trucks North America for the U.S. Department of Transportation as part its Intelligent Vehicle Initiative. This four-year Field Operational Test (FOT) Project joined government and industry partners together to evaluate the performance of heavy vehicles integrated with advanced safety systems. The vehicles were operated within the national fleet of US Xpress commercial revenue-generating service.[19] Forward collision warning, adaptive cruise control, and disc brakes with electronically controlled brake systems comprised the advanced safety systems that were studied. The project involved 100 new tractors, 50 built to US Xpress fleet standard specifications, and 50 built with the advanced safety systems.

The advanced safety systems performed well in the FOT. During the 3 years of data collection there were no major system failures. The durability and reliability of the advanced safety systems was as good as or better than comparable standard systems.

The 2005 FOT showed a 28% reduction in rear-end crashes as a result of the CWS, ACC, and brake systems bundled together and a 21% benefit from the CWS alone. Deployment of the CWS system to the 1.8 million vehicle truck fleet was projected to prevent 4,700 rear-end crashes, 2,500 injuries, and 96 fatalities each year. The field test included a driver survey to evaluate driver acceptance. Most drivers said they believed the technologies made them drive safer and over 80% indicated that they would prefer to drive a truck equipped with a CWS. The major complaint about the CWS was the incidence of false alarms. This issue has been addressed by all of the systems detailed in this report, and according to manufacturers, has improved over the past 5 years.

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[15] Crete Carrier Corporation is based in Lincoln Nebraska and is one of the largest nation-wide trucking companies.
[16] Maverick Transportation LLC is based in Littlerock, Arkansas. Maverick is specialized in hauling steel, glass, machinery, and building materials and has an estimated 1,200 power units.
[17] Mobileye is a factory installation option for passenger cars, including BMW, Volvo, GM, Ford, and Hyundai.
[18] C.R. England is a multifaceted trucking company based in Utah that has approximately 3,500 tractors, 5,600 trailers, and 4,600 drivers.
[19] U.S. Xpress Enterprises, INC. is a long haul, expedited, dedicated, and regional transportation company based in Tennessee. U.S. Xpress was established in 1986 and employees about 8,000 people.

Analysis of the CWS was done on the basis of specific, similar initial conditions of driving conflicts in order to isolate the actual effects on driver behavior. The CWS provided a significant risk reduction for rear-end collisions by allowing more time for the driver to react to high-risk, fast-closing situations. CWS reduced the risk of crashes with vehicles ahead in that braking occurred generally earlier in the conflict for trucks with a CWS than for trucks without it. Additionally, drivers generally adopted longer following-distance driving behavior while using CWS. The results of the FOT indicated that the advanced safety systems provide improved safety with regard to rear-end collisions and are ready for commercial deployment.

The FMCSA published *Analysis of Benefits and Costs of Forward Collision Warning Systems for the Trucking Industry* in February 2009. This analysis estimated that the average costs of rear-end crashes are approximately $122,650, $239,063, and $1,056,221 for property-damage-only crashes, injury crashes, and fatal crashes, respectively. It was estimated that between 8,597 and 18,013 rear-end crashes could have been prevented through use of the FCWS from 2001 to 2005. In this FMCSA report the technology and deployment cost estimates for FCWS ranged from approximately $1,415 to $1,843. The FMCSA analysis concluded that many motor carriers will achieve positive returns on investment by purchasing and using FCWS, and even small carriers could realize added benefits related to insurance implications if one or more crashes are preventable using FCWS.

According to Bendix, industry research shows that the VORAD system pays for itself within one year, and can prevent one death per year for every 500 trucks equipped, and that fleets using the VORAD system have reported 73% fewer accidents.[20]

Ongoing research into CWS includes the National Highway Traffic Safety Administration (NHTSA) Crash Avoidance Research Program, which is currently looking into collision warning systems for heavy trucks. NHTSA's Crash Avoidance Research Program also includes the Integrated Vehicle-Based Safety Systems (IVBSS) initiative that addresses forward collision warning, lane departure warning, lane change warning, and curve speed warning. According to the Field Operational Test Plan, published in December 2008, 10 commercial trucks will be included in the fleet of vehicles that are being equipped and tested with crash avoidance technology.[21]

H. SUMMARY

Collision warning systems are available on all newly manufactured truck tractors and are affordable when considering the overall cost of new truck tractor. Fleets are realizing the financial and society benefits of collision warning systems and implementing them voluntarily without mandatory standards or regulations.

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[20] http://www.roadranger.com/Roadranger/productssolutions/collisionwarningsystems/Safety/index.htm

[21]. U.S. Department of Transportation, National Highway Traffic Safety Administration, *Integrated Vehicle-Based Safety System Field Operational Test Plan*, DOT-HS-811-058 (Washington, DC: USDOT, 2008).

The added ability to apply the brakes of a heavy vehicle to help avoid or reduce the severity of a collision when the situation is detected by a CWS is no longer a future characteristic of these systems. In fact, two of the three manufacturers of the systems detailed in this report offer a product that utilizes active braking. Of course all of these systems rely on good foundation brakes that are capable of decelerating the vehicle as efficiently as possible, accordingly proper brake adjustment and maintenance is still important.

And although, like most technologies, CWS are evolving to include new and better features in each new version, the safety advantages of the systems that are on the market today are proven to beneficial in reducing accidents and the injuries and fatalities that they cause.