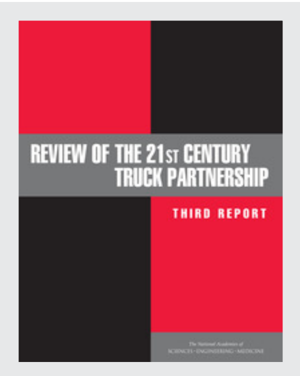

Review of the 21st Century Truck Partnership: Third Report

DETAILS

202 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-37710-2 | DOI 10.17226/21784

CONTRIBUTORS

Committee to Review the 21st Century Truck Partnership, Phase 3; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; National Academies of Sciences, Engineering, and Medicine

7

Safety

INTRODUCTION

> Safety is a central element in the 21CTP vision—and truck manufacturers have stated on numerous occasions that safety is their number one priority. The public has also placed a high premium on safety with concern about driver distraction, driver fatigue, truck aggressivity, and risks associated with exposure to heavy trucks. While truck safety statistics show steady improvement, crashes involving heavy trucks still account for about one out of ten motor vehicle fatalities in the United States. (21CTP, 2013)

Although the 21st Century Truck Partnership (21CTP) focuses on the development of technologies to reduce fuel consumption, an important consideration in the development of any vehicle technology is to maintain or improve safety for the driver and other motorists. 21CTP has recognized the relationship between vehicle safety and the introduction of a new vehicle technology. The Partnership also states that it supports the development and early adoption of safety technology with the objective of

> [Promoting] the development and early adoption of technologies and processes to improve truck safety, resulting in the reduction of fatalities and injuries in truck-involved crashes, thus enabling benefits related to congestion mitigation, emission reduction, reduced fuel consumption, and improved productivity" (21CTP, 2013).

Truck and bus manufacturers, industry suppliers, and federal agencies that participate in 21CTP are working to ensure that as fuel consumption improvements are pursued through advances in technology, safety remains uncompromised.

A priority of the Department of Transportation (DOT) is to pursue solutions that help prevent crashes altogether, through collision warning systems, automatic vehicle control intervention technologies, and/or enhanced vehicle inspection and enforcement systems that help to identify and correct mechanical or operational conditions that could compromise safety.

> Implementation of such technologies and systems is expected to help substantially in reducing fatalities and injuries, and will also have secondary benefits of reducing congestion and idling—thereby reducing fuel consumption and improving overall productivity of the trucking industry (21CTP, 2013).

This safety chapter focuses on a review of the safety-related responses of the Partnership to the NRC Phase 2 report, an assessment of the Partnership's progress toward the safety goals, and a discussion of truck safety activities undertaken by the DOT. These activities include the following:

- Summary of federal government (primarily DOT) activities related to truck safety
- Safety technology, including brakes, roll and electronic stability control, and forward collision avoidance technology and cab crashworthiness.

The 21CTP goals related to safety are as follows:

(1) Ensure that advancements in truck design and technology to improve fuel efficiency do not have any negative impacts on safety and
(2) Ensure that efforts to improve safety do not reduce efficiency—and, where possible, actually contribute to improvements in overall motor carrier industry system efficiency.

Goal 1 is addressed in Chapter 8 in the discussion of technologies implemented in the SuperTruck projects. A general summary of truck safety was presented in the previous NRC Phase 2 report (NRC, 2012). To progress with the assessment, this review will focus more specifically on safety matters as it reviews and evaluates federal safety activities and safety technologies considered by 21CTP.

SUMMARY OF FEDERAL GOVERNMENT ACTIVITIES RELATED TO TRUCK SAFETY

The DOT regulates heavy-duty vehicle safety in the United States under three separate administrations. The National Highway Transportation Safety Administration (NHTSA) has responsibility for new vehicle safety requirements focused at the level of the original equipment manufacturers (OEM). The Federal Highway Administration (FHWA) governs vehicle size and weight, including gross vehicle weight (GVW), axle weight, and vehicle length, width, and height, which are key vehicle design parameters. The Federal Motor Carrier Safety Administration (FMCSA) has responsibility for vehicle and fleet operating regulations, including vehicle operator matters such as hours of service.

The following is a brief synopsis of federal DOT activities related to safety and their distribution across these three agencies.

NHTSA has examined the effectiveness of systems such as the Electronic Stability Control system and the Roll Stability Control system, Forward Collision Avoidance and Mitigation (F-CAM), and Lane Departure Warning (LDW).[1] In a presentation to the committee, NHTSA outlined its efforts to improve truck crashworthiness, rear-underride guard improvements, and truck cab crashworthiness in particular. Pilot studies and research related to vehicle-to-vehicle (V2V) communications are also ongoing.

The FHWA is conducting the Map-21 Truck Size and Weight Study, which has a substantial safety component and also has very significant implications for specific fuel consumption and emissions by virtue of the increased vehicle cargo capacity (Hughes Raymand, 2014). In her presentation to the committee, Ms. Hughes Raymand[2] outlined the Smart Roadside Initiative (SRI), focused on improving the efficiency and safety of U.S. roadways by providing for the exchange of important safety and operational information among the users and operators of the system, including commercial vehicles and roadside and central office systems (RITA, 2014).

As part of the program, DOT is overseeing the development of several prototypes that were scheduled to have been deployed in early 2015 at multiple weigh stations and other strategic points along commercial vehicle routes across the country. These prototypes will demonstrate the integration of multiple technologies that together will facilitate the following:

- Exchange of driver, carrier, vehicle identification, and status information between commercial vehicles and commercial vehicle management systems at highway speeds.
- Integration of roadside applications with external information systems to seamlessly share information on commercial vehicle safety history, inspection status, and credential status.
- Determination of truck weight by weigh-in-motion technology, which uses dynamic weigh scales imbedded in the traffic lane that measure vehicle axle weights as it drives at highway speeds.
- Roadside access for law enforcement to information that supports the identification of the driver, vehicle, and motor carrier.

FHWA has funded recent efforts that use technology to improve truck parking in the United States. The lack of suitable parking for trucks has safety implications—for example, when truck drivers have exhausted their hours of service and must still park their vehicles, if there is no available space at parking facilities they sometimes park on the side of a road, which presents a significant safety risk to the truck and motoring public. The technology being developed uses electronic systems to inform the driver of parking space availability at designated sites so the driver can confidently navigate to a parking facility that still has space.

The FMCSA has supported the development of a web-based course to train commercial vehicle inspectors on how to detect leaks from natural gas and propane trucks and buses and another web-based course to familiarize commercial vehicle inspectors with the safety aspects of electric-drive commercial vehicles. Updates have been made to the Federal Motor Carrier Safety Regulations to address electric-drive commercial vehicles.

The above discussion of activities summarizes the current government-sponsored work being performed having to do with truck safety. Table 7-1 provides a summary of safety-related project expenditures funded by DOT.

Override and Underride Issues

A clinical review of the Large Truck Crash Causation (LTCC) database was undertaken as an exploratory evaluation of front override and side underride in serious truck crashes for NHTSA (Blower and Woodrooffe, 2012). The goals were to determine the incidence of front override and side underride (i.e., whether there is a significant safety problem) and to develop an understanding of the data elements needed to determine the best way to address the problem.

Overall, in front and side impact crashes, some underride was identified in 53.9 percent of the crashes, and passenger compartment intrusion (PCI) was coded in 44.2 percent. The rate of override/underride in side impacts is lower than the rate when the front of the truck is involved. There was some override or underride in 72.0 percent of front impacts, compared with 53.9 percent when the truck side is struck. Rates

[1] A. Svenson, NHTSA, "Heavy Vehicle Safety Research," Presentation to the committee on May 14, 2014.

[2] C. Hughes Rayman, "Supporting Safe and Efficient Goods Movement on the Nation's Highways: An Overview of Research and Data Programs," Presentation to the committee on November 18, 2014.

TABLE 7-1 Summary of DOT Expenditures on Safety-Related Projects by Fiscal Year (dollars)

Project	Sponsor	2012 Funding	2013 Funding	2014 Funding	Total	Recipient
Safety Systems	NHTSA	500,000	600,000	500,000	600,000	Various
Crash Avoidance	NHTSA	700,000	1,100,000	1,000,000	2,800,000	Various
System for Automatically Maintaining Truck Pressure in a Commercial Truck Tire	DOE	571,189	713,810	161,535	1,446,534	Goodyear and The Rubber Company
Update FMCSA regulations to address electric-drive commercial vehicles	FMCSA			150,000	150,000	Various
Web-based course to train commercial vehicle inspectors on how to detect leaks from natural gas and propane trucks and buses	FMCSA				150,000	Various
Web-based course to familiarize commercial vehicle inspectors with safety aspects of electric drive commercial vehicles	FMCSA				150,000	Various
Intelligent Transportation Systems	NHTSA	2,500,000	2,000,000	3,700,000	8,200,000	Various
Heavy Vehicles	NHTSA	2,100,000	2,400,000	2,100,000	6,600,000	Various
Wireless Roadside Inspection	FMCSA		3,000,000		3,000,000	Various

of light vehicle PCI are also lower in side impact crashes, with PCI identified in 65.4 percent of front impacts but only 48.5 percent of side impacts. Underride and PCI could not be determined in 7.9 percent and 7.3 percent of front and side impacts, respectively.

Impacts to truck fronts and to the sides of trailers tended to result in override or underride at higher rates than impacts to the sides of truck cabs or to straight truck cargo bodies. When the truck front was involved, there was identifiable override in 72.0 percent of the impacts. Similarly, impacts on trailer sides resulted in underride in 68.9 percent of the crashes. Side impacts to truck or tractor cabs resulted in underride in 43.5 percent of cases, and side impacts to the cargo body area of straight trucks resulted in underride in about 52.6 percent of such crashes.

In frontal impacts, truck bumper height appears to have a linear relationship with the probability of override. Override occurred in 87.3 percent of frontal impacts where the bottom of the front bumper was above the axle, 72.4 percent when the bumper was at the axle, and only 57.7 percent when the bottom of the bumper was below the axle.

Front axle setback did not appear to affect the incidence of override, but there did appear to be some effect on PCI, such that there was somewhat more PCI identified for setback front axles than for axles set forward. In side impacts, the important elements were cargo bed height and whether the striking vehicle hit the axles. Only low cargo beds were associated with lower probabilities of underride (about 30.0 percent). Standard height (about dock height, or 48-50 in.) and high cargo beds had statistically indistinguishable rates of underride.

Light vehicles hit the truck's axles in 73.9 percent of side impacts, and overall light vehicles that hit the truck's axles actually underrode the truck at higher rates than light vehicles that did not. However, it was found that the geometry of the crash had a significant effect on whether striking the truck's axles would prevent underride. In crashes in which the light vehicle was going in the same direction as the truck and sideswiped it, and in crashes where the light vehicle struck the truck at about a 90 degree angle, hitting the truck's axles prevented underride in about 35 percent of cases. But when the light vehicle was going in the opposite direction as the truck and moved into it at a shallow angle, hitting the axles prevented underride in only about 20.7 percent of crashes.

The review of LTCC cases produced evidence that front override and side underride are significant problems in serious crashes between heavy trucks and light vehicles. Front override and side underride were found in most of the crashes examined. Preliminary estimates from this review are that override occurs in almost three-quarters of crashes involving the front of the truck and in over half of the crashes when the sides of the trucks were struck (Blower and Woodrooffe, 2012).

SAFETY TECHNOLOGIES BEING CONSIDERED BY THE PARTNERSHIP

Several potential countermeasures to reduce deaths and injuries related to truck crashes have been identified by the 21CTP. These include various crash avoidance technologies as well as crashworthiness initiatives that improve occupant protection in the event of an incident. The 21CTP has identified several areas of accident avoidance and these are excerpted below.

> Crash avoidance initiatives fall into six primary categories: (1) improved braking performance including roll and stability control systems; (2) collision mitigation technologies that directly intervene to warn drivers and/or take control of the vehicle in collision imminent situations; (3) diagnostic technologies that improve the ability to maintain safety-critical systems; (4) human factors research to improve the driver-vehicle interface, identify sources of distraction and enhance driver performance through a variety of technology and operational strategies; (5) SmartRoadside; a program to improve how state, local and federal officials interact with commercial vehicle operators and drivers at the “roadside” to reduce down-time associated with vehicle inspections, port operations, border crossings and other venues. Components of this program include wireless roadside inspections, size and weight compliance, and other state-based programs; and (6) cross-cutting research related to dedicated short-range communications (DSRC)-based systems—a set of technologies and applications focused on establishing standardized wireless communications between vehicles to support safety, mobility and efficiency within the motor carrier industry. (21CTP, 2013)

Of these primary categories, items 1 through 4 have safety implications at the vehicle level and will be discussed in this section of the report.

Crash Avoidance Technologies

Improved Braking Performance

Brake performance remains a long-standing challenge for heavy vehicles. New crash avoidance systems rely on well-adjusted brakes to function properly, and this requirement strongly favors disc brake technology. The Partnership notes that NHTSA Final Rule FMVSS No. 121 requires a 30 percent reduction in stopping distance for new commercial tractors. The Partnership’s Roadmap identifies disc brakes and more powerful drum brakes as the most likely strategy to meet new standard. The superior performance of disc brakes and their ability to remain in adjustment suggest that they would be a better choice than drum brakes. Disc brakes have better heat rejection characteristics than drum brakes, which is important given that aerodynamic drag is greatly reduced in fuel-efficient vehicles, thus requiring brakes to extract more energy. The current FMVSS No. 121 does not address “brake out of adjustment,” which is arguably the most critical brake issue facing the trucking industry.

Therefore, the 21CTP has stated that “increased research and analysis on the use of disc brake systems for tractor trailers is supported by the 21CTP.” According to the Roadmap, disc brake systems offer increased reliability, shorter stopping distance, and opportunities for mass reduction since they are lighter and less expensive to maintain than drum brake systems.

Air disc brakes offer a proven alternative to drum brake designs. When compared to drum brakes, air disc brakes have a number of advantages, including these:

- *No exaggeration of friction coefficient differences*. This results in improved side-to-side consistency between left and right brakes.
- *Reduced fade*. Consistent contact between the friction surfaces remains, even with brake disc warm-up and radial expansion.
- *High thermal load capacity*. Heat dissipation is efficient for internally vented brake discs. As such, it is possible to maintain high braking performance, even under demanding conditions.
- *Minimal and consistent hysteresis*. This is due to the high efficiency of the actuating mechanism.
- *Servicing ease when changing brake pads*. Compared to drum brakes, disc brakes require only a fraction of the service time.

Unfortunately, the air disc brake system market penetration rate in the United States remains low, so that mechanisms to encourage industry acceptance of this foundation brake technology may be required.

21CTP considers electronically controlled braking systems (EBS) to be important technologies. These systems replace the pneumatic brake activation signal with an electronic activation signal. The main benefit of this system is reduced lag time between operator execution and brake response time, which reduces stopping distance. EBS offers more precise brake control and will provide the platform for the advanced safety systems of the future. Furthermore, the elimination of signal lag ensures that every wheel-end brakes at the same time, which improves vehicle control.

21CTP considers improved brake systems as an enabler for other safety technologies. Having well-adjusted brakes with reliable braking performance is essential for the operation of many of the advanced collision avoidance technologies. In a presentation to this committee, NHTSA noted that out-of-service brake problems are detected in 20-30 percent of trucks inspected.[3] Most of these problems are associated with out-of-adjustment brakes and of these, virtually all are related to antiquated drum brake design, which is inherently

[3] L. Loy, “FMCSA Research and Technology,” Presentation to the committee on November 18, 2014.

susceptible to adjustment problems but is nonetheless used on most tractor-trailer combinations in North America. As mentioned previously, out-of-adjustment is an important characteristic, since electronic stability control (ESC), roll stability control (RSC), and forward collision avoidance and mitigation (F-CAM) systems all rely on properly functioning brake systems to maximize safety performance. When the brake systems are out of adjustment or compromised, crash avoidance system performance suffers. It should also be noted that in Europe, air disc brakes have experienced high market penetration and out-of-adjustment problems are less common (Marmy, 2015).

Roll Stability Control and Electronic Stability Control

RSC systems are designed to reduce the probability of vehicle rollover in a curve by sensing lateral acceleration and reducing speed when threshold limits are exceeded. ESC provides rollover prevention similar to that provided by RSC, with the added ability to address vehicle loss of control (LOC) due to understeer or oversteer through selective braking at the tractor. The overlapping characteristic of these technologies centers on the ability of ESC to manage LOC scenarios as well as to replicate the functionality of an RSC system for curve-related roll stability cases.

RSC and ESC technologies are able to assess vehicle mass by monitoring engine torque and vehicle acceleration performance on a continuous basis. An onboard algorithm uses this data to set the lateral acceleration threshold and establish mass-related braking strategies for vehicle deceleration during challenging curve maneuvers. The technology has the ability to override driver power commands to the engine and can activate the vehicle retarder/engine brake as well as the foundation brakes. The degree of intervention depends on the amount of lateral acceleration (over-speed in a curve) that the vehicle experiences. RSC and ESC technologies perform almost identically when controlling for excessive speed in a curve with the exception that ESC can apply the foundation brakes (all tractor axle and trailer axle brakes), including the tractor steer axle, while RSC can apply the foundation brakes but not the tractor steer axle.

RSC and ESC are both mature commercially available technologies that cannot be retrofitted. DOT has initiated rulemaking to require ESC to be fitted on new Class 8 trucks. The University of Michigan Transportation Research Institute (UMTRI) conducted a study for NHTSA to quantify performance and estimate the benefits of this technology (Woodrooffe et al., 2009).

Collision Mitigation Technology

The 21CTP identifies advances in collision warning and avoidance systems as an area of research that has a potentially high payback when it comes to improving safety. The Roadmap identifies the following crash avoidance systems for future research: lane departure warning (LDW), forward collision warning (FCW), side object detection (blind spot monitoring, or BSM), lane change/merge (LCM), and rear object detection and collision warning FCW and Mitigation F-CAM systems are defined as forward-looking radar-based systems that combine FCW with automatic collision mitigation braking (CMB) capability. The FCW feature generates visual, audible, and/or haptic warnings for the driver when/if a lead vehicle comes within a predefined distance and closing rate with the subject vehicle (i.e., the F-CAM equipped vehicle). If the driver does not respond to the warning with a braking input, and if the threat continues to worsen, then the F-CAM system applies foundation brakes at a point when the collision is determined to be "imminent" (i.e., not avoidable through an evasive steering or lane change maneuver). Driver warnings and automatic braking actions of current production systems could be effective at helping to mitigate crash severity or to avoid the crash altogether. It should be noted that F-CAM technology is not meant to convey or imply an adaptive cruise control (ACC) feature, even though all commercial vehicles offering F-CAM systems do in fact include ACC capability. F-CAM systems address truck striking rear-end collisions, which are the most common crash type on the divided highway network.

The estimated reduction in fatalities and injuries related to collisions with a truck striking the rear end of another vehicle was computed in Table 7-2 (Woodrooffe et al., 2013).

Woodrooffe et al. (2013) show that the current generation, commercially available technology will reduce fatalities by 24 percent, injuries by 25 percent, and property-damage-only crashes by 9 percent (see Table 7-2). The data also suggest that the second- and third-generation versions of the system will bring substantially greater benefits. The second -generation system is able to detect stationary threat objects in the roadway, typically through the fusion of radar and vision systems. The third generation has more aggressive automated braking deceleration, achieving 0.6 *g*. This is highly relevant

TABLE 7-2 Reduction in Injury Severity by Collision Mitigation Capability for Tractor Semitrailers (F-CAM components) (percent)

Capability	Fatal	Injury	No Injury
F-CAM subsystem contribution			
FCW only	31	27	11
CMB only, 2nd generation	26	32	10
CMB only, 3rd generation	44	42	19
Complete F-CAM system contribution			
Current generation	24	25	9
Second generation	44	47	20
Third generation	57	54	29

NOTE: The benefits assume that all tractor semitrailers operating in the United States were fitted with the technology. Also note: "No injury" means property damage only. SOURCE: Woodrooffe et al. (2013).

to 21CTP as it represents an area where the needed research and development have indicated the potential for substantive safety improvement.

Safety System Diagnostic Technologies

A vehicle with a safety system that is not functioning properly is a safety risk to both its occupant and society generally. DOT is supporting the development of systems that inspect, monitor, and diagnose the vehicle components and technologies that influence vehicle safety. The 21CTP Roadmap identifies tire pressure monitoring systems (TPMS) and brake system out-of-adjustment diagnostics as two distinct areas that will benefit from onboard diagnostics (OBDs).

Tire Pressure Monitoring Systems

The 21CTP's vision for the future truck includes an efficient, accurate, and cost effective tire pressure monitoring system. Tire pressure monitoring systems can improve safety while also reducing operating costs for the vehicle owner. These systems continually measure the air pressure for all tires and relay that information to the operator via a dashboard-mounted OBD interface or transmit the data to a fleet's manager, or both. Having properly inflated tires will reduce blowouts, vehicle sliding in inclement weather, and improve vehicle handling. Properly inflated tires will also reduce fuel consumption directly since a properly inflated tire will provide lower fuel consumption than an improperly inflated tire because of the additional power that is required to move a vehicle with one, or many, underinflated tires (see Chapter 5, section on "Tire Rolling Resistance").

Brake System Sensors and Diagnostics

As previously mentioned, many of the new crash avoidance and mitigation technologies rely on well-adjusted brake systems. DOT is sponsoring research on more reliable and accurate brake system diagnostic systems. It identifies the leading brake diagnostic system as the on-board stroke monitoring system, which is a strong indicator of the state of drum brake adjustment. These systems will enable the driver or the fleet to receive real-time information on the condition of the vehicle's braking system. These systems also increase safety by notifying the operator, or fleet manager, of vehicles with brake systems that are out of adjustment.

Cab Crashworthiness

A "fatal truck crash" is defined as a crash in which someone (an occupant of the truck, an occupant of another vehicle, or a pedestrian) is killed. In the early 2000s, 700 to 800 hundred truck drivers were killed in truck crashes each year. In recent years, the number of truck driver fatalities has decreased, in large part owing to a general reduction in truck fatal crashes. However the proportion of drivers killed in relation to the number of fatal truck crashes has remained between 14 and 16 percent over the years. In 2003 and 2004, 700 truck drivers were fatally injured in crashes, and the number increased substantially in each of the next 3 years. The trend in the number of truck drivers killed began to decline after 2007, possibly due to a reduction in truck travel brought on by the recession. In 2007, a total of 796 truck drivers were killed in 5,049 fatal truck crashes, a 15.8 percent occurrence (Jarossi et al., 2012). In 2008, there were 639 truck drivers killed in 4,352 fatal truck crashes (14.7 percent); in 2009, there were 487 drivers killed in 3,450 fatal truck crashes (14.1 percent); and in 2010, 540 truck drivers were killed in 3,699 fatal crashes (14.6 percent). While the number of truck drivers killed in traffic crashes has fluctuated over the period, the ratio of drivers killed in relation to fatal truck crashes shows little change, indicating that crash safety for drivers is not improving.

It is estimated that 757 truck occupant fatalities occur per year; about 3,000 A-injuries[4] and about 7,700 B-injuries. Most of the fatalities occurred in truck-tractors, with an average of 425 per year. Single unit trucks (SUTs) had an average of 324 fatalities annually.

A recent UMTRI study (Woodrooffe and Blower, 2013) found that rollover and frontal impact were identified as the collision types associated with the most serious driver injuries. Rollover and frontal impact in collisions accounted for 72.7 percent of all tractor-trailer driver fatalities and A-injuries in crashes. Rollover is the dominant crash mode, accounting for 44.5 percent of fatalities, and everyday A-injuries frontal collision events account for 28.2 percent. No other crash event comes close to the share of these two crash types.

In events where the truck rolls over, one in eight truck drivers dies or receives incapacitating injuries. In contrast, in crashes where the truck does not rollover one in 167 drivers die or receive incapacitating injuries.

Rollover events with belted drivers account for 37 percent of all injured truck drivers while unbelted drivers account for 50 percent. Focusing on the risk associated with rollover, one in nine belted drivers die or receive incapacitating injuries while one in three unbelted drivers die or receive incapacitating injuries. Seat belts were shown to be particularly effective at reducing fatalities and incapacitating injuries in rollover events by a factor of three.

Ejection is highly associated with the most severe injuries. Among SUT drivers, almost 39.9 percent of ejected drivers suffered fatal injuries, and almost 24.6 percent were coded with A-injuries. Among tractor-trailer drivers, 25.4 percent

[4] A-injuries: incapacitating, which prevent the injured person from walking, driving or normally continuing the activities he was capable of performing before the injury occurred. B-injuries: nonincapacitating injury other than a fatal injury or an incapacitating injury, which is evident to observers at the scene of the accident in which the injury occurred.

of ejected drivers suffered fatal injuries and an additional 19.0 percent suffered A-injuries. Ejection accounted for 35.0 percent of SUT driver fatalities and 22.6 percent of tractor-trailer driver fatal injuries.

Seat belt use was shown to virtually eliminate complete ejection for both SUT and tractor-trailer drivers (though a small percentage of belted drivers are partially ejected in some crashes). Furthermore, rollover accounts for almost 65 percent of ejected tractor-trailer drivers in fatal crashes.

There are challenges to the acceptance of safety technology in the heavy commercial vehicle industry. While vehicle manufacturers offer safety technology beyond that required by the Federal Motor Vehicle Safety Standards (FMVSS), the commercial uptake for these technologies are for the most part very low. Given that most commercial drivers have no influence on the vehicle purchasing process, including specifying vehicle safety content, this may tend to slow the adoption of safety protection available to heavy vehicle occupants.

Several potential countermeasures have been identified:

- Measures to increase seat belt usage may include the installation of enhanced seat belt warning systems that activate a visual and audible warning when truck drivers and other vehicle occupants fail to use their seat belt.
- Increasing the integrity and robustness of cab structures and the protection of cabs particularly with respect to rollover.
- The installation of side curtain air bags to prevent occupant ejection through the side windows and head trauma.
- Increasing occupant head space during rollover events through installation of automatic pull-down seats.

The regulation of safety content of commercial vehicles has not progressed to the same degree as it has in light-duty vehicles. For example, air bag systems are not mandatory in heavy trucks and to date, only one vehicle manufacturer offers front air bags as standard. No manufacturers offer side curtain air bags, which counteract partial and full driver ejection during rollover events, a major cause of driver injury and death (Woodrooffe and Blower, 2013).

Given the 21CTP goals for improved safety and the interagency cooperation that defines the program, it is not unreasonable to expect that DOT should have a safety related program along the lines of SuperTruck, with its own focus on improving safety for truck drivers involved in accidents. Areas of potential emphasis include improved cab structural integrity and prevention of driver ejection during rollover events.

RESPONSE TO RECOMMENDATIONS FROM THE NRC PHASE 2 REPORT

The following section discusses this committee's evaluation of the Partnership's responses to the recommendations of the NRC Phase 2 report.

> **NRC Phase 2 Recommendation 7-1.** The Partnership should review the wording of its safety goals and consider rewording them so as to unambiguously state that safety will not be compromised in reducing fuel consumption.
>
> **21CTP Response:** The Partnership will review wording of safety goals to ensure appropriate emphasis is placed on safety—and that safety is not compromised in achieving fuel efficiency goals.

Committee Comment on Response to 7-1

The Partnership agreed with the Phase 2 committee's recommendation that wording of the safety goals should be clarified to emphasize that safety will not be compromised to achieve reductions in fuel consumption. However, this correction of the wording has not occurred to date. Additionally, it appears that the roadmap section on safety was revised in the most recent 2013 publication, but this specific goal was never revised. The Partnership has indicated that it is open to ideas from the NRC committee on how to reword this goal to clarify the intended meaning (21CTP, 2013).

***

> **NRC Phase 2 Recommendation 7-2.** The committee supports the emphasis that the DOT and the 21CTP are giving to crash-avoidance technologies and recommends that crash-avoidance technologies continue to be given high priority and technical support.
>
> **21CTP Response:** The Partnership agrees with the committee's observations and recommendations.

Committee Comment on Response to 7-2

The Partnership responded favorably to the recommendation for giving crash avoidance technologies a high priority and has made modest gains in this area. Partnership assessments were conducted on truck-related crash-avoidance technologies such as ESC, RSC and F-CAM systems (described in earlier sections). Of the technologies assessed by the Partnership, it is this committee's opinion that the F-CAM systems show the best potential for further development. Disc brake technology can also be viewed as a crash-avoidance technology since it brings about shorter stopping distances with improved thermal capacity compared to conventional braking systems. Implementation of disc brake systems will also reduce the chronic problems of conventional brakes requiring constant readjustment. The Partnership also supports continued research in the following crash-avoidance technologies:

- Lane departure warning (LDW)
- Forward collision warning (FCW)
- Side object detection (blind spot monitoring, BSM) and lane change merge (LCM)
- Rear object detection and collision warning

***

NRC Phase 2 Recommendation 7-3. The DOT should evaluate the conclusions and recommendations of the TRB study Achieving Traffic Safety Goals in the United States: Lessons from Other Nations of highway safety in other nations, and consider the possibility of establishing more aggressive initiatives and goals for highway safety in general. The DOT should also consider establishing more aggressive goals for heavy-duty truck safety.

21CTP Response: DOT will review the TRB study (Achieving Traffic Safety Goals in the United States: Lessons from Other Nations). DOT regularly re-evaluates its safety goals each year, and will take into consideration information from this study, as well as the special circumstances impacting traffic safety in United States.

Committee Comment on Response to 7-3

There is no evidence that this particular recommendation has been addressed at this time.

***

NRC Phase 2 Finding 7-4. Some of the potential safety improvements considered by the committee may have negligible impact on fuel consumption and, in some cases, appear to have positive implications. However, further study of the potential highway safety impact of high productivity vehicles is warranted.

Partnership Response: USDOT will launch a major study of this issue based on direction given in MAP-21; specifically, Section 32801 requires completing a "Comprehensive Truck Size and Weight Limits Study." The scope of this study can be found in the authorizing legislation.

Committee Comment on Response to 7-4

The Map-21 Truck Size and Weight Study is currently under way and attempting to address this question, albeit in a limited manner.

FINDINGS AND RECOMMENDATIONS

Finding 7-1. Many safety technologies could be effectively evaluated and demonstrated in a safety-focused program—for example, a Safety SuperTruck similar to the DOE fuel consumption reduction SuperTruck program.

Recommendation 7-1. DOT should consider implementing a Safety SuperTruck program to develop, integrate, and evaluate safety technologies such as cab structural integrity, side curtain airbags, advanced forward warning and collision mitigating systems to help industry attain a more integrated and complete safety package with a view to generating greater purchaser acceptance of safety technology not mandated by law.

Finding 7-2. Properly performing and well-adjusted braking systems form an essential platform for the crash avoidance technologies being assessed by the 21CTP. In terms of stopping distance, braking control, brake adjustability, and thermal capacity, disc brake systems are superior to drum brakes. Disc brakes provide a better foundation than drum brakes for future technologies dependent on reliable brake performance.

Recommendation 7-2. 21CTP should assess ways to encourage industry to adopt disc brakes and measures should be taken to encourage broad adoption of these superior brake systems.

Finding 7-3. The current generation of commercially available Forward Collision Avoidance and Mitigation systems should reduce fatalities in truck striking rear-end collisions by 24 percent, injuries by 25 percent, and property damage only crashes by 9 percent. Second- and third-generation versions of the system will bring substantially greater benefits. Second-generation systems will be able to detect stationary threat objects in the roadway through the fusion of radar and vision systems, while third-generation systems have more aggressive automated braking deceleration, achieving 0.6 *g*.

Recommendation 7-3. 21CTP should assess future generation Forward Collision Avoidance and Mitigation system development to identify barriers to development and establish incentives to foster commercialization.

REFERENCES

21CTP (21st Century Truck Partnership). 2013. Roadmap and Technical White Papers. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. https://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/21ctp_roadmap_white_papers_2013.pdf.

Blower, D., and J. Woodrooffe. 2012. Heavy Vehicle Crash Data Collection and Analysis to Characterize Rear and Side Underride and Front Override in Fatal Truck Crashes. UMTRI Report UMTRI-2012-31.

FHWA (Federal Highway Administration). 2014. MAP-21 Comprehensive Truck Size and Weight Limits Study. http://www.ops.fhwa.dot.gov/freight/SW/map21tswstudy/index.htm.

Jarossi, L., D. Hershberger, and J. Woodrooffe. 2012. Trucks Involved in Fatal Accidents: Codebook 2010. Center for National Truck and Bus Statistics, University of Michigan Transportation Research Institute. UMTRI-2012-30, November.

Marmy, J. 2015. International Road Transport Union. Geneva, Switzerland.

NRC (National Research Council). 2012. *Review of the 21st Century Track Partnership: Second Repor*t. Washington, D.C.: The National Academies Press.

RITA (Research and Innovative Technology Administration). 2014. Smart Roadside. http://www.its.dot.gov/factsheets/pdf/Smart%20Roadside.pdf.

Woodrooffe, J., C. Flannagan, D. Blower, S. Bogard, P.E. Green, and S. Bao. 2013. Automated Control and Brake Strategies for Future Crash Avoidance Systems–Potential Benefits. SAE 13CVA-0024.

Woodrooffe, J., and D. Blower. 2013. Heavy Truck Crashworthiness: Injury Mechanisms and Countermeasures to Improve Occupant Safety. UMTRI Report 2013-41.

Woodrooffe, J., D. Blower, T. Gordon, P.E. Green, B. Liu, and P.F. Sweatman. 2009. Safety Benefits of Stability Control Systems for Tractor-Semitrailers. NHTSA DOT HS 811.