

**Concept of Operations and  
Voluntary Operational Requirements  
for  
Forward Collision Warning Systems (CWS)  
and  
Adaptive Cruise Control (ACC) Systems  
On-board Commercial Motor Vehicles**



**U.S. Department of Transportation  
Federal Motor Carrier Safety Administration**

**July 2005**

## **Foreword**

The Federal Motor Carrier Safety Administration's (FMCSA's) safety goal is to reduce the number and severity of large truck fatalities and crashes. During the last several years, FMCSA has collaborated with the trucking industry to test and evaluate several on-board safety systems for commercial motor vehicles to increase the safety and security of all roadway users. FMCSA is now promoting voluntary adoption of these systems within trucking fleets by initiating steps to work closely with the trucking industry to define vendor-independent, voluntary requirements.

The purpose of this document is to relay a better understanding of the functions of on-board safety systems for vehicle stability and to provide insight into the safety and efficiency benefits of using the systems. This document describes the concept of operations and voluntary requirements for Collision Warning Systems and Adaptive Cruise Control (ACC) systems for large trucks greater than 10,000 pounds gross vehicle weight rating (GVWR). Concepts of operations provide information about how each user interacts with these safety systems and their operational conditions. Voluntary requirements describe features and functions used to define the safety systems and their operational functionality. The information has been developed in collaboration with trucking industry stakeholders, including representatives from manufacturers, insurance companies, commercial vehicle carriers, drivers and academia.

The results from this project can be used by motor carriers as system guidelines for voluntary adoption of on-board safety systems within their trucking fleets.

This is a final report developed under FMCSA's deployment of on-board safety system program. It does not supersede an earlier report on the subject.

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**SI\* (MODERN METRIC) CONVERSION FACTORS**

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
<u>LENGTH</u>					<u>LENGTH</u>				
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	Yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
<u>AREA</u>					<u>AREA</u>				
in <sup>2</sup>	square inches	645.2	square millimeters	mm <sup>2</sup>	mm <sup>2</sup>	square millimeters	0.0016	square inches	in <sup>2</sup>
ft <sup>2</sup>	square feet	0.093	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	10.764	square feet	ft <sup>2</sup>
yd <sup>2</sup>	square yards	0.836	square meters	m <sup>2</sup>	m <sup>2</sup>	square meters	1.195	square yards	yd <sup>2</sup>
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>	km <sup>2</sup>	square kilometers	0.386	square miles	mi <sup>2</sup>
<u>VOLUME</u>					<u>VOLUME</u>				
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	l	l	liters	0.264	gallons	gal
ft <sup>3</sup>	cubic feet	0.028	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	35.71	cubic feet	ft <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.765	cubic meters	m <sup>3</sup>	m <sup>3</sup>	cubic meters	1.307	cubic yards	yd <sup>3</sup>
<u>MASS</u>					<u>MASS</u>				
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.202	pounds	lb
T	short tons (2000 lbs)	0.907	megagrams	Mg	Mg	megagrams	1.103	short tons (2000 lbs)	T
<u>TEMPERATURE (exact)</u>					<u>TEMPERATURE (exact)</u>				
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
<u>ILLUMINATION</u>					<u>ILLUMINATION</u>				
fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m <sup>2</sup>	cd/m <sup>2</sup>	cd/m <sup>2</sup>	candela/m <sup>2</sup>	0.2919	foot-Lamberts	fl
<u>FORCE and PRESSURE or STRESS</u>					<u>FORCE and PRESSURE or STRESS</u>				
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

\* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

## 1. INTRODUCTION

The Federal Motor Carrier Safety Administration's (FMCSA's) safety goal is to reduce the number and severity of large truck fatalities and crashes. During the last several years, FMCSA has collaborated with the trucking industry to test and evaluate several on-board safety systems for commercial motor vehicles to increase the safety and security of all roadway users. FMCSA is now promoting voluntary adoption of these systems within trucking fleets by initiating steps to work closely with the trucking industry to define vendor-independent, voluntary requirements for these systems.

The purpose of this document is to relay a better understanding of the functions of on-board safety systems and to provide insight into the safety and efficiency benefits of using the systems. The information has been developed in collaboration with expert panels consisting of trucking industry stakeholders, including representatives from manufacturers, insurance companies, commercial motor vehicle carriers, drivers, and academia.

This document describes the concept of operations and voluntary requirements for Forward Collision Warning Systems (CWS) and Adaptive Cruise Control (ACC) systems for large trucks greater than 10,000 pounds gross vehicle weight rating (GVWR). Concepts of operations provide information about how each user interacts with these safety systems and their operational conditions. Voluntary requirements describe features and functions used to define the safety systems and their operational functionality.

This document discusses CWS and ACC systems provided by manufacturers, such as:

- Delphi Electronics and Safety
- Eaton VORAD
- Mobileye

Descriptions of these currently available systems are in Appendix A. United States Department of Transportation (USDOT) websites that contain further information on governmental research, testing and evaluation of CWS and ACC systems include:

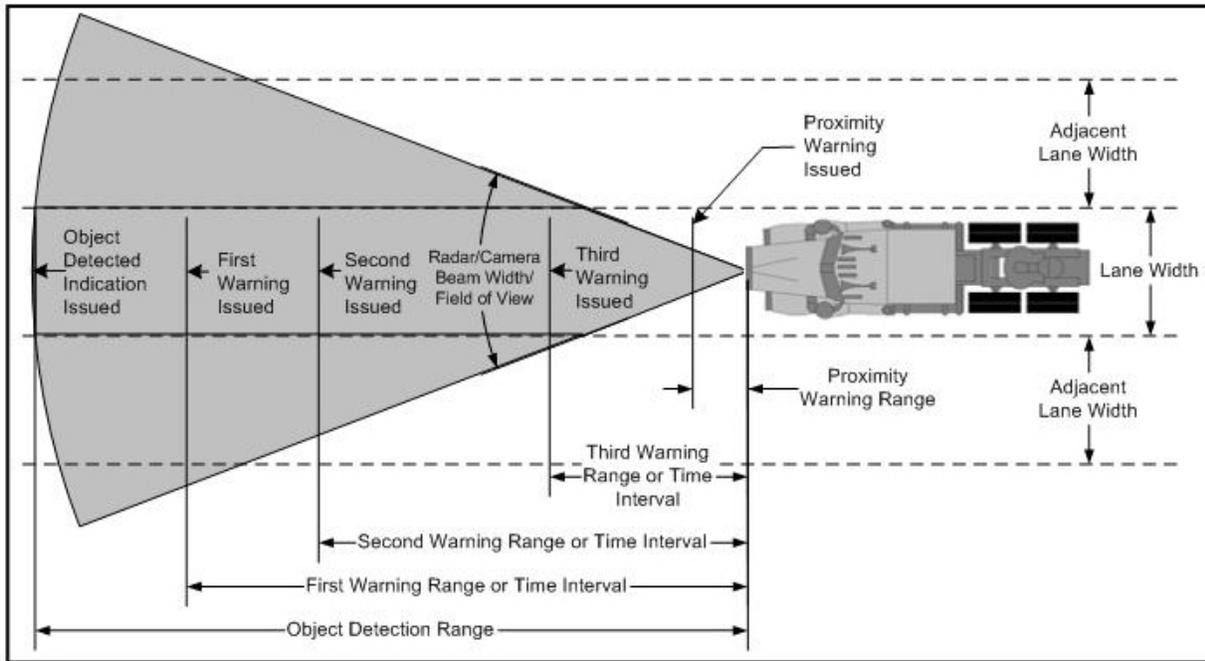
[www.its.dot.gov/ivi/ivi.htm](http://www.its.dot.gov/ivi/ivi.htm)

[www.fmcsa.dot.gov/safetyprogs/research/researchpubs.htm](http://www.fmcsa.dot.gov/safetyprogs/research/researchpubs.htm)

## 2. CONCEPT OF OPERATIONS

### ***Description – Forward Collision Warning Systems***

CWS are in-vehicle electronic systems that monitor the roadway in front of the host vehicle and warn the driver when a potential collision risk exists. For example, currently available radar-based CWS use algorithms to interpret transmitted and received radar signals to determine distance, azimuth, and relative speed between the host vehicle with the CWS and the vehicle or object ahead of it in the lane. When the host vehicle is traveling along the roadway, the CWS can warn the driver when a vehicle or object is in its lane within a predefined closing time threshold. Currently, CWS do not take any automatic action to avoid a collision or to control the vehicle; therefore, drivers remain responsible for the safe operation of their vehicles using both steering and braking, if safe to do so, to avoid a crash. As the time interval to the vehicle ahead decreases, CWS issue a progressively more urgent warning. The system's beam width/field of view forms an isosceles triangle with its apex at the front center of the vehicle. As an object gets closer to the front of the vehicle, a different range or time interval is reached, and the system issues a different type of alarm. The system manufacturers set these warning thresholds. Figure 1 illustrates these progressive thresholds. CWS also warn the driver if the system malfunctions. CWS may be integrated with ACC systems.

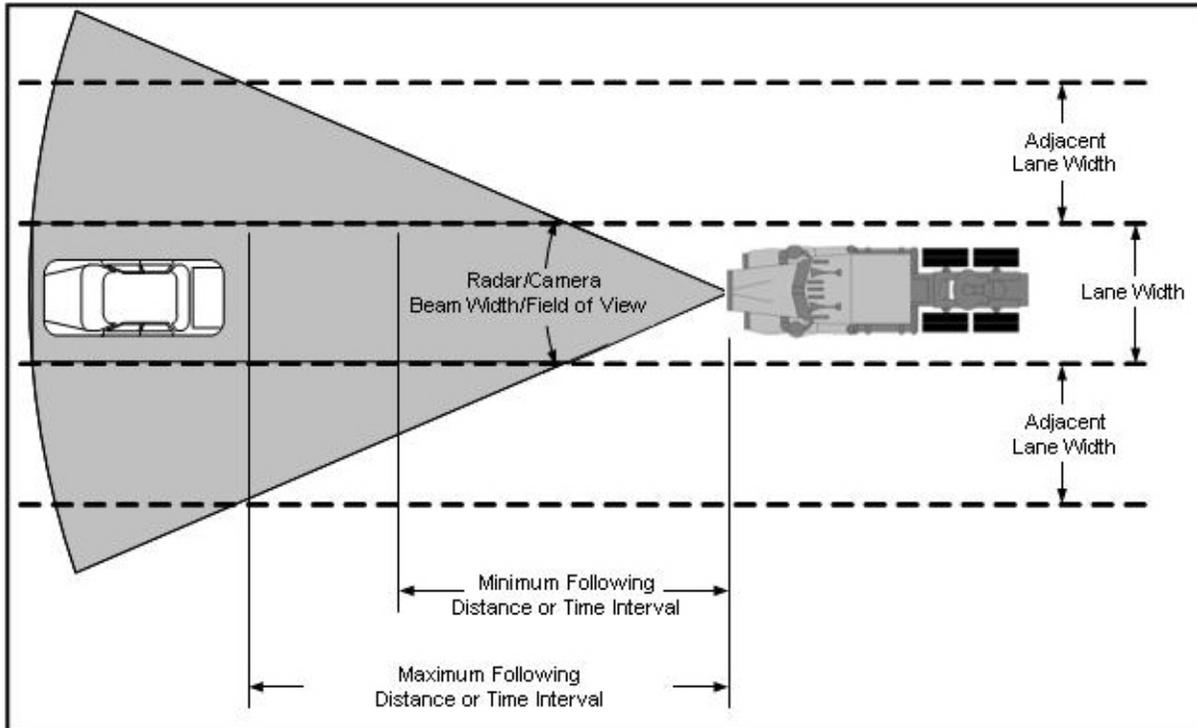


**Figure 1**  
**CWS Object Detection Ranges and Collision Warning Thresholds**

***Description – Adaptive Cruise Control Systems***

ACC systems are in-vehicle electronic systems that automatically maintain a minimum following interval to a lead vehicle in the same lane. The ACC system utilizes components of the collision warning system and a conventional cruise control system. When the host vehicle with the ACC system is traveling above a minimum speed threshold, the ACC system controls the engine throttle, and if available, engine brake and automatic transmission to maintain the following interval. The driver can set and adjust his following interval. In the absence of a vehicle ahead, the ACC system operates like a conventional cruise control by maintaining the speed set by the driver. The ACC system will notify the driver if the system detects a malfunction. Figure 2 illustrates the general thresholds used by an ACC system. The system's beam width/field of view forms an isosceles triangle with its apex at the front center of the vehicle. It graphically displays minimum and maximum following distance or time intervals in which the system operates.

Although ACC systems automatically take action to control the vehicle's speed, they may not sufficiently decelerate the vehicle in all circumstances to avoid a crash. Depending on the vehicle load, road grade, and vehicle performance parameters, the level of deceleration control typically used by the system is limited to a range between 0.1 and 0.2 g, where g is a unit of force equal to the force exerted by gravity. As a result, drivers remain responsible for the safe operation of their vehicles, and they should use steering and apply the service brakes, if safe to do so, to avoid a crash.



**Figure 2**  
**ACC System Vehicle Following Intervals**

### **Crash Prevention**

CWS and ACC systems can help reduce crashes when vehicles are equipped with these systems. In particular, these systems may prevent rear-end crashes and forward impact crashes with objects in the travel lane. These systems may also reduce the impact speed and the crash severity. This section describes these crash types.

- Rear-end Crash** – Rear-end crashes occur when the front of a following vehicle strikes the rear of a lead vehicle. Data derived from the 2003 General Estimates System<sup>1</sup> (GES) indicates that 42,800 rear-end crashes involving large trucks occurred in 2003, resulting in 290 fatalities. “In 18 percent of all rear-end crashes where the truck was the striking vehicle, there were three or more vehicles involved in the crash. The difference is even greater in fatal rear-end crashes. Almost 46 percent of fatal rear-end truck-striking crashes involved three or more vehicles, while only 16 percent of fatal truck-struck rear-end crashes involved three or more vehicles. The large difference between the mass of trucks and the mass of other vehicles may explain this phenomenon. A typical loaded tractor semi-trailer has a gross weight of 80,000 pounds, while most cars weigh less than 4,000 pounds. Striking a passenger vehicle in the rear will not bring a heavy truck to a stop or even slow it appreciably. Thus, the impact itself does relatively little to keep the truck from continuing on and involving other vehicles.”<sup>2</sup> CWS can reduce the risk of

<sup>1</sup> The General Estimates System is directed by the National Center for Statistics and Analysis, which is a component of The Office of Research and Development in NHTSA. Data for GES come from a nationally representative sample of police reported motor vehicle crashes of all types, from minor to fatal. The system began operation in 1988, and was created to identify traffic safety problem areas, provide a basis for regulatory and consumer initiatives, and form the basis for cost and benefit analyses of traffic safety initiatives. The information is used to estimate how many motor vehicle crashes of different kinds take place, and what happens when they occur.

<sup>2</sup> Craft, Ralph. FMCSA Paper: Rear-End Large Truck Crashes, 2002.

these rear-end crashes by identifying fast closing situations and providing the driver with additional time to react. ACC systems function to maintain a driver-set following interval behind another vehicle, thereby providing more time to resolve driving conflicts to reduce the probability of a rear-end collision.

- **Forward Impact with Objects in Travel Lanes** – These crashes occur when a vehicle strikes an object that is in the vehicle's travel lane. Data from the 2003 GES indicates that large trucks were involved in 18,000 crashes of this type in 2003, resulting in 160 fatalities. CWS can reduce the risk of these crashes by warning the driver of the presence of these objects, thereby allowing them additional time to take the appropriate avoidance maneuvers.

Additional benefits of ACC systems and CWS may include the reduction of hard braking events.

### ***Operations and Users***

This section describes how drivers, fleet managers, and fleet maintenance personnel interact with CWS and ACC systems and potential benefits that each stakeholder may realize with these systems.

The commercial vehicle population is comprised of a wide variety of vehicle types and uses. At a high level, two types of vehicles are predominant, combination vehicles (tractors-trailers) and straight trucks. These two types of vehicles have very different operating characteristics. In general, straight trucks tend to be used in a more local setting, used to provide deliveries of goods and services to customers generally within a 50 to 100 mile radius of their base of operations, while combination vehicles are more often utilized in regional and long distance applications. Combination vehicles account for about 30% of total commercial vehicles, but 65% of the commercial vehicle miles traveled. Due to their high mileage exposure and severity of crashes, combination-unit trucks have the highest crash cost per vehicle over the operational life of the vehicle.<sup>3</sup> Therefore, CWS may provide a relatively higher safety benefit for operators of this class of trucks.

The trucking industry is actually a broad collection of many industries, each with operating characteristics as diverse as the industries they service. Segmentation of the trucking industry is often based on the size of fleets, the geographic range of its operations, and the commodities hauled. Usually one characteristic is not adequate to describe a particular segment, but rather combinations of characteristics are required to best describe operations. For example, there may be a trucking firm with a large fleet providing package delivery type service to a relatively small geographic area, while there may be a single truck company that provides general freight services to all states in the continental United States.

The movement of goods by truck is conducted on all types of roads, at all hours of the day, and in all types of driving conditions. Since collisions with other vehicles or obstacles can occur along any route, many fleet types may benefit from using CWS, yet they may be most promising for trucks with high mileage accumulated over their operational life or that operate under conditions that may present driving challenges such as nighttime or limited visibility due to weather. Also, currently, CWS operate at any vehicle speed. ACC systems only operate above a specified minimum vehicle speed, which typically limits the systems' use to roadways where drivers travel at or above this minimum speed in accordance with the posted speed limits. The application of these systems to specific fleets may be determined by the amount of time the fleet's vehicles operate in these roadway types.

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<sup>3</sup> Wang, J.S.; Knipling, R.R.; and Blincoe, L.J. The dimensions of motor vehicle crash risk. *Journal of Transportation and Statistics*. Volume 2, No. 1, pp. 19-43, ISSN 1094-8848, May 1999.

## **Drivers**

Drivers are the primary CWS and ACC system users, as described in the following daily operational scenarios:

**Normal system startup operation** – When the driver turns the ignition switch to start the vehicle, CWS and ACC systems perform a power-up self-test. The driver scans the warning indicators to determine any system malfunctions. If necessary, the driver may alert fleet maintenance personnel for corrective action. A driver can scan the CWS or ACC system status indicator to verify that the system operation has commenced.

**System fault conditions** – If a system fault occurs or the system cannot detect vehicles ahead or control the speed of the host vehicle, the driver is provided with a message via the system status indicator. Some CWS and ACC systems may display warning indicators relating to specific faults or other detected conditions.

**Progressive CWS warning/alert situations** – When traveling at or above the minimum CWS detection speed, the host vehicle will encounter other vehicles ahead within the travel lane. As the host vehicle approaches the vehicle ahead, the CWS may provide a series of progressive alerts to the driver. These progressive alerts indicate that the following interval is decreasing and the driver should take action. These progressive warnings can escalate from audio tone only to audio, visual, or other warning modes.

**ACC system operation** – ACC systems automatically maintain a minimum following interval between the driver's vehicle and the vehicle ahead of it. When no vehicle is present in front of the vehicle with the ACC system, the ACC system maintains the speed set by the driver as in current cruise controls. The system has a self-diagnosis mode that can detect system faults. If the system is active when a fault is detected, the ACC system reverts to manual throttle control.

**On-road use of CWS and ACC systems** – A driver may encounter several types of roadways where these systems provide a potential benefit. Yet, some systems may have limitations, including false positive indications, such as the identification of signs, barrels, and other roadside objects that may not be actual obstacles in the travel lane.

**Divided highways and interstates/Straight and large radius curved flat roads** – “Trucks Involved in Fatal Accidents (TIFA) and GES data show that rear-end truck crashes are more likely to occur on divided roadways and interstate highways—overlapping categories—than other truck crashes. With regard to fatal crashes, 58 percent of truck striking crashes occurred on interstate highways, as opposed to 19 percent of all truck fatal crashes.<sup>4</sup>” These road types are where CWS and ACC systems could provide the greatest benefit. While the vehicle is operating on these roads, CWS can detect vehicles ahead and issue warnings to the driver when it detects an excessive closing speed condition. ACC systems will control the speed of the host vehicle and interval to the lead vehicle.

**Two-way roads with sharp curves** – CWS and ACC systems could have limited azimuthal coverage to the front of the vehicle. When the host vehicle is traversing sharp curves, the lead vehicles may no longer be in the range of the host vehicle's sensor coverage area. When these situations arise, each system has a different means of accommodating the loss of detecting the lead vehicle. CWS may not re-detect the lead vehicle until the host vehicle enters the curve. The ACC system will revert to

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<sup>4</sup>Craft, Ralph. FMCSA Paper Rear-End Large Truck Crashes.

conventional cruise control by maintaining the current set speed until the lead vehicle is detected again. When the lead vehicle is detected, the ACC system will revert to the set following interval.

**Roads with hills and valleys** – CWS may produce false positive indications when the host vehicle is on a roadway with major changes in elevation. When a host vehicle is traveling up a hill, current CWS may detect objects such as overhead signs. Other roadway features that could cause loss of vehicle tracking or false alarms include dips in the roadway and hillcrests.

### ***Fleet Management***

Fleet managers are responsible for all administrative, financial, and operational aspects of the fleet. Safety officers focus on the fleet's operational safety issues and examine the safety aspects of the fleet's vehicles in accordance with USDOT safety regulations. They also work with drivers to provide safety and operational training, verify that drivers are complying with safety regulations, and examine how well drivers operate their vehicles (e.g., logging accidents, traffic infractions, etc.).

These personnel examine various types of available safety equipment, evaluate the equipment, justify the purchase of all equipment, determine the overall effectiveness of this equipment, and calculate the return on investment (ROI) for their fleet. They work with the maintenance department and drivers to explain CWS and ACC system benefits. CWS and ACC systems may have the capability to store operational data internally for retrieval by the fleet. This data may be useful in reconstructing an accident or as training feedback in analyzing a driver's performance. Fleet managers may obtain operational data (e.g., number of hard-braking events) from CWS and ACC systems via the in-vehicle network and analyze the data to determine any systemic problems with their fleet operations (e.g., disproportionate number of close-following events with certain drivers, high number of hard-braking events on certain routes). These in-vehicle networks provide a data "backbone" to the truck, permitting the sharing of various system level data, such as engine and transmission performance. Research has indicated that the monitoring of driver behavior can have a positive effect on driver and fleet safety.<sup>5</sup>

### ***Maintenance Management and Installation***

Maintenance managers and service technicians are responsible for the proper functioning of all equipment installed on the fleet's vehicles and for installing and maintaining CWS and ACC systems on the fleet. The maintenance managers support fleet operations by maintaining CWS and ACC systems. They acquire and relay operational and reliability data to the fleet managers and work with suppliers to resolve any problems encountered with system use.

CWS and ACC systems have different installation requirements for each vehicle type and model. Depending on the system, CWS and ACC systems may be installed by a truck original equipment manufacturer (OEM) or as an aftermarket accessory by the fleet or other service personnel. When installed by a truck OEM, the CWS and ACC system component locations and mounting methods are identical for each vehicle model. The OEM provides dedicated wiring harnesses for the connection between the CWS and ACC systems and the vehicle. When installed as an aftermarket accessory, CWS and ACC systems' components should be in

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<sup>5</sup> Knipling, R.R.; Boyle, L.N.; Hickman, J.S.; York, J.S. Daecher; C., Olson, E.C.B.; and Prailey, T.D. *Synthesis Report # 4: Individual Differences and the High-Risk Commercial Driver*. Project Final Report, Transportation Research Board Commercial Truck and Bus Synthesis Program. ISSN 1544-6808, ISSN 0-309-08810-0, available at [http://trb.org/news/blurb\\_browse.asp?id=11](http://trb.org/news/blurb_browse.asp?id=11), 2004

the proper locations and orientations as described in the installation manual with the key parameters entered into the system. Furthermore, the systems will require periodic maintenance, particularly in the area of component (e.g., radar, camera, antennae) alignment.

### **3. VOLUNTARY REQUIREMENTS**

The voluntary requirements included in the following sections define fundamental CWS and ACC system features and the ability of the systems to withstand the electrical and environmental extremes commonly found on commercial vehicles.

The types of voluntary requirements for CWS include:

1. Functional Requirements
2. Data
3. Hardware and Software Requirements
4. Driver Vehicle Interface (DVI) Requirements
5. Maintenance and Support Requirements

CWS and ACC system manufacturers may include additional functions to augment system capability and features that may be useful beyond minimum system functionality; the operational features that fall into this category are labeled with the term “OPTIONAL”. However, in all cases, CWS and ACC systems must comply with all existing FMCSA Safety Regulations. The requirements numbering system designates defining requirements with an “R” and optional features with a “T”.

#### **3.1 Functional Requirements**

Functional requirements refer to basic system functionality and operation of CWS and ACC systems.

- R1-1** CWS and ACC systems should perform a self-test that checks all major system sensors and components and operate within 30 seconds of starting the vehicle. System status results should be provided to the driver within the 30 seconds time interval.
- R1-2** CWS should detect, track, and issue warnings for the following potential pre-collision conditions based on following interval thresholds when the functional requirements R1-3 and R1-4 are met:
- Host vehicle closing on a lead vehicle with constant velocity
  - Host vehicle closing on a lead vehicle that is accelerating
  - Host vehicle closing on a lead vehicle with both vehicles decelerating
  - Host vehicle closing on a lead vehicle preceded by a lane change
  - Host vehicle closing on a stopped lead vehicle
  - Host vehicle closing at a constant speed on a decelerating lead vehicle
  - Host vehicle closing on a stationary object in the roadway

- R1-3** CWS and ACC systems should be capable of detecting a vehicle in the travel lane of the vehicles with the CWS and ACC systems to a distance of up to 100 meters (328 feet) on straight roads and on curves with radius greater than 500 meters (1640 feet).
- R1-4** CWS and ACC systems should be capable of differentiating between oncoming traffic on two-way curved roadways and vehicles in the travel lane of the vehicles with the CWS and ACC systems.
- R1-5** CWS and ACC systems should function under all potential weather conditions such as clear weather, rain, snow, fog, or combinations of these conditions. If the system cannot function in these conditions, the driver should be provided with a clear indication that the system is not functioning.
- R1-6** CWS and ACC systems should be capable of differentiating stationary roadside objects such as guardrails, signs, and bridges from moving vehicles in both the travel lane and opposing lanes of the vehicles with the CWS and ACC systems.
- R1-7** If CWS and ACC systems engage the vehicle's service brakes, the vehicles brake lights should be activated in compliance with Federal Motor Vehicle Safety Standard 108.
- R1-8** CWS should use progressive warnings to provide the driver with sufficient time to avoid forward crashes.
- T1-1** **OPTIONAL** – CWS may interact with an ACC system to maintain a safe following interval to the vehicle ahead.
- T1-2** **OPTIONAL** – CWS may issue proximity warnings when the host vehicle is slowly moving forward (less than 2 mph) towards a stationary object or if an object ahead is slowly rolling towards the front of the host vehicle.

### 3.2 Data

This section defines the format of data generated by or can be obtained directly in real-time from CWS and ACC systems. Two Society of Automotive Engineers (SAE) standards specify in-vehicle data communication in heavy trucks:

- SAE J1587, "Electronic Data Interchange between Microcomputer Systems in Heavy-Duty Vehicle Applications" (message definition for the J1708 data bus), or
- SAE J1939-71, "Recommended Practice for Control and Communications Network for On-Highway Equipment – Vehicle Application Layer"

Although neither of these standards defines CWS messages, it would be beneficial if CWS suppliers adopt a common set of standard CWS messages. Drivers and fleet managers could obtain these CWS messages via the in-vehicle data network. SAE J1939-71 already defines the data available from ACC systems via the on-board diagnostic (OBD) connector.

- T2-1** **OPTIONAL** – ACC systems may issue various data messages about the operating states and modes of the system on the in-vehicle data network, which may be custom messages or as defined by SAE standard J1939<sup>6</sup>.
- T2-2** **OPTIONAL** – CWS and ACC systems may have the capability to store operational data for providing driving feedback to drivers.

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<sup>6</sup> Heavy trucks may have either or both J1708 and J1939 networks. J1708 (J1587) is typically more easily accessible by the fleet, and J1939 is typically reserved for high-priority engine-transmission control data. However, CWS may interface with either or both networks. See Section 4.4 for a listing of CWS' network messages.

### 3.3 Hardware and Software Requirements

Hardware and software requirements deal directly with the detailed functionality of the hardware, environmental and electrical concerns, mounting/installation issues, and software design. Figures 3 and 4 illustrate the major functional components and interfaces of CWS and ACC systems as described in the following sections, respectively. Figure 3 shows the inter-relationship of the CWS components. The electronic control unit (ECU) accepts data from the forward-looking sensor. Through the vehicle network (J1708 or J1939), the ECU monitors the brake activation status and engine power. The output of the system is a status indicator and, when necessary, a warning, which appear on the driver-vehicle interface. Figure 4 shows the inter-relationship of the ACC system components. The ECU has the same input and outputs as in a CWS, but it has the additional capability to control the engine speed or to shift the automatic transmission. Both figures show that the CWS and ACC are often integrated into a single system.

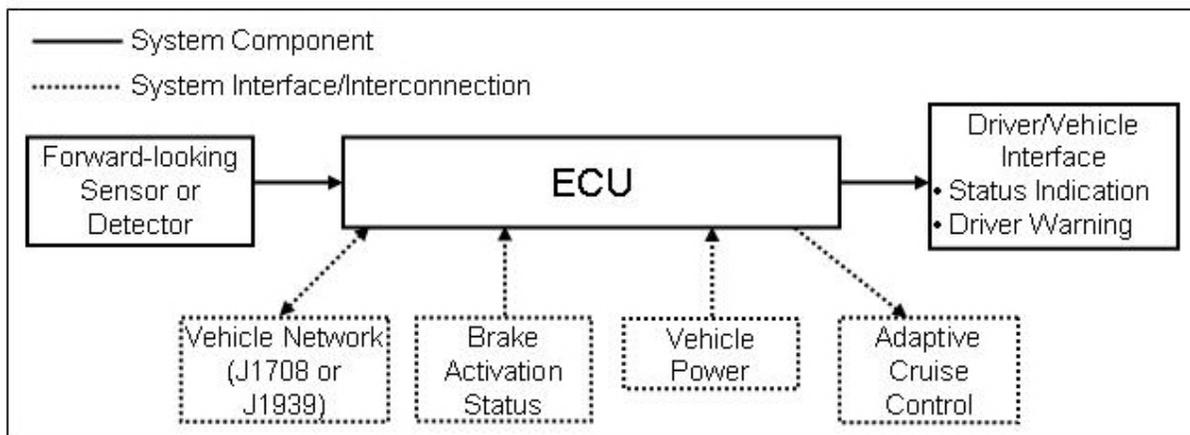


Figure 3  
CWS Major Functional Components

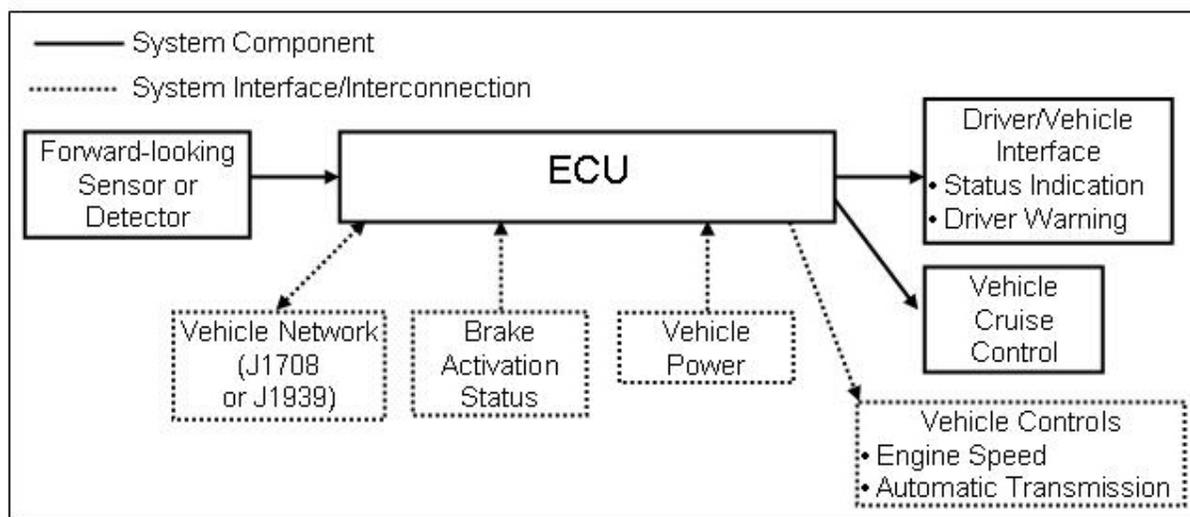


Figure 4  
ACC System Major Functional Components

## **Typical System Hardware**

This section describes the functionality of the primary physical components of CWS and ACC systems. They refer to the functional blocks shown in Figures 3 and 4.

- R3-1**            **Forward-looking Sensor or Detector** – CWS and ACC systems should have a sensor or apparatus that detects vehicles in the front of the host vehicle. This sensor or apparatus should be capable of determining the distance and location of moving or stationary vehicles in the travel lane of the host vehicle. CWS and ACC systems should be capable of detecting moving or stationary vehicles to at least 100 meters (328 feet) ahead of the vehicle.
- R3-4**            **Electronic Control Unit (ECU)** – The CWS and ACC systems' ECU should be used to gather data for calculating key parameters to provide warnings. For the ACC system, the ECU should be capable of controlling the engine speed or shifting the automatic transmission.
- R3-2**            **Driver Vehicle Interface** – CWS and ACC systems should provide a driver vehicle interface (DVI) to permit the driver to interact with the systems. A DVI consists of controls and indicators for CWS and ACC systems related to the system operation. The DVI includes progressive audible and visual warnings of a potential collision threat to the host vehicle. CWS and ACC systems should provide a visual indication of the status of the systems. System status includes operational/non-operational, tracking/not-tracking, and system fault conditions. See Section 3.4 for complete DVI requirements.
- T3-1**            **OPTIONAL – Adaptive Cruise Control** – CWS may interact with an ACC system to maintain a safe following interval between the host vehicle and the vehicle in front of it.
- T3-2**            **OPTIONAL – Vehicle Network** – CWS and ACC systems may use the in-vehicle data network (SAE J1708 or J1939) for data communication to data recording or diagnostic devices.

## **Environmental Requirements**

The environmental conditions that exist in heavy trucks are very severe. The SAE has developed a comprehensive standard that describes various aspects of the heavy truck environment in its J1455 standard. The standard also includes procedures that are used to verify system compliance.

- R3-3**            CWS and ACC systems should meet the environmental requirements as stated in the most recent version of the following SAE standard:

SAE Standard J1455, "Joint SAE/Technology and Maintenance Council (TMC) Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)".

The following environmental aspects are covered by the standard:

- Altitude
- Fungus
- Mechanical Shock
- Mechanical Vibration
- Relative Humidity
- Temperature
- Salt Spray Atmosphere
- Immersion and Splash
- Steam Cleaning and Pressure Washing
- Dust, Sand, and Gravel Bombardment

## ***Electrical Requirements***

In a truck's electrical power distribution system, the system voltage may vary, the alternator may generate electrical noise, and various types of transients may momentarily place more than 100 volts direct current (VDC) on the electrical distribution system's wiring. In addition, there may be electrostatic discharge into the system from a buildup of static electricity. Because CWS and ACC systems connect to the truck's electrical power distribution system, they should function normally throughout all of these perturbations without damage.

**R3-4** CWS and ACC system power should be derived from the vehicle electrical system.

**R3-5** CWS and ACC systems should meet the electrical requirements as stated in most current version of the following SAE standards:

SAE Standard J1455, "Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks)".

SAE Standard J1113, "Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft) (60 Hz to 18 GHz)".

The following environmental aspects are covered by the standards:

- Steady State Electrical Characteristics
- Transient Electrical Characteristics
- Electromagnetic Susceptibility
- Electromagnetic Emission

**R3-6** CWS and ACC system data should not be destroyed nor corrupted during a power surge.

## ***Mounting and Installation Requirements***

Mounting and installation requirements include all aspects related to the installation of CWS and ACC system hardware onto the truck, including the mounting of the individual system components. There are no specific requirements pertaining to system size or weight.

**R3-7** CWS and ACC systems should be installed per manufacturer's recommendations.

**R3-8** Major CWS and ACC system components, other than cabling or small mounting components, should be marked with the manufacturer's identification.

## ***Software Requirements***

Software requirements refer to the embedded software that runs in CWS and ACC systems and controls all system functionality. The microcontroller or microprocessor continuously runs the system software when CWS and ACC systems are active.

**T3-3** **OPTIONAL** – CWS and ACC systems may include software for downloading ASCII data files that can be easily read into a statistical, database, or spreadsheet software package.

**T3-4** **OPTIONAL** – The embedded software of CWS and ACC systems can be field upgradeable via the in-vehicle network connection (i.e., J1587 or J1939) or other common data interface (e.g., RS-232 or Universal Serial Bus (USB)).

Only authorized personnel should upgrade embedded software.

### 3.4 Driver-Vehicle Interface Requirements

These requirements define specific ways in which CWS and ACC systems interface with the driver (i.e., Driver-Vehicle Interface), and include indicators, displays, and warning methods. The National Highway Traffic Safety Administration (NHTSA) Federal Motor Vehicle Safety Standard 101 (FMVSS 101) should be used as a guide for CWS and ACC system indicators.

- R4-1** CWS should utilize different audible tones (e.g., different pitches, patterns, lengths, etc.) or tactile warnings to provide multiple warnings as an object crosses the warning thresholds.
- R4-2** CWS and ACC systems should include a visual indicator when no vehicles or objects are in the lane. The indication may be provided by an instrument panel warning light or an indicator that is integral to each system.
- R4-3** CWS and ACC systems should use a visual indicator to provide system operational status. This status may be indicated by an instrument panel warning light or an indicator that is integral to each system.
- R4-4** CWS and ACC systems should use a visual or audible indicator to indicate a system failure or malfunction. This status may be indicated by an instrument panel warning light or an indicator that is integral to the system.
- R4-5** CWS and ACC system indicators should be clearly discernable in direct sunlight and at night.
- T4-1** **OPTIONAL** – CWS should utilize combinations of audible, visual and tactile indicators to provide multiple warnings of object detection and impending collision.
- T4-2** **OPTIONAL** – CWS may allow the volume of the audible warnings to be adjusted, but not below a minimum sound level of 65 dBA<sup>7</sup>.
- T4-3** **OPTIONAL** – CWS and ACC systems may provide operational or diagnostic messages or codes, such as “System Operational” on an alphanumeric display to alert the driver of specific faults, conditions, or concerns.

### 3.5 Maintenance and Support Requirements

Maintenance and support requirements include functionality/features that should be provided to ensure CWS and ACC systems will be operated correctly and properly maintained.

- R5-1** CWS and ACC systems should be serviced periodically in accordance with system maintenance instructions to maintain system functionality. This process maintains the proper alignment and calibration of integral CWS and ACC system components, such as the radar sensor, camera, and antennae.
- R5-2** Users should be provided with a manual and training for CWS and ACC systems.
- R5-3** At a minimum, the user’s manual should include information on the minimum vehicle speed at which CWS and ACC systems operate, the conditions under which the systems can/cannot detect and track vehicles, and the types of indicators used to inform the driver if the systems are functioning properly.

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<sup>7</sup> For reference: 90 dBA = heavy truck at 10m, 80 dBA = curbside of busy street, 70 dBA = car interior, 60 dBA = normal conversation at 1m (3.28 ft.), and 50 dBA = office noise.

- R5-4** Manufacturers should provide product support for users and fleets to ask questions regarding capabilities and resolve problems with systems.
- T5-1** **OPTIONAL** – Video, audio, or computer-based training material may be provided for fleet management and/or drivers.
- T5-2** **OPTIONAL** – CWS and ACC systems may be transferable from one vehicle to another. System recalibration and/or resetting of system parameters should be performed when the system(s) are moved between vehicles.

#### 4. ACRONYMS

<b>Acronym</b>	<b>Definition</b>
ACC	Adaptive Cruise Control
ASCII	American Standard Code for Information Exchange
COTS	Commercial Off-The-Shelf
CWS	(Forward) Collision Warning System(s)
DVI	Driver-Vehicle Interface
ECU	Electronic Control Unit
EV	Eaton VORAD
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standard
GES	General Estimates System
GVWR	Gross Vehicle Weight Rating
kph	Kilometers per Hour
mph	Miles per Hour
NHTSA	National Highway Traffic Safety Administration
OBD	On-Board Diagnostic
OEM	Original Equipment Manufacturer
ROI	Return on Investment
SAE	Society of Automotive Engineers
TIFA	Trucks Involved in Fatal Accidents
TMC	Technology and Maintenance Council
USB	Universal Serial Bus
USDOT	United States Department of Transportation
VDC	Volts Direct Current

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SAE Standard J1587, "Electronic Data Interchange between Microcomputer Systems in Heavy-Duty Vehicle Applications," February 2002.

SAE Standard J1708, "Serial Data Communications between Microcomputer Systems," October 1993.

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## A. APPENDIX A – COMMERCIAL-OFF-THE-SHELF CWS AND ACC SYSTEMS

The following Commercial-Off-the-Shelf (COTS) CWS are currently available:

**Delphi Electronics and Safety** ([www.delphi.com](http://www.delphi.com)) – Delphi is developing CWS for commercial vehicles. The CWS uses a radar sensor to detect slower moving vehicles in-lane at a range of up to 80 meters on straight roads and curves of constant radius greater than 500 meters. The system provides a warning in sufficient time to avoid a collision when the following interval is a minimum of 2 seconds. The system does not feature side or rear-object detection or an interface to an ACC system.

**Eaton VORAD (EV)** ([www.roadranger.com/VORAD](http://www.roadranger.com/VORAD)) – The EV EVT-300 CWS is part of a larger system including ACC, side object detection, and trip/accident reconstruction data recording. The EV CWS uses a front bumper mounted radar sensor and an in-vehicle processor to detect and provide warnings of vehicles within the same lane up to 150 meters (500 feet) ahead. To permit detection around curves, a yaw gyro provides road curvature estimates. A driver display unit, which contains the audible and visual warning devices, enables driver adjustment of some of the system's operating characteristics.

**Mobileye** ([www.mobileye.com](http://www.mobileye.com)) – The “Mobileye Advanced Warning System” is a camera-based system that includes a small camera and a processing unit mounted to the upper center of the windshield and a cell phone-sized alphanumeric/graphic driver display on the dashboard. Two in-cab speakers, one on either side of the vehicle, provide audible warnings with adjustable volume control. When lane markings are not visible due to dense fog, heavy rain or snow, roads covered with mud, ice, or snow; the systems notify the driver and shut down. This system is available as a stand-alone system or as an additional feature in a more extensive system including lane departure warning, headway indication and warning, and cut-in warning and lane change assist features.

The following COTS ACC systems will be available currently or in the near future:

**Delphi Electronics and Safety** ([www.delphi.com](http://www.delphi.com)) – Delphi is developing ACC systems for commercial vehicles. The radar-based systems detect vehicles in-lane at a range of up to 80 meters on straight roads and curves of constant radius greater than 500 meters.

**Eaton VORAD (EV)** ([www.roadranger.com/VORAD](http://www.roadranger.com/VORAD)) – The EV “SmartCruise” ACC system is an optional part of a larger system including CWS, side object detection, and trip/accident reconstruction data recording. The EV ACC system uses radar to detect vehicles up to 500 feet ahead. To permit detection around curves, a yaw gyro provides road curvature estimates. A driver display unit enables driver adjustment of the system's operating characteristics.

**Mobileye** ([www.mobileye.com](http://www.mobileye.com)) – The “Mobileye Advanced Warning System” includes a small camera and a processing unit mounted to the windshield behind the rear-view mirror and a cell phone-sized alphanumeric/graphic driver display on the dashboard. The system detects and tracks vehicles ahead of the host vehicle, monitors the distance and following time interval to them, and issues commands to the vehicle's cruise control system to maintain a safe following interval. The following interval is adjustable. It is available as a stand-alone system or as an additional feature in a more extensive system including lane departure warning, forward collision warning, headway indication and warning, cut-in warning, and lane change assist features.

## Summary of CWS COTS System Features

Table A-1 provides comparative information relative to the features of each of the COTS systems described in this appendix. Each manufacturer provided this information.

**Table A-1**  
**Summary of COTS CWS Features**

<b>Feature</b>	<b>Delphi</b>	<b>Eaton-VORAD</b>	<b>Mobileye</b>
Detects obstacles, moving and fixed	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Operates on straight and curved roads	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Detects closing rate and alerts driver above a threshold	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Tracks multiple vehicles and objects	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Uses audible and visual collision warnings	*	<b>Yes</b>	<b>Yes</b>
Uses progressive alert levels	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Permits adjustment of warning threshold location	*	<b>Yes</b>	<b>Yes</b>
Permits adjustment of audible warning volume	*	<b>Yes</b>	<b>Yes</b>
Permits temporary disabling of detection	*	<b>Yes</b>	<b>No</b>
Has visual tracking indicator	*	<b>Yes</b>	<b>Yes</b>
Has visual system status indicator	*	<b>Yes</b>	<b>Yes</b>
Has audible or visual system failure indicator	*	<b>Yes</b>	<b>Yes</b>
Provides a Driver Interface Unit	*	<b>Yes</b>	<b>Yes</b>
Has a proximity alert	*	<b>Yes</b>	<b>No</b>
Interfaces to ACC System	*	<b>Yes</b>	<b>Yes</b>
Logs data internally	<b>No</b>	<b>Yes</b>	<b>Yes</b>
Data messages available	*	<b>Yes</b>	<b>No</b>
Data link used	*	<b>J-1587/ J-1939</b>	<b>Ethernet or USB 2.0</b>
Aftermarket installation by fleets possible	*	<b>Yes</b>	<b>Yes</b>

\* As of release of this document, details for this feature have not been determined.

## Summary of ACC System COTS System Features

Table A-2 provides comparative information relative to the features of each of the COTS systems described in this appendix. Each manufacturer provided this information.

**Table A-2**  
**Summary of COTS ACC System Features**

<b>Feature</b>	<b>Delphi</b>	<b>Eaton-VORAD</b>	<b>Mobileye</b>
Operates on straight and curved roads	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Tracks multiple objects	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>
Provides a Driver Interface Unit	*	<b>Yes</b>	<b>Yes</b>
Has system status indicator	*	<b>Yes</b>	<b>Yes</b>
Displays range and following interval to vehicle ahead	*	<b>No</b>	<b>Yes</b>
Permits adjustment of following interval	*	<b>Yes</b>	<b>Yes</b>
Interfaces to CWS	*	<b>Yes</b>	<b>Yes</b>
Logs data internally	<b>No</b>	<b>Yes</b>	<b>No</b>
Data messages available	*	<b>Yes</b>	<b>Yes</b>
Data link used	*	<b>J-1587/ J-1939</b>	<b>Ethernet or USB 2.0</b>
Aftermarket installation by fleets possible	*	<b>Yes</b>	<b>Yes</b>

\*As of release of this document, details for this feature have not been determined.



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