School Bus Stop Alerts in Connected Vehicles: Concept of Operations

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October 1, 2016
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Scope

Identification

This document describes the Concept of Operations (ConOps) for a School Bus Stop Alert (SBSA) system for connected vehicles and is part of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) research program. The purpose of the CVI-UTC research program is to conduct innovative research using connected-vehicle and infrastructure technologies to improve transportation safety, state of good repair, economic competitiveness, livable communities, and environmental sustainability. [1]

The SBSA ConOps describes the characteristics of a future SBSA system. The objective of the ConOps is to provide a high-level identification of user needs and system capabilities in terms that all stakeholders and laypersons can understand. The document answers questions about who, what, when, where, why, and how in relation to the SBSA system.

This document specifically describes the ConOps for the alerts and notifications given as a school bus approaches and stops at a school bus stop. It also covers alerts and notifications given when a school bus is stopping at a railroad crossing. The alerts and notifications include those employed for both safety-related and non-safety-related applications hosted by school buses and other vehicles.

Key objectives of this ConOps include:

- Explaining the main purpose of the SBSA system
- Identifying the stakeholders that may use the SBSA system
- Describing the types of notifications and alerts the SBSA system will relay
- Considering the impacts an SBSA system may have on users

Document Overview

This SBSA ConOps is modeled after the Core ConOps developed by the Lockheed Martin Corporation and the United States Department of Transportation (U.S. DOT). The overarching Connected Vehicle Core System ConOps follows the structure recommended by the Institute of Electrical and Electronics Engineers (IEEE) Standard 1362-1998, “IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document.” The SBSA ConOps will also follow this structure. The ConOps will include the following nine main sections:

- Section 1 – Scope. This section provides the scope of the ConOps and introduces the ConOps document.
• **Section 2 – Referenced Documents.** This section identifies foundational documents used as background in developing the ConOps document.

• **Section 3 – Current System.** The SBSA system is being designed to relay messages when a school bus is stopping or stopped. This section of the report describes the typical reasons a school bus must stop and current procedures that bus drivers perform when stopping a school bus. This section also discusses potential stakeholders for an SBSA system.

• **Section 4 – Justification for and Nature of Changes.** This section discusses some of the reasons why a connected vehicle SBSA system is needed. For instance, currently it is difficult to notify vehicles of a stopped school bus; notification is limited to visual line of sight or by static road signs that indicate “School Bus Stop Ahead.” This lack of real-time notification can be a problem on hills and blind curves where the visual line of sight may be obstructed.

• **Section 5 – Concepts for the Proposed System.** This section describes the connected vehicle SBSA system, which will use connected vehicle technology to alert traffic that a school bus is stopped or stopping in the immediate vicinity. Communication of this information will be particularly important around blind areas such as hills and curves. This section will also describe the potential educational aspects of the SBSA system.

• **Section 6 – Operational Scenarios.** This section provides scenarios in which an SBSA system would be expected to relay information to other connected vehicles. It will cover scenarios under which a bus currently stops and how this system would be used in those operational scenarios. The operational scenarios were drawn in part from focus groups conducted with school bus drivers and light-vehicle drivers.

• **Section 7 – Summary of Impacts.** This section discusses potential impacts of the SBSA system on the user (i.e., driver) and other stakeholders.

• **Section 8 – Analysis of Proposed System.** This section summarizes the potential benefits and drawbacks of implementing the SBSA system.

• **Section 9 – Notes.** This section includes all acronyms used in the document.

**Referenced Documents**

**Foundational Documents**

This section lists documents that are foundational to this ConOps document.


**Reference List**
The following documents are cited in the text.


Current System

This section of the ConOps briefly describes the current school bus system in the United States and outlines the capacity of connected vehicle technology to relay messages between school buses and other vehicles.
**School Bus System in the United States**

Every day in the United States approximately 480,000 school buses [1] transport over half of America’s schoolchildren (25 million children) to and from school [2]. School bus transportation is often considered one of the safest modes of travel [3,4] since it only accounts for 2% of the total number of motor vehicle fatalities of school-aged children [5]. However, if one considers all of the vehicles involved in school-bus-related crashes, such as an injury or fatality in a passenger vehicle that collided with a school bus, there are approximately 140 fatalities of school-aged children and 85,000 injuries each year due to school-bus-related crashes [6].

**Current State of the Practice**

While traveling to and from school, school buses stop on different types of roadways (e.g., straight, curvy, hilly, divided, undivided, etc.) with varying speed limits. Typically, school buses stop to load students, unload students, and to check for approaching trains prior to crossing railroad tracks. When stopping a school bus, bus drivers must be cautious of hills and curves where other drivers may not see their stopped bus or schoolchildren crossing the road.

**Use of Bus Stop Ahead Sign**

Placing bus stops along curvy or hilly terrain is sometimes unavoidable. The current state of practice for dealing with these situations involves placing a fluorescent yellow-green SBSA sign according to the following guidance from the Manual on Uniform Control Devices (MUTCD):

“The School Bus Stop Ahead (S3-1) sign should be installed in advance of locations where a school bus, when stopped to pick up or discharge passengers, is not visible to road users for an adequate distance and where there is no opportunity to relocate the school bus stop to provide adequate sight distance.” [7]
While the MUTCD provides some direction as to when SBSA signs are to be used, they are simply guidelines, not requirements. Additionally, these signs, as described, provide no indication of the school bus schedule, which leaves other drivers in the dark as to whether or not they may come across a school bus.

Older versions of the SBAS sign may still exist at some locations as text with a yellow background [8]. These older signs may confuse some drivers about whether or not both signs are valid, thus causing a safety concern if drivers ignore the sign.

**Laws Regarding Stopped School Buses at Bus Stops**

The legality of passing a stopped school bus varies based on State laws. While all States require drivers to stop when approaching a stopped school bus from behind regardless of road type or number of lanes, 90% of the States provide exceptions to the stopping rule when the driver is approaching the bus from the opposite direction depending on the roadway’s attributes. Figure 3 graphically shows the circumstances in which a driver is not required to stop for a school bus that is stopped and loading or unloading students. More specifically, as shown in Table 1, over half of the States allow drivers to pass a stopped school bus when they are traveling in the opposing direction on a divided highway regardless of the number of lanes on the roadway. Five States specify that drivers may pass a stopped bus when they are traveling in the opposing direction on a roadway with four or more lanes, even if the road lacks a physical median or other barrier. Other exceptions to the stopping requirement include a requirement to slow down to 10 mph when approaching a school bus that is stopped on the opposite side of a divided highway and a special rule that drivers are allowed to pass a stopped school bus when they are traveling on a different roadway, controlled access highway, and/or stopped in a loading zone where pedestrians may not enter the roadway.
Figure 3. Graphical representation of state exceptions to the stopped school bus law.

Table 1. Percentage of States with Roadway-specific Exceptions to the Stopped School Bus Law

<table>
<thead>
<tr>
<th>Percent</th>
<th>Scenarios Where Drivers are Exempt from Stopping for a Stopped Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>63%</td>
<td>Opposite side of a divided highway or roadway (median or barrier)</td>
</tr>
<tr>
<td>16%</td>
<td>Opposite side of roadway with 4 or more lanes</td>
</tr>
<tr>
<td>12%</td>
<td>4-lane divided highway moving in the opposite direction</td>
</tr>
<tr>
<td>10%</td>
<td>Other</td>
</tr>
<tr>
<td>10%</td>
<td>No Exceptions</td>
</tr>
</tbody>
</table>

School bus drivers must be cognizant of other drivers who may ignore or be unaware of current school bus stop laws. The general procedure for warning other vehicles that a school bus is about to stop involves activating the bus’s amber and red flashing lights, which are located on the front and rear of the school bus. The bus driver first activates the amber warning lights by pressing the amber light switch on the driver console. This is expected to happen at least 100 feet prior to the bus stop. Once the bus comes to a complete stop and the driver opens the door, the bus’s lights automatically switch from the amber lights to the red lights. At this time, the stop sign installed on the left side of the bus extends to display a “STOP” sign to the surrounding drivers [9].

In a survey of school bus drivers in three Florida counties, bus drivers perceived illegal passing by other motorists as the biggest safety problem facing school transportation vehicles [6]. This claim
is substantiated by a field study in Florida, which identified 10,590 instances of vehicles illegally passing 3,427 school buses on a single day. Fifty-six percent of the illegal passing maneuvers occurred on two-lane roads and more than half of those (66%) were by vehicles traveling in the opposing lane. On average, there were 5.9 incidents per bus per day on routes that utilized primarily main roads, whereas mostly minor-road routes with light traffic averaged 3.1 incidents per bus [6]. Although injuries caused by illegally passing vehicles are rare, reported injuries generally involved a pedestrian with serious head injuries and a variety of fractures. Sometimes, illegal passing also resulted in sideswipe crashes that caused cosmetic damage to the bus, but few injuries or fatalities were reported as a result of those crashes [6].

Due to the overwhelming number of vehicles that illegally pass school buses on a regular basis, 11 states (Arkansas, Connecticut, Georgia, Illinois, Maryland, North Carolina, Rhode Island, South Carolina, Virginia, Washington, and West Virginia) allow the use of cameras on the outside of school buses to capture images of motorists illegally passing a school bus [10]. Within these States, school districts may implement a program to automatically photograph and issue citations to vehicles that pass a school bus while the stop arm is extended and the red lights on the rear of the bus are flashing. While this system makes progress in issuing citations to drivers who illegally pass stopped school buses, the system does not actively prevent crashes between pedestrians and illegally passing vehicles.

**Laws Regarding Stopped School Buses at Railroad Tracks**

School buses throughout the United States are expected to stop and check for traffic prior to crossing railroad tracks. The only exception to this required stop-and-check is if a railroad crossing is fixed with a sign that reads “EXEMPT CROSSING” or other sign that indicates that the tracks have been certified by transportation officials as out of service [11].

**Other Reasons School Buses May Stop**

School buses may stop for reasons other than bus stops and railroad crossings. As part of this project, two focus groups were conducted to gather information for the ConOps. One focus group included light-vehicle drivers and the other included actively employed school bus drivers. The school bus participants were asked to explain the circumstances in which they needed to stop their bus. Participants mentioned a variety of reasons other than the typical bus stop and railroad crossing, including the following:

- Emergency inside the bus (e.g., student sick on the bus)
- Emergency outside the bus/obstacle (e.g., tree in the road, flooding, animals in the road)
- Equipment issues (e.g., flat tire, broken mirror, emergency exit door/lever open)
- School children at locations other than designated stops (this usually occurs during the first 2 weeks of school as schoolchildren are learning where their stop is located)
• Other stopped buses (i.e., stop when facing or behind another bus)
• Road work (e.g., construction)
• Car braking ahead
• Funeral

While it is important to understand the range of reasons why a school bus driver may unexpectedly stop the bus, these scenarios are outside the scope of this project. Other connected vehicle applications, such as forward collision warning, emergency braking, or disabled vehicle applications, are likely to cover several of these scenarios.

**Connected Vehicle Environment**

The connected vehicle system aims to improve transportation safety by opening a communication network that allows communication among vehicles as well as between vehicles and transportation infrastructure to reduce crashes and improve the mobility of people and goods. Unlike current radar and video-based safety improvement systems that have field-of-view constraints, connected vehicle technology enables vehicles to collect data from all directions, providing a 360-degree awareness of their surroundings. The use of dedicated short-range communication (DSRC) channels provides an “extended information horizon” that lets the drivers “see over hills and around curves” [12] up to approximately 3,000 feet away under ideal conditions [13].

The capabilities of the connected vehicle system enable vehicles to send and receive information related to driving tasks and road conditions. This may include messages such as speed limit signs, horizontal curve warnings, collision warnings, emergency vehicle warnings, inclement weather alerts, and more. The means of displaying each message and the priority in which they are displayed are currently being evaluated.

The connected vehicle system enables wireless communication between a nearly limitless number of road users. Frequently referred to as V2X, or vehicle-to-X, the system focuses on vehicle communication with a variety of other devices where the X part of the name is replaced by the receiving road user. For example, V2I represents vehicle-to-infrastructure communication, V2V represents vehicle-to-vehicle communication, and V2P represents vehicle-to-pedestrian communication.

In February 2014, the U.S. DOT issued an announcement that they will begin taking steps to enable widespread use of this technology as it pertains to light vehicles [14]. At this point, the system mostly focuses on a vehicle’s ability to send out speed and position data; however, advancements are being made to enhance these messages by allowing specialty vehicles to broadcast special safety messages, such as an alert that an emergency vehicle is approaching. The U.S. DOT currently supports the system as a means of disseminating safety messages. The system has not advanced to the point of allowing automated driving without driver intervention.


**Vehicle-to-Infrastructure Communication**

Vehicle-to-infrastructure communication refers to communication between a vehicle’s onboard equipment and a radio receiver that is part of the transportation infrastructure. With V2I communication, any vehicle capable of connected vehicle communication may send and receive messages. These messages may include indications of near-crash events, road conditions, weather conditions, and/or other special events.

**Vehicle-to-Vehicle Communication**

The safety benefits of a vehicle-to-vehicle communication system are dependent on each vehicle’s ability to send and receive data via a piece of onboard equipment that may be mounted on or in a vehicle. Since these units are regularly moving, they are required to send out telemetry data that include current location, heading, speed, and acceleration. Data are sent and received through the V2V system and then evaluated to identify potential risks of surrounding vehicles.

**Basic Safety Messages**

The basic safety message (BSM) contains the standard safety data required to communicate vehicle information, such as vehicle telemetry and vehicle type. It is frequently sent at a rate of 10 times per second. The safety message may contain up to two parts: one related to the basic safety information from the vehicle and the other related to optional policies that may impact BSMs in the future. All BSMs must contain Part I; Part II is optional at this time. Figure 4 provides a listing of the BSMs as specified in SAE J2735.
**connected vehicle environment** consists of a variety of applications that aim to improve environmental conditions, traffic mobility, transportation safety, and overall transportation system support. The Connected Vehicle Reference Implementation Architecture (CVRIA) provides a repository for applications that have been developed by various connected vehicle programs. Examples of each are presented below:  

- **Environmental**: connected eco-driving; dynamic eco-routing; eco-approach and departure at signalized intersections; eco-cooperative adaptive cruise control; eco-integrated corridor management decision support system; eco-lanes management; eco-multimodal real-time traveler information; eco-ramp metering; eco-smart parking; eco-speed harmonization; eco-traffic signal timing; eco-transit signal priority; electric charging stations management;

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**Figure 4. Basic safety message as specified in the SAE J2735 [15].**

**Connected Vehicle Reference Implementation Architecture**

The connected vehicle environment consists of a variety of applications that aim to improve environmental conditions, traffic mobility, transportation safety, and overall transportation system support. The Connected Vehicle Reference Implementation Architecture (CVRIA) provides a repository for applications that have been developed by various connected vehicle programs. Examples of each are presented below:

- **Environmental**: connected eco-driving; dynamic eco-routing; eco-approach and departure at signalized intersections; eco-cooperative adaptive cruise control; eco-integrated corridor management decision support system; eco-lanes management; eco-multimodal real-time traveler information; eco-ramp metering; eco-smart parking; eco-speed harmonization; eco-traffic signal timing; eco-transit signal priority; electric charging stations management;
low emissions zone management; roadside lighting; enhanced maintenance decision support system; road weather advisories and warnings for motorists; road weather information and routing support for emergency responders; road weather information for freight carriers; road weather information for maintenance and fleet management system; variable speed limits for weather-responsive traffic management

- **Mobility**: border management systems; container security; container/chassis operating data; smart roadside initiative; freight drayage optimization; freight-specific dynamic travel planning; ad hoc messages; performance monitoring and planning; advanced automatic crash notification relay; emergency communications and evacuation; incident scene pre-arrival staging guidance for emergency responders; incident scene work zone alerts for drivers and workers; cooperative adaptive cruise control; queue warning; speed harmonization; vehicle data for traffic operations; emergency vehicle priority; freight signal priority; intelligent traffic signal system; pedestrian mobility; transit signal priority; dynamic ridesharing; dynamic transit operations; integrated multi-modal electronic payment; intermittent bus lanes; route ID for the visually impaired; smart park and ride system; transit connection protection; transit stop request; advanced traveler information systems; receive parking space availability and service information; traveler information - smart parking

- **Safety**: transit pedestrian indication; transit vehicle at station/stop warnings; vehicle turning right in front of a transit vehicle; curve speed warning; oversize vehicle warning; pedestrian in signalized crosswalk warning; railroad crossing warning; red light violation warning; reduced speed zone warning; restricted lane warnings; spot weather impact warning; stop sign gap assist; stop sign violation warning; warnings about hazards in a work zone; warnings about upcoming work zone; blind spot warning + lane change warning; control loss warning; do not pass warning; emergency electronic brake light; emergency vehicle alert; forward collision warning; intersection movement assist; pre-crash actions; situational awareness; tailgating advisory; vehicle emergency response

- **Support**: communications support, core authorization, data distribution, infrastructure management, security and credentials management, signal phase and timing

The applications listed above are in various stages of development. Several of the applications have direct relevance to the current project and have provided the baseline for establishing the algorithms and diagrams within this ConOps, as follows: (1) do not pass warning, (2) transit pedestrian indication, (3) reduced speed zone warning, (4) stop sign violation warning, (5) emergency vehicle alert, and (6) forward collision warning.

**Stakeholders**

The primary stakeholders in an SBSA system are the school bus driver and other vehicles in the vicinity of the school bus. In the present system, other vehicle drivers receive information about
school buses from sources including road signs, lights mounted on the bus, and the bus stop arm. School bus drivers receive very little, if any, information from other vehicles on the roadway.

Another potential stakeholder in an SBSA system is law enforcement. While it is challenging for school bus drivers to record and report a license number, camera systems are already being implemented in some school districts around the nation to assist school bus drivers in reporting illegal passing behavior. Connected vehicle technology could be another avenue for relaying illegal passing of school buses to law enforcement and other agencies in charge of processing violations. While it is technically feasible for connected vehicle technology to relay violation information, the National Highway Traffic Safety Administration (NHTSA) has said that connected vehicle technology is not intended for enforcement of speeding and other violations [17].

Railways are another potential stakeholder for an SBSA system. Communication between a school bus and train could be used to alert a train if a school bus is stuck on railroad tracks. While communications between trains and school buses are beyond the scope of this ConOps, the potential need for a communication system between trains and school buses is described in the future research needs section of the ConOps.

**Justification For and Nature of Changes**

Connected vehicle communication, particularly DSRC, could be used to provide direct vehicle-to-vehicle communication between a school bus and an approaching vehicle, especially when the bus is stopped over a hill or around a blind curve. In the connected vehicle environment, messages from school buses may be relayed wirelessly to other vehicles (e.g., bus stopping ahead, bus stopping at railroad crossing). In addition, messages from other vehicles may be relayed to bus drivers (e.g., vehicle approaching, vehicle stopping). Section 6 (Operational Scenarios) discusses potential messages relayed via an SBSA system in more detail.

An SBSA system may help save the lives of school children as they wait for a school bus or cross the street when embarking or disembarking from a school bus. Additionally, it could help save the lives of occupants in vehicles driving near school buses. For instance, in 2012, 101 school buses were involved in fatal crashes [18]. While crashes between a school bus and another vehicle are of concern for the occupants of the school bus, the most common fatality involving a school bus is to the motorist that collides with the bus [19]. The SBSA system will assist other drivers on the road by providing them with information to help them predict school bus behavior and avoid collisions with school buses. The system would be particularly beneficial at areas such as hills and blind curves where a driver’s line of sight may be obscured; however, it is unknown how many crashes this particular system will directly prevent.

NHTSA reports that since 2003, 119 school-age pedestrians (younger than 19) have died in school-transportation-related crashes [20]. Sixty-five percent were struck by school buses, 5% by vehicles
functioning as school buses, and 30% by other vehicles involved in the crash [20]. An SBSA system could assist in preventing some of these fatalities by alerting other vehicles, in real-time, that a school bus is stopped at a school bus stop to load and unload school children. The system could also remind those drivers to be alert for students who may be crossing the street. Again, the SBSA system would be particularly beneficial at areas such as hills and blind curves where sight restrictions may block a driver’s view of the school bus or a student crossing the road.

The SBSA system may also include messages that can inform other vehicles of the law regarding stopped school buses with the objective of reducing illegal passing of school buses. Illegal passing behavior of vehicles around school buses jeopardizes the lives of school children every day across our nation. The National Association of State Directors of Public Transportation Services (NASDPTS) conducted a one-day survey with school bus drivers in 29 states. During the survey, over 97,000 school bus drivers reported 75,966 vehicles illegally passing their buses on a single day [21]. These findings are in line with an entrance survey given to school bus drivers who were brought in to provide input as part of the development of this ConOps. In the entrance survey, half of the participants (three of six) indicated that on a daily or weekly basis, vehicles illegally pass their school bus while they are stopped at a bus stop.

In focus groups conducted with light-vehicle drivers as part of the ConOps development, VTTI researchers found that some drivers were uncertain about when it is legal to pass a stopped school bus. For instance, one participant said, “Isn’t there one situation like a divided highway or something where you don’t have to stop?” Participants indicated that an SBSA system could raise awareness of when it legal to pass a school bus and when it is not.

Through the use an SBSA system, school bus drivers can be provided with knowledge regarding the movement of traffic around their bus as they approach and come to a stop. This could assist them in making safety-critical decisions such as when to allow students to exit the bus if oncoming traffic is not abiding by the extended stop arm. Such a system could also inform other vehicle drivers in the area when a school bus is approaching a stop or when it is stopped to load or unload children. Through these V2V based communications, the connected vehicle SBSA system has the potential to improve the safety of students as well as other vehicles that are sharing the road with school buses.

Concepts for the Proposed System

Description of the Proposed System
This section of the ConOps details the “who, what, when, where, why, and how” of the SBSA system.

- **Who will use it?** School bus drivers and drivers of other vehicles are the anticipated users of an SBSA system.
• **What will it relay?** Messages may be relayed between school buses and other vehicles. Below are some examples of the messages that could be relayed between the various stakeholders. Additional examples are presented in Section 6: Operational Scenarios.

  o Safety messages from school bus to other vehicles at school bus stops and railroad crossings:
    ▪ School Bus Stopped Ahead
    ▪ School Bus Stopping Ahead
  o Safety messages from other vehicles to school bus at school bus stops:
    ▪ Approaching vehicle not reducing speed
    ▪ Following vehicle not reducing speed
  o Information regarding the legality of passing a stopped school bus at school bus stops and railroad crossings.
    ▪ Stop! It is illegal to pass this school bus.
    ▪ Proceed with caution. It is legal to pass this school bus.
  o Other information:
    ▪ You are currently on an active school bus route.

• **When will it be used?** The primary instances when the SBSA system will be necessary is when a bus is stopping or stopped to load or unload students and to check for oncoming trains at railroad crossings. The distances at which a message may be relayed will depend on the context of the situation (i.e., speed, visibility, school bus stopping laws) and the content of the message.

• **Where will it be used?** The SBSA system will be useful in any case where other vehicles need to be made aware that a bus is stopping or stopped along the road. It will be especially beneficial in areas with hills and blind curves where line of sight is limited. Railroad crossings are another location where the SBSA will be useful to alert other drivers of a school bus driver’s potentially unexpected stopping behaviors.

• **Why will it be used?** As mentioned in Section 4 (Justification for and Nature of Changes), the SBSA system has the potential to reduce crashes and protect children boarding or exiting buses and crossing the street.

• **How will it be used?** Messages will be relayed between school buses and other surrounding vehicles via connected vehicle technology. Connected vehicle
communications, particularly DSRC, could be used to provide surrounding traffic with in-vehicle notifications of the stopped bus. Such a system could prove particularly effective when the bus is stopped over a hill or around a blind curve. Figure 5 demonstrates a basic schematic of the possible communications that are shared between school buses and approaching vehicles. This message will likely be contained within the second part of the BSM. Although the message may be attached to the BSM, each automobile must be equipped with the technology to read and process the information required for the SBSA.

![Figure 5. Schematic of the SBSA.](image)

This system operates on the assumption that roadside devices are strategically placed along the roadside in a manner that facilitates seamless communication between vehicles even when vehicles or objects are otherwise obscured. In the case of the actuated roadside sign, the system assumes that a school bus is equipped with an onboard device that can communicate directly with the sign and activate flashing beacons once a bus is in the vicinity. The in-vehicle safety messages operate under the assumption that each vehicle receives a message via their onboard safety equipment.
Diagrams of Enterprises that Interact with the SBSA

Figure 6 depicts the required relationships between organizations and enterprises that may be involved in the development and installation of the SBSA system. This includes relationships between vehicle manufactures, onboard equipment manufacturers (OEMs), and the mobile component system. The figure shows which enterprises own, operate, and develop the system in addition to information on the agreements that are likely to be required in the development and installation of this connected vehicle application. The key point within this figure is that many layers of coordination will be required between all vehicle and component manufacturers to ensure a well-functioning and reliable system.
Figure 7 depicts the required relationships between organizations that may be involved in the operation of the system between school buses and other vehicles. Similar to the system installation diagram in Figure 6, this figure depicts relationships between vehicle owners, drivers, and onboard equipment devices. For example, a vehicle’s driver may be the vehicle’s owner or may have an agreement with the vehicle’s owner to operate the vehicle. The vehicle itself is equipped with a device, designated the onboard equipment (OBE), that includes the V2V basic safety messages and bus stop notification application. There are other implied, written, or verbal agreements between the vehicle owner and the usage of the OBE, as well as an agreement between the vehicle owner and the basic safety message and bus stop application. Similar agreements exist among the school bus fleet owners, school bus drivers, and school bus OBE manufacturers.

Figure 7. Enterprise relationships for system operation.
Figure 8 depicts the required relationships between organizations that may be involved in the maintenance of the SBSA system on school buses and non-school-bus vehicles. This includes relationships and agreements between vehicle owners, vehicle manufacturers, the mobile component system, and OBE devices. In general, the vehicle or fleet owner is provided with warranties and maintenance agreements between the vehicle OBE manufacturer and application provider. The mobile component maintenance and development system owns and operates the application that has been provided to the vehicle or fleet owners. As with the previous figures, inherent agreements provide manufacturers access to the vehicle data required to process the applications.

Figure 8. Enterprise relationships for system maintenance.
Figure 9 depicts the required relationships between organizations that may be involved in the certification of the SBSA system. This includes relationships between Federal and State regulations and certification requirements.

In this figure, the application component certification requirements represent the functionality, performance, and operational environment in which a connected vehicle application must operate. The connected SBSA application is constrained by these requirements. These requirements are governed by the application certification entity that determines which applications may be deployed and operated within the connected vehicle environment. The application certification entity consists of members representing Federal and State regulators and vehicle manufacturers.

A similar process occurs with the vehicle OBE. The devices have their own set of device certification requirements that are governed by a device certification entity that is composed of Federal and State regulators, vehicle manufacturers, and OBE manufacturers.
Diagram of the Functional Properties of the SBSA

Table 2 demonstrates the required functionality of the SBSA, representing the needs of the system and the content that the application requires in order to process whether or not to display an SBSA message.

Table 2. Functional Properties Required of the SBSA

<table>
<thead>
<tr>
<th>Needs for the System</th>
<th>Required Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needs to warn nearby vehicles of bus location and behavior</td>
<td>Shall determine vehicle location</td>
</tr>
<tr>
<td></td>
<td>Shall determine and communicate the status of the stopped bus (i.e., the bus is stopped on the road with its stop sign extended and its red strobe lights flashing)</td>
</tr>
<tr>
<td>Needs to advise each vehicle whether or not it is required to stop</td>
<td>Shall determine other vehicles’ projected paths via current position and trajectory data</td>
</tr>
<tr>
<td></td>
<td>Shall acquire road geometry data from the road geometry database or from a roadside device</td>
</tr>
<tr>
<td></td>
<td>Shall call upon State laws and exceptions pertaining to passing a stopped school bus with its stop sign extended and its red strobe lights flashing</td>
</tr>
</tbody>
</table>

Diagram of Physical Objects that Provide Functionality

Figure 10 depicts the relationships and interactions between the physical elements that work together to produce SBSA messages.
Figure 10. Conceptual view of the physical system interactions.

**User Interface System**

The applications described within this ConOps rely on up to two forms of user notifications: external roadside notifications and internal driver notifications. It is anticipated that in the near term, the connected vehicle system will mostly rely on communication with roadside infrastructure. Several of the applications described in this ConOps are expected to interact with roadside devices, such as existing roadside signs, which may activate flashing beacons when a particular operational scenario occurs. For example, an existing SBSA sign may display flashing lights when a school bus passes the sign as it is preparing to stop.

With the exception of the actuated roadside SBSA sign, all of the proposed applications contain specific in-vehicle messages that are expected to be displayed on the driver’s in-vehicle messaging and/or navigation system. As described in Section 0 (Operational Scenarios), some of these messages may involve user interaction. For example, a passenger vehicle driver may receive a message that indicates the vicinity of a school bus. That driver may choose to either acknowledge and dismiss the message or may choose to seek additional information related to the message, such as laws regarding passing of a stopped school bus or the bus’s direction of travel.

The visual-based, in-vehicle notifications may also be accompanied by an auditory signal to draw the driver’s attention to the message or to direct the driver’s attention toward the hazard. The
auditory signal is only intended to be used during imminent or cautionary collision warnings and may include simple tones, earcons, and auditory icons as described in the *Human Factors Insights and Lessons Learned on Crash Warning System Interfaces* [22].

**Operational Scenarios**

This section of the ConOps provides scenarios in which an SBSA system would be expected to relay information to other vehicles and in which other vehicles would be expected to relay information to a school bus.

In each of the operational scenarios below, the application will follow an algorithm to determine whether or not the driver will receive a warning message. In general, these steps are as follows; however, the algorithm is subject to change depending on advancements in connected vehicle technology and system capabilities:

1. Connected vehicles broadcast position and telemetry data that are used to locate a vehicle’s position relative to a nearby school bus or school bus stop.

2. The application checks the status of the school bus’s stop arm and red strobe lights to determine if students are loading or unloading from the bus.

3. If the stop arm is extended and red strobe lights are flashing (implying that the vehicle is stopped and loading or unloading students), the algorithm obtains detailed roadway data to determine the geometric characteristics of the roadway.
   
   a. Vehicles that are approaching the school bus from behind are required to stop until the bus resumes moving.
   
   b. Vehicles at intersections are also required to come to a complete stop until the bus resumes moving.
   
   c. Vehicles that are approaching the school bus from the opposing direction may or may not be required to stop depending on the characteristics of the roadway with respect to State laws.
   
   d. Vehicles moving in the same direction as the school bus are not required to stop if the vehicle is already ahead of the school bus.

4. Drivers of other vehicles will receive a variety of messages or warnings when they are approaching a stopped school bus.
   
   a. Drivers will receive an informational message when students are waiting at a school bus stop on the roadside.
b. Drivers will receive an informational message when they are driving in the vicinity of a school bus.

c. Drivers will receive a warning when they are approaching a stopping or stopped school bus, especially in situations where the bus may be obscured from view.

d. Drivers will receive an imminent collision warning when their time-to-collision with a school bus indicates that a collision is likely. This warning is most frequently expected when a vehicle is approaching a stopped bus at a school bus stop or railroad crossing.

e. Drivers will receive an informational message to inform and educate them when they violate State laws for passing a stopped school bus.

The distances at which a driver receives an alert may vary based on environmental conditions such as time of day, weather condition, and other road conditions.

The operational scenario messages listed in Tables 3 through 6 were drawn from suggestions made by school bus and light-vehicle focus group participants. A complete listing of the types of information focus group participants suggested is found in Appendix A. The wording of the messages is likely to be modified as the SBSA system is developed and tested.

**Operational Scenario: School Bus Stop to Vehicles in the Vicinity**

**Description**

Table 3 lists the messages that drivers may receive as they approach an occupied school bus stop. The intent of these messages is twofold: (1) to inform drivers that there may be children on the roadside and (2) to indicate that they should decrease their speed to increase student safety.

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Example Message/Visual Display</th>
<th>Example Audible Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Bus Stop Ahead</td>
<td>In-vehicle message</td>
<td>None</td>
</tr>
<tr>
<td>Children near roadside</td>
<td>Activate flashing beacon on existing “School Bus Stop Ahead” signs</td>
<td></td>
</tr>
<tr>
<td>Reduce speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This system may broadcast the message based on pre-programmed times in which students are expected at the bus stop or it may use a video feed and image-detection software to passively determine the presence of students waiting at a bus stop. If students are expected at the bus stop or detected with the video system, the system activates the flashing beacon on the roadside signs,
such as the SBSA sign, or it sends a connected vehicle message to be displayed inside the driver’s vehicle.

The system may also reduce the speed limit in the area surrounding the bus stop in order to improve pedestrian survivability in case of a crash. This is possible through the use of variable speed limit signs or through in-vehicle notifications. While it is expected that some locations, such as neighborhoods with implied speed limits of 20 mph or under, may not require speed reductions, other bus stop locations on high-speed and/or high-volume roads may greatly benefit from this system.

Method

The method for determining when to dispense these messages or activate roadside devices is as follows:

1. The application determines the presence of students at a bus stop using video feed and image-detection software.
2. A positive reading of students waiting at the designated bus stop initiates the “Children on Roadside” message set.
3. The roadside devices receive indications to activate flashing beacons or to reduce speed limits in the vicinity.
4. Vehicles with connected vehicle capabilities broadcast telemetry data, which are used by the roadside device to determine whether drivers are within the area of influence and should receive the in-vehicle message.
   a. All vehicles within a small radius of the bus stop will receive a message that children may be near the roadside.
   b. If a speed limit reduction is in effect, vehicles within this radius may also receive a message to inform drivers of a new speed limit or advisory speed.
   c. Vehicles that are approaching the bus stop may receive a more specific message that they are approaching an occupied school bus stop.

Operational Scenario: School Bus to Other Vehicles in the Vicinity

Description

Table 4 lists the messages school buses may send to other vehicles when they are within the vicinity of a school bus. The primary point of these messages is to inform drivers that a school bus is in the area and that they should be alert and prepared to stop if needed.
Table 4. Message School Bus May Relay to Other Vehicles when a School Bus Is in the Vicinity

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Example Message/Visual Display</th>
<th>Example Audible Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>School bus in the area</td>
<td>“School Bus in the Vicinity”</td>
<td>None</td>
</tr>
<tr>
<td>• School bus may stop to pick up or drop off children.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Direction of travel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Information regarding stopping laws</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hidden school bus ahead (contingent on known sight restriction)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This message is distributed when a driver is within the vicinity of a school bus regardless of direction of travel or whether the school bus is stopping or stopped. The driver may acknowledge the message to dismiss it, or may choose to ask the system to provide more information, such as its direction of travel and information regarding the school bus passing laws within the State.

**Method**

The method for determining when to dispense these messages is as follows:

1. The connected school bus broadcasts telemetry and vehicle type data to roadside devices and/or other vehicles.

2. Other vehicles with connected vehicle capabilities broadcast telemetry data, which are used by the roadside device to determine whether drivers are within the area of influence and should receive the in-vehicle message.
   a. All vehicles within a specified radius of the bus stop will receive a message that they are traveling in the vicinity of a school bus.

3. Drivers who receive a message are provided with the option to acknowledge and dismiss the message or to seek additional information.
   a. Should the driver dismiss the message, the driver will not receive additional warnings when reentering the radius of the same school bus or entering the radius of another school bus unless significant time has passed.
   b. Should the driver seek additional information, the driver may navigate the in-vehicle driver interface to determine the bus’s direction of travel or to explore State requirements regarding stopping for a stopped school bus.
   c. If the roadside device indicates that the driver is traveling along a road with significant sight restrictions, the message may include a warning that the school bus may be obscured from view.
Operational Scenario: School Bus to Other Vehicles while Stopped at Bus Stop

Description

Table 5 lists the messages school buses may send to other vehicles. The primary point of these messages is to alert other drivers that they are approaching a school bus that is stopping or has stopped ahead, in particular when views are obstructed. Such warnings could also include alerts that children are boarding or exiting the bus and may be crossing the street.

Table 5: Messages School Bus May Relay to Other Vehicles when a School Bus Is at a Bus Stop

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Example Message/Visual Display</th>
<th>Example Audible Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>School bus ahead – presented when approaching drivers have a restricted line of sight</td>
<td>In-vehicle message</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Flashing beacons on an existing SBSA sign</td>
<td></td>
</tr>
<tr>
<td>School bus is stopped ahead – presented when approaching drivers have a restricted line of sight</td>
<td>In-vehicle message</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>• Include alert that children are boarding or exiting the bus and may be crossing the street.</td>
<td></td>
</tr>
<tr>
<td>Imminent collision warning – approaching driver is not reducing speed and thus may collide with the bus or a child on the road.</td>
<td>In-vehicle message</td>
<td>Auditory alert</td>
</tr>
<tr>
<td>Stopping law violation</td>
<td>In-vehicle message that allows driver interaction</td>
<td></td>
</tr>
</tbody>
</table>

There are three stages of this message that drivers may experience as they approach a stopped or stopping school bus. The first stage is a cautionary collision warning that considers whether the bus is stopped or in the process of stopping as indicated by the dynamic properties of the school bus and the status of the amber and red flashing lights on the rear of the school bus. This message is especially pertinent for drivers who may have an obscured view as they approach the bus. The second stage of this message is an imminent collision warning for drivers who are on track for a collision with a school bus or potentially a student. It is expected that this alert may overlap with some of the capabilities of other forward collision warning systems. The third and final stage of this message is an informational message for drivers who have performed an illegal maneuver by passing a stopped school bus with its red lights flashing and its stop sign extended. Drivers who receive this message may dismiss it or choose to receive extra information on the violation. This informational message is contingent on the ability of the SBSA system to receive geometric roadway information about the road on which the school bus is stopped.
Method

The method for determining when to dispense these messages or activate roadside devices is as follows:

1. The connected school bus broadcasts telemetry, vehicle type data, and stopping indicators (amber flashing lights, red flashing lights, and extended stop arm) to roadside devices and/or other vehicles.

2. Roadside devices or receivers on SBAS signs receive data from the school bus and evaluate whether to dispense the SBAS message based on the status of the amber flashing lights, red flashing lights, and stop arm.
   a. If the amber lights are flashing and the school bus is not near a railroad crossing, the message is disseminated and the flashing beacons on the roadside signs are activated.
   b. If the red lights are flashing and the stop arm is extended, the message is disseminated and the flashing beacons on the roadside signs are activated.
   c. The message is not disseminated when a school bus stops with its amber lights on at a railroad crossing. The operational scenario in Section 6.5 covers this situation.

3. Other vehicles with connected vehicle capabilities broadcast telemetry data, which are used by the roadside device to determine whether the drivers are within the area of influence and should receive the in-vehicle message.
   a. All vehicles within a specified radius of the bus stop will receive a message that there is a stopped school bus ahead.

4. Should the approaching vehicle not display an intent to stop (i.e., the time-to-collision is below an acceptable value), the driver will receive an imminent collision warning.

5. Should the driver violate the laws pertaining to the legality of passing a stopped school bus, the driver will receive an informational message indicating that they have violated the law by passing a stopped school bus. In this case, the driver may acknowledge and dismiss the message or seek additional information regarding the violation.

Operational Scenario: Other Vehicles to School Bus While Stopped at Bus Stop

Description

Table 6 lists the type of information other vehicles may send to school buses when the bus is stopped or stopping at a school bus stop. A warning message related to approaching vehicles that
are not slowing down to stop could help school bus drivers hold students on the bus or signal them
to wait on the side of the road when an approaching vehicle is not stopping.

Table 6: Messages Other Vehicles May Relay to School Bus at Bus Stop

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Example Message/Visual Display</th>
<th>Example Audible Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash warning – approaching driver is not reducing speed and thus may collide with the bus or a child on the road.</td>
<td>Flash screen at a rate of 4 Hz [23] with graphic and text Lights or screen on the front of the vehicle to notify students</td>
<td>None</td>
</tr>
</tbody>
</table>

This message is intended to be the only message that school bus drivers may receive as a part of the SBUSA application. Although audible alerts are recommended for imminent crash warnings, the environment in which a school bus driver operates is not conducive for hearing audible warning sounds. Instead, this application is intended to draw attention to the warning by flashing the screen. A similar screen may be fixed to the outside of the bus to warn students of an imminent danger as well.

**Method**

The method for determining when to dispense this message is as follows:

1. The connected school bus broadcasts telemetry, vehicle type data, and stopping indicators (amber flashing lights, red flashing lights, and extended stop arm) to roadside devices and/or other vehicles.
2. Other connected vehicles broadcast telemetry data.
3. Roadside devices receive basic safety data from the school bus and other vehicles.
4. If the red lights on the school bus are flashing and the stop arm is extended, the system identifies any connected vehicle whose time-to-collision is approaching a dangerous level. The system also obtains detailed roadway data to determine the geometric characteristics of the roadway and State laws regarding the legality of passing a stopped school bus.
   a. If the time-to-collision is below an acceptable value, the system verifies the location of that vehicle, its direction of travel, the roadway’s geometric characteristics, and the State laws pertaining to the state in which the driving is taking place.
   b. If the vehicle is required by State law to stop for the school bus and should the vehicle not display an intent to stop (i.e., releasing the gas pedal and pressing the brake pedal) when approaching a school bus, the driver of the school bus will
receive an imminent collision warning and will be instructed to prevent students from exiting the bus and/or crossing the street.

Operational Scenario: School Bus to Other Vehicles at Railroad Crossing
Description

Table 7 provides a message that school buses may send to other drivers when the bus is stopping or stopped at a railroad crossing. The primary point of these messages is to alert drivers that a school bus is stopping or stopped ahead, in particular when views are obstructed. The suggested message is similar to that of a school bus at a bus stop, though the concerns related to children loading or unloading are absent.

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Example Message/Visual Display</th>
<th>Example Audible Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash warning – approaching driver is in the same lane as the bus and not reducing speed</td>
<td>In-vehicle message: Warning, bus stopped ahead.</td>
<td>Simple tone or auditory icon</td>
</tr>
</tbody>
</table>

This message is an imminent collision warning that may be displayed to drivers who are approaching a stopped school bus at a railroad crossing. The message is intended to alert drivers within the same lane as the school bus who are not displaying any intent to stop. It is expected that this alert may overlap with some of the capabilities of other forward collision warning systems.

Method

The method for determining when to dispense this message is as follows:

1. The connected school bus broadcasts telemetry, vehicle type data, and stopping indicators (amber flashing lights, red flashing lights, and extended stop arm) to roadside devices and/or other vehicles.
2. Connected vehicles broadcast telemetry data.
3. Roadside devices receive basic safety data from the school bus and other vehicles.
4. If the amber lights on the school bus are flashing and the door of the vehicle is open (without the stop arm extended), the system obtains detailed roadway data to confirm whether the school bus is approaching a railroad crossing.
5. The system identifies any connected vehicle whose time-to-collision is approaching a dangerous level.
   a. If the time-to-collision is below an acceptable value, the system verifies the location of that vehicle, its direction of travel, and its current lane of travel.
If the vehicle is traveling in the same lane as the school bus and not displaying an intent to stop (i.e., releasing the gas pedal and pressing the brake pedal) when approaching a school bus, the driver will receive an imminent collision warning and will be instructed to avoid collision with the school bus.

**Summary of Impacts**

This section discusses potential impacts of the SBSA system on the user (i.e., school bus driver or driver of another vehicle) and other stakeholders and how those impacts might be addressed.

**Operational Impacts**

Use of the SBSA system can afford new opportunities to ensure the safety of schoolchildren and occupants of other vehicles, yet it is important that these capabilities do not lose their potential benefit by increasing the risk that a bus driver or other vehicle driver becomes distracted or confused. Some key operational impacts that should be considered and how they might be addressed include the following:

- **Industry and Government Cooperation:** Development of an SBSA system will require the participation of government agencies, vehicle manufacturers, and application developers to establish workable standards that establish message content, message priorities, driver workload assessment, and regulation of information flow to drivers.

- **Accurate Information:** The SBSA system information will need to be up-to-date and accurate. For instance, there could be legal implications if the system informs drivers that it is legal to pass a school bus when it is not.

- **Retrofit Buses and Vehicles:** School buses and other vehicles will need to be retrofitted with the connected vehicle technology required for the SBSA system while simultaneously incorporating the technology in new school buses and vehicles. According to the National Association of State Directors of Pupil Transportation, the suggested lifespan of a Type “C” school bus under normal operating conditions is 12 to 15 years [23]. Similarly, the average age of a U.S. car is estimated at over 11 years [24]. For this reason, options for retrofitting school buses and other vehicles should be made readily available.

- **Prioritize Messages:** The SBSA system will be operating in an environment with other connected vehicle technologies that provide safety-critical messages. For this reason, some low-priority messages may be delayed or suppressed. For instance, a message about alternate route options when on an active school bus route is a low-priority message that should be suppressed if a higher priority message such as a crash warning needs to be relayed. Some light-vehicle focus group participants indicated a desire to choose which notifications they would like to receive. One participant expressed the desire to be able to “turn off the routine things and leave the emergency things on.”
• **Minimize Distraction:** Procedures will need to be created to ensure that school bus drivers are not overburdened with information that exceeds their immediate capacity to process and understand. School bus drivers operate in a stressful environment requiring their focus to be on the safety of the schoolchildren. As one bus driver said, “In a classroom teachers have 20 or less kids. For a school bus we can have all the way up to 77 and it is just one adult, plus you are focused on driving and being responsible there. Because these kids behind you cause a racket. High school, middle school can be fighting. But then at the same time you are needing to let this kid cross to get on the bus or get off the bus, it is kind of a … big responsibility.” Due to the stress in the current school bus environment, technology that distracts the school bus driver from the focus on driving and student safety should be avoided.

• **Provide Training:** Procedures will need to be created for school bus drivers so that the messages from the SBSA system are treated as supplemental information, not a replacement for normal safety procedures. For instance, school bus drivers should still hold children until they see that an approaching vehicle has stopped even if the SBSA system is indicating that a vehicle is stopping.

**Analysis of the Proposed System**

This section summarizes the potential benefits and drawbacks of an SBSA system from the perspective of users. Though school bus and light vehicle participants were not specifically asked about the benefits and drawbacks of the technology, discussion about benefits and drawbacks arose over the course of the focus groups. A list of the issues raised during the focus groups is listed in Table 8 and described in this section.

**Table 8: Potential Benefits and Drawbacks**

<table>
<thead>
<tr>
<th>Potential Benefits</th>
<th>Potential Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Warning</td>
<td>Annoying</td>
</tr>
<tr>
<td>Information Sharing</td>
<td>Distracting</td>
</tr>
<tr>
<td>Crash Prevention</td>
<td>False Warnings</td>
</tr>
</tbody>
</table>

**Summary of Potential Benefits**

Participants from both the light vehicle and school bus groups described the potential benefits of the system, including providing advanced warning, preventing crashes, and sharing information. Participants from both the light vehicle and school bus focus groups mentioned the benefit of providing advanced warnings of a school bus stopping or stopped ahead, in particular at a location with reduced visibility, such as a curve. This advanced warning would allow other vehicle drivers to be aware of the situation and begin to slow down.
Participants suggested that providing information about when it is legal to pass a bus would be helpful at bus stops and railroad crossings. A few school bus drivers mentioned experiencing frustrated drivers who did not understand that school buses must stop at railroad crossings and that they are allowed to pass if a lane is available and no train is coming.

Summary of Potential Drawbacks

Light vehicle participants raised a few potential drawbacks to a school bus stop alert system; bus participants did not raise drawbacks during the course of discussion. Again, note that participants were not prompted to discuss drawbacks or concerns about the system. The issues mentioned here are ones that arose from participant discussions during the course of the focus groups.

Light vehicle participants raised concerns about the system being potentially annoying or distracting. In terms of the system being annoying, a few participants thought that they might get sick of hearing alerts. Other participants brought up concerns related to distraction. For instance, it was mentioned that such a system might cause people to look away from the forward roadway if the alert was displayed on a screen. The system might also cause drivers to get overloaded and miss important information.

Future Research Needs

Focus group participants brainstormed ideas for the SBSA system that are not included in the body of this ConOps because they were considered longer-term or lower-priority issues. All of the ideas participants brainstormed during the focus groups are listed in Appendix A. Some examples of ideas from the focus group that could be considered for future research include:

- **Location of school bus stops/routing**: Light-vehicle participants mentioned wanting to know where the school bus would be stopping and whether alternate routes would prevent them from being stopped behind a bus.
- **Stop arm violation**: School bus participants mentioned wanting the SBSA system to relay stop arm violations to law enforcement.

During the focus groups, participants also mentioned information sharing between buses and trains and/or rail infrastructure. While this issue is important, it is outside the scope of this current study. It is recommended that future work be conducted to develop a Concept of Operations for a connected train alert system that could relay messages between school buses and approaching trains at railroad crossings.
Notes

Glossary of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSM</td>
<td>Basic Safety Message</td>
</tr>
<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>CV</td>
<td>Connected Vehicle</td>
</tr>
<tr>
<td>CVI-UTC</td>
<td>Connected Vehicle/Infrastructure University Transportation Center</td>
</tr>
<tr>
<td>CVRIA</td>
<td>Connected Vehicle Reference Implementation Architecture</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated Short-Range Communications</td>
</tr>
<tr>
<td>FMCSA</td>
<td>Federal Motor Carrier Safety Administration</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>MUTCD</td>
<td>Manual on Uniform Control Devices</td>
</tr>
<tr>
<td>NASDPTS</td>
<td>National Association of State Directors of Public Transportation Services</td>
</tr>
<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
</tr>
<tr>
<td>OBE</td>
<td>Onboard Equipment</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>SBSA</td>
<td>School Bus Stop Alert</td>
</tr>
<tr>
<td>U.S. DOT</td>
<td>United States Department of Transportation</td>
</tr>
<tr>
<td>V2I</td>
<td>Vehicle-to-Infrastructure</td>
</tr>
<tr>
<td>V2P</td>
<td>Vehicle-to-Pedestrian</td>
</tr>
<tr>
<td>V2V</td>
<td>Vehicle-to-Vehicle</td>
</tr>
<tr>
<td>V2X</td>
<td>Vehicle-to-X</td>
</tr>
</tbody>
</table>
Appendix A. Focus Group Results

Both sets of focus group participants were asked what, if any, information school buses should relay to other vehicles when the bus is at a bus stop. Participants brainstormed ideas and discussed them for clarification. After the focus group, a researcher grouped the ideas into common clusters and gave each cluster a title. The research team then looked at the clusters and ranked them as high, medium, or low priority for the SBSA system. The prioritization was based on what the research team felt was safety-critical, with high being the most safety-critical for the system to address. Other messages may be considered in future studies. The brainstormed comments, clusters, and prioritizations are listed in the table below.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Participant Brainstorming Ideas</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kids are loading/unloading a school bus. Be alert to kids crossing the road.</td>
<td>How many kids</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Left or right side? (Which direction are kids going)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How many kids will be getting off?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whether kids will be crossing the road.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Which sides kids are getting off the bus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Caution that children are waiting for the bus</td>
<td></td>
</tr>
<tr>
<td>School bus is stopping ahead</td>
<td>Bus ahead, slow down and come to a complete stop ahead</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Big RED lights (lights help me know bus is stopping)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maybe a warning. Everyone must stop and not try to make it before the bus comes to a stop.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speed (bus is slowing down)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flashing lights when school bus is about to stop displayed on dash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strobe lights flash more as it gets closer to stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slow down and look for the lights that come on and stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amber lights—slow down; red lights—stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lights (help alert that bus is stopping)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children on board warning when approaching stop (<em>bus is going to stop</em>)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>800 foot stop/pick-up</td>
<td>Medium</td>
</tr>
<tr>
<td>Cluster</td>
<td>Participant Brainstorming Ideas</td>
<td>Priority</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Distance to the school bus stop</td>
<td>When it is stopping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How soon will it be stopping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance to stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance to Bus Stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How long before stopping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Next stop is how far (i.e., 200 ft. or ½ mile) from this stop?</td>
<td></td>
</tr>
<tr>
<td>School bus stop laws</td>
<td>A large bus next to you (full of students) that is not moving (<em>must stop for bus</em>)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Information about who must stop</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brief reminder of school bus stop law</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is it ever okay to pass a stopped or stopping bus? (bicycles, pedestrians, and cars)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stop when no median strip on 4 lane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When bus is making left turn, do not stop (<em>school buses must yield at left turns</em>)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do not motion bus to go (light-vehicles shouldn’t motion a bus to go)</td>
<td></td>
</tr>
<tr>
<td>Wait time at school bus stop</td>
<td>Is bus equipped for special needs passengers (stops may take longer)</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>How long it will be stopped</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How long will it be stopped</td>
<td></td>
</tr>
<tr>
<td>Location of school bus stops/routing</td>
<td>Where is it stopping</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Alternate route available?</td>
<td></td>
</tr>
</tbody>
</table>

*Italics used for clarification.*

School bus participants were also asked what information other vehicles should relay to buses when a school bus is at a bus stop. Participants brainstormed ideas and discussed them for clarification. After the focus group, a researcher grouped the ideas into common clusters and gave each a title. Since there were only six participants commenting on the topic, sometimes clustering was not possible (e.g., stopping behavior). The research team then looked at the clusters and ranked them as high, medium, or low priority for the SBSA system. The brainstormed comments, clusters, and prioritizations are listed in the table below. It should be noted that one of the ideas (i.e., stop arm violation) was considered to be not applicable to the SBSA, at least at this time. NHTSA has
indicated that connected vehicle (CV) technology will not be used for law enforcement, which in this case would apply to stop arm violations.

Table 10: Information Other Vehicles Should Relay to Buses when a School Bus Is at Bus Stop

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Participant Brainstorming Ideas</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopping behavior</td>
<td>When they are going to stop or turn (avoid hard braking event)</td>
<td>High</td>
</tr>
<tr>
<td>Relay safety -critical information</td>
<td>Accident ahead/road hazard ahead If there is an emergency in the car (what can the driver do to get the car around traffic)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>In a low visibility area—let other vehicles know you are there</td>
<td></td>
</tr>
<tr>
<td>Stop arm violation</td>
<td>Relaying vehicle information (license plate, etc.)</td>
<td>N/A – NHTSA indicated CV technology will not be used for enforcement</td>
</tr>
</tbody>
</table>

*Italics used for clarification.*

Participants from both groups were asked what, if any, information school buses should relay to other vehicles when a school bus is at a railroad crossing. Light-vehicle and school bus participants brainstormed ideas and discussed them for clarification. After the focus group, a researcher grouped the ideas into common clusters and gave each cluster a title. The research team then looked at the clusters and ranked them as high, medium, or low priority for the SBSA system. The brainstormed comments, clusters, and prioritizations are listed in the table below.

Table 11: Information Buses Should Relay to Cars When Bus Is at Railroad Crossing

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Participant Brainstorming Ideas</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>School bus is stopping ahead</td>
<td>Short simple warning bus may stop at crossing You have to stop (there is a bus stopped ahead that must stop behind) Tell cars around you that you are slowing to stop It should be the law for cars or buses to stop/listen/look no matter what! Alert cars ahead of time. (alert others that the bus will stop at crossing)</td>
<td>High</td>
</tr>
<tr>
<td>Distance to railroad crossing</td>
<td>How soon to crossing they will stop at Distance to stop How far is bus from crossing When will bus be stopping How long before stopping</td>
<td>Medium</td>
</tr>
<tr>
<td>Railroad crossing law</td>
<td>When one is coming up (to trains that bus on track; LV, go around) (let LV know if they can go around) Road configuration and location of bus on road (let LV know if they can go around) I need to stop—State Law Railroad crossing law Be kind, we have to stop (to look both ways) How long school bus has to stop at crossing</td>
<td>Medium</td>
</tr>
</tbody>
</table>

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Appendix B. Existing Recommended Procedures

As of October of 2014, the National Safety Council provided a list of recommended procedures for school buses and other vehicles as they interact with school buses. These recommendations were intended to supplement current State or local laws; as such, they not intended to supersede existing legislation or required procedures. Although the recommendations are no longer available on the National Safety Council website, the information is reproduced in this appendix since it plays a large part in understanding the procedures that school bus drivers must follow when loading or unloading students or when approaching an at-grade railroad crossing. Recommendations for other drivers have also been reproduced to explain the general regulations regarding driver behavior around stopped school buses.

Existing Recommended Procedures for School Buses Loading and Unloading

The National Safety Council reports that the most dangerous part of the school bus ride is loading and unloading the school bus. Though state laws and regulations vary somewhat across the United States, the National Safety Council has prepared the following recommended procedures for loading and unloading students from school buses in a document titled School Bus Loading & Unloading Safety Facts and Tips [25]:

1. Activate warning flasher system at least 100 feet prior to making a stop.

2. Approach the loading zone slowly and carefully. Direct students to wait in an orderly fashion safely back from the roadway.

3. Stop the vehicle 10 feet, or 15 feet if space is available, from students before loading (direct students to walk to the bus when the door is opened and the driver signals them to load).

4. Place the vehicle’s transmission in neutral and set the parking brake before opening the door to load or unload.

5. Ensure that traffic is stopped in both directions before allowing the pupils to approach or exit the bus.

6. Unload the pupils that cross the street prior to those who do not cross.
7. Count students to know how many are loading on or unloading from the bus, where they are, and where they are going. If count is lost, do not move the bus. If necessary, shut off the bus, secure it, and check underneath before moving the bus.

8. Ensure that students cross far enough in front of the bus so that the driver can see them even if they drop something. Require students to maintain eye contact with the driver.

9. Instruct students to look to the driver for a signal and check for traffic before continuing across the roadway. All drivers in the fleet should utilize the same signal – confusion could lead to tragedy.

10. Establish a pre-arranged danger signal, such as the horn, in case a vehicle does not stop for the bus while children are loading or unloading. Make sure students know exactly what to do if they hear the danger signal; for instance, “Go back to the side of the road you started from.” All drivers should utilize the same danger signal and instructions.

11. Load and unload at designated pick-up and drop-off points.

12. Back only at approved turn-around if backing is necessary near a bus stop. Prior to backing, ensure students are inside the bus. For instance, load children before backing up in the morning and unload children after backing up in the afternoon.

13. Do not unload children at corners immediately before making a right turn. Discharge children after making the turn.

14. Pick up and drop off pupils on their own side of the street if possible.

15. Instruct pupils never to cross behind the school bus.

16. Double-check all crossover and side mirrors for students and traffic before leaving the bus stop.

17. Do not put the bus in motion until all students outside are at a safe distance from the bus and all students inside are properly seated.

18. Before moving the bus after loading or unloading students, look and listen for any last second warnings from others nearby that a child might be near the bus. A parent, teacher, motorist, another bus driver, or students on the bus might see a child near or even under the bus. Turn off noisy equipment and silence passengers so warnings can be heard.

19. Instruct students in the proper procedure for loading and unloading within the first week of school and throughout the school year.

20. Be cautious when students are carrying loose papers or books which they might drop near the bus – encourage students to use a book bag.
21. Be aware of the dangers of clothing, book bag, backpack, and jacket strings/straps that could become entangled in the doorway of the school bus.

22. Upon completion of the route, walk through the bus to check for sleeping students, vandalism, and forgotten articles.

23. Report the license number of vehicles passing a stopped school bus with an operating stop signal arm and/or warning light system.

24. Examine stops regularly and report unsafe conditions to the supervisor.

Step 5 in this list of recommendations is worth noting in particular with regards to an SBSA system. School bus drivers must ensure that traffic is stopped in both directions before allowing pupils to approach or exit the bus. An SBSA system should assist school bus drivers in knowing that traffic is stopped in both directions and that there is not a vehicle approaching around a blind curve.

Existing Recommended Procedures for Other Vehicles at School Bus Stops

Though states vary in their laws regarding sharing the road with school buses, the National Safety Council has put together a list of common policies and procedures for vehicles driving around school buses. The generalized policies and procedures were found in a document titled Back to School: Safety Tips for Motorists [26]:

1. All 50 states have a law making it illegal to pass a school bus that is stopped to load or unload children.
2. School buses use yellow flashing lights to alert motorists that they are preparing to stop to load or unload children. Red flashing lights and an extended stop sign arm signals to motorists that the bus is stopped and children are getting on or off the bus.
3. All 50 states require that traffic in both directions stop on undivided roadways when students are entering or exiting a school bus.
4. While state laws vary on what is required on a divided roadway, in all cases, traffic behind the school bus (traveling in the same direction) must stop.
5. The area 10 feet around a school bus is where children are in the most danger of being hit. Stop your car far enough from the bus to allow children the necessary space to safely enter and exit the bus.
6. Be alert. Children are unpredictable. Children walking to or from their bus are usually very comfortable with their surroundings. This makes them more likely to take risks, ignore hazards or fail to look both ways when crossing the street.
7. Never pass a school bus on the right. It is illegal and could have tragic consequences.

Step 2 in this list of recommendations is worth noting in particular with regards to an SBSA system. The yellow and red flashing lights that school buses use to alert motorists to the bus stopping are only effective if other vehicles are able to see the warning lights. An SBSA system should assist other vehicles in knowing that a school bus is stopping at a bus stop on a blind curve or over a hill where the motorist view is obstructed.
Existing Recommended Procedures for School Buses at Railroad Crossings

Another common reason a school bus must stop is for a railroad crossing. The bus must stop whether or not students are on the bus, unless State laws specify otherwise. The National Safety Council has recommended procedures for school bus drivers at railroad crossings. Again, these must be considered in light of individual state laws and regulations. The National Safety Council’s recommended procedures for school buses at railroad crossings, as listed in the Recommended Procedures for School Bus Drivers at Railroad Crossings include [27]:

1. When making stops for railroad crossings, carefully observe all traffic. Use school bus hazard warning lamps, and tap the brakes to communicate to traffic that the bus is about to stop. Take these actions far enough in advance to avoid startling motorists behind the bus, which could cause panic stops or rear-end collisions.

2. Bring the bus to a full and complete stop before crossing any track, whether or not the bus is carrying passengers. Stop the bus within not less than 15 feet or more than 50 feet from the rails nearest the front of the bus.

3. On multiple-lane roads, stop only in the right lane unless it is necessary to make a left turn immediately after crossing the railroad tracks.

4. After stopping the bus, fully open the service door and the driver’s side window, turn off all noisy equipment (radios, fans, etc.), instruct students to be quiet, and look and listen in both directions along the track or tracks for approaching trains. In instances where school bus loading/unloading red warning lamps are activated by opening the service door, deactivate such lamps by using the master control switch.

5. If the view of the railroad track or tracks is not adequate, do not attempt to cross the tracks until you can see that no train is approaching.

6. If a train passes from one direction, make sure that another train, possibly hidden by the first train, is not approaching on an adjacent track.

7. For railroad crossings equipped with warning devices such as lights, bells, and/or gates, always obey the signals. Never ignore railroad crossing signals. If a police officer or flagman is present at the crossing, obey their directions, but be sure to make your own visual check.

8. Before crossing the tracks, ensure there is adequate room on the other side of the tracks and train right-of-way for the entire bus. It is always possible that the bus may have to stop immediately after crossing the railroad tracks.

9. When the tracks are clear, completely close the bus service entry door and place the transmission in a gear that will not require changing gears while crossing the tracks. In
instances where school bus loading/unloading red warning lamps are activated by opening the service door and such lamps were deactivated by using the master control switch, reactivate the school bus loading/unloading lamps. Leave all noisy equipment turned off and continue looking in all directions as the bus crosses the tracks. After safely crossing the tracks, turn off the hazard warning lamp.

10. If the bus stalls while crossing the tracks, evacuate the students and move them a safe distance away from the bus as quickly as possible. If a radio or telephone is available, notify the school bus dispatcher of the situation. If a train is approaching, have everyone walk in the direction of the train at a 45 degree angle away from the train tracks.

11. Weather conditions, such as fog, snow, rain, and wind can affect the driver’s ability to see and hear an approaching train and to determine the safety of crossing railroad tracks. Additional caution must be exercised during such conditions.

12. Report malfunctioning railroad signals or hazardous railroad crossing conditions to the appropriate school transportation personnel.

Step 1 in this list of recommendations describes how school buses should use hazard warning lamps and brake lights to communicate to traffic that the bus is about to stop. Providing advance warning is described as important so that motorists are not startled, which could lead to panic stops or rear-end collisions. An SBSA system should assist other vehicles by alerting them in advance that a railroad crossing is ahead and that the school bus must stop. It may also be able to inform them if a lane is available that they could use to pass the school bus if no trains are coming.

Existing Recommended Procedures for Other Vehicles at Railroad Crossings

The National Safety Council did not provide guidance for drivers who approach a stopped school bus at an at-grade railroad crossing; however, the Drive Right driver’s education textbook provides general guidelines [28]. All vehicles should be mindful of safety procedures when crossing railroad tracks. Drivers should be aware that most areas across the country require school buses to stop at railroad crossings. If there is no passing lane available, other vehicle drivers must be patient and wait for the school bus to check that no train is coming. The SBSA system could help other vehicle drivers become more aware of the requirement for school buses to stop at railroad crossings so that panic stops and rear-end collisions behind school buses are reduced in these scenarios.