Automated Driver and Responder Alert System (ADRAS)

Operational Field Assessment Report

February 2019

RT-T-R-10

FOREWORD

The U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) First Responder Technologies Division (R-Tech)[i] works closely with the nation's emergency response community to identify and prioritize mission capability gaps, and to facilitate rapid development of critical solutions to address responders' everyday technology needs.

R-Tech gathers input from local, tribal, territorial, state and federal first responders and engages them in all stages of research and development—from building prototypes to operational testing to transitioning the tools that enhance safety and performance in the field—with the goal of advancing technologies that address mission capability gaps in a rapid time frame, and then promoting a quick transition of these technologies to the commercial market for use by the nation's first responder community.

As R-Tech projects near completion, the National Urban Security Technology Laboratory (NUSTL) conducts an operational field assessment (OFA) of the technology's capabilities and operational suitability to verify and document that the project goals were achieved.

NUSTL's R-Tech OFA reports are posted on the First Responder Communities of Practice (FRCoP) website, which is a professional networking, collaboration and communication platform created by the DHS S&T to support improved collaboration and information sharing amongst the nation's first responders. This vetted community of members focuses on emergency preparedness, response, recovery and other homeland security issues. To request an FRCoP account, complete the online form on www.communities.firstresponder.gov.

Visit the R-Tech website, www.dhs.gov/science-and-technology/first-responder-technologies for more information on R-Tech and its projects.

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[i] This report was developed under the S&T program formerly known as Responder Technologies (R-Tech). As of October 1, 2018, R-Tech is no longer an S&T program.

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EXECUTIVE SUMMARY

When working on roadways, the safety of responders and incident management personnel is at risk. Each year there are fatalities of and injuries to responders on roadways who are struck by motorists who may not see them. There is a need for additional mechanisms to alert motorists of an upcoming incident scene and to alert responders working on the roadway about oncoming vehicles.

The U.S. Department of Homeland Security Science and Technology Directorate's First Responder Technologies Division (R-Tech) initiated a project with the goal of enhancing roadway safety for responders. The Automated Driver and Responder Alert System (ADRAS) is designed to alert motorists to use caution as they approach a roadside incident, and to provide audible, tactile and visual alerts to responders at the incident site when inbound vehicles pose a hazard. ADRAS consists of two main components: (1) a vehicle-mounted mast comprised of loudspeakers, a radar system, a low frequency tone siren and two video cameras, and (2) a safety vest enhanced with light-emitting diode (LED) lights and a small oscillatory motor.

The National Urban Security Technology Laboratory conducted an operational field assessment (OFA) of ADRAS on August 23, 2018, at the Federal Law Enforcement Training Center in Cheltenham, Maryland. Six evaluators—with competencies in roadway safety and responder operations—operated and wore components of ADRAS during simulated roadway incidents. Evaluators then provided feedback on ADRAS' suitability to meet its intended objectives.

The OFA results included in this report are grouped into four categories of evaluator feedback: (1) effectiveness for responders, (2) effectiveness for motorists, (3) optimal operational use cases and (4) suggested enhancements.

(1) Effectiveness for responders—Evaluators agreed ADRAS provided sufficient alerts to inform responders about an oncoming vehicle. Evaluators also agreed ADRAS would be easy to deploy; however, opinions differed as to whether employing the technology would impede response operations. While operational scenarios were conducted in daylight, evaluators expected the enhanced safety vest lighting would increase their conspicuity during night time operations. Lastly, evaluator opinions varied on the usability of the video cameras for their operations.

(2) Effectiveness for motorists—Evaluators agreed it was easier to hear the loudspeaker in a quiet vehicle, when vehicles were traveling at slower speeds, and when vehicles were in close proximity to the incident scene. Evaluators varied on their ability to understand the instructions conveyed by the loudspeaker; however, all evaluators concluded the audible alerts would not be distracting to motorists.

(3) Operational use cases to optimize use—After completing the activities, evaluators provided feedback on possible uses cases where the benefits of ADRAS may be maximized.

(4) Suggested enhancements—Evaluators discussed enhancements to ADRAS to increase its effectiveness for use among responder agencies. The discussion centered around making the components of ADRAS into a "menu of options" for responder organizations to choose from based on their existing equipment and needs.

Overall, the evaluators found that ADRAS would be beneficial as part of the suite of tools at their disposal for improving safety of responders on the roadway.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

In 2015, the U.S. Department of Homeland Security (DHS) Science and Technology Directorate's (S&T's) First Responder Technologies Division (R-Tech) issued a Broad Agency Announcement (BAA) (U.S. Department of Homeland Security (DHS), Science and Technology Directorate, 2015)[ii] for technology solutions to meet the goal of enhancing roadway safety for responders, with a specific focus on maximizing visibility of the responder through personal protective equipment (PPE). This requirement was identified through DHS S&T First Responder Resource Group (FRRG), a collection of more than 100 first responders from across the country with experience and proficiency in various areas of emergency response activities. In 2016, Applied Research Associates Inc. (ARA) was awarded a contract by DHS S&T to develop a technology called the Automated Driver and Responder Alert System (ADRAS) to meet the stated objectives of the BAA.

ADRAS combines driver notification, increased responder and responder vehicle visibility and multi-modal warnings (visual, tactile and audible) to improve the safety of responders facilitating roadway emergency operations. ADRAS consists of two main components: (1) a vehicle-mounted mast comprised of loudspeakers, a radar system, a low frequency tone siren and two video cameras, and (2) an enhanced safety vest equipped with light-emitting diode (LED) lights and a small oscillatory motor. For the purpose of this report, "responders" will be used to describe the roadway incident response personnel for whom this technology has been designed. Roadway incident response personnel includes, but is not limited to, the following core competencies: law enforcement, fire services, emergency medical services, roadway incident management and towing.

R-Tech's goal is to develop technologies that address mission capability gaps in a rapid time frame. As R-Tech projects near completion, the National Urban Security Technology Laboratory (NUSTL) conducts an operational field assessment (OFA) of the technology's capabilities and operational suitability to verify and document that project goals were achieved. On August 23, 2018, NUSTL conducted an OFA of ADRAS at the Federal Law Enforcement Training Center (FLETC) in Cheltenham, Maryland. During this OFA, six responders served as evaluators and engaged in various activities using ADRAS's vehicle mounted system and enhanced safety vest. They provided feedback on the effectiveness, functionality, deployability and usability of the technology in various roadway scenarios. This report describes the OFA activities performed, the results from those activities and the evaluators' feedback.

1.1 PURPOSE

The purpose of the OFA was to assess ADRAS's effectiveness, functionality, deployability and usability for responders in a simulated operational environment.

[ii] The Emergency Vehicle Safety Initiative (U.S. Department of Homeland Security (DHS), Federal Emergency Management Agency, February 2014) stated that "historically approximately 25% of all firefighter fatalities in the U.S. are the result of vehicle-related incidents" and "the leading cause of law enforcement officer fatalities in the last 11 of the 12 previous years at the time this report was concluded." Note that not all vehicle-related incidents occur when responding to emergency scenes on roadways; it also includes vehicle crashes in both official and personally owned vehicles.

1.2 OBJECTIVES

The OFA was designed to assess the:

- Effectiveness of the audible system (loudspeakers) and enhanced safety vests in alerting motorists of an incident scene on the roadway
- Effectiveness and functionality of the vehicle-mounted system and enhanced safety vest in alerting responders of an inbound vehicle in time to take proper protective action
- Deployability of the technology without impeding standard procedures
- Usability and donning of enhanced safety vests

1.3 PARTICIPANTS

Table 1-1 lists the OFA participants. Six evaluators from five different agencies participated, along with assessment team members, the technology developer, and stakeholder observers.

Table 1-1 OFA Participants

Role	Organization
Evaluators	- Maryland Department of Transportation (MD DOT) - Silver Spring Fire Department (Maryland) - Narragansett Police Department Retiree (Rhode Island) - Federal Highway Administration (FHWA) - National Highway Traffic Safety Administration (NHTSA)
Venue Host/Motorists	Federal Law Enforcement Training Center (FLETC)
Program Managers and Support Staff	U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) First Responder Technologies Division (R-Tech)
OFA Test Director and Data Collectors	DHS S&T National Urban Security Technology Laboratory (NUSTL)
Technology Developer	Applied Research Associates Inc. (ARA)
Observers	DHS S&T, Department of Justice, FHWA
Photographer and Videographer	DHS S&T Communications, Outreach and Responder Engagement

1.4 REQUIREMENTS

Table 1-2 summarizes the requirements of ADRAS and how it was assessed during the OFA. These requirements are drawn from the *Enhanced Roadway Safety for First Responders Statement of Objectives* (U.S. Department of Homeland Security (DHS), Science and Technology Directorate, 2015) and compiled into a Needs Notification Form completed by the R-Tech Program Manager and provided to NUSTL.

Table 1-2 ADRAS Requirements Matrix

Capability	Requirement	Test Method
Effectiveness for Motorist(s)	Audible System (vehicle-mounted) • Loudspeakers provide clear instructions to the motorist(s) to take action • Loudspeakers do not distract or inhibit the oncoming motorist(s) from driving safely • Loudspeakers are installed on a tall upright pole (mast) to increase conspicuity of the responder vehicle for motorist(s) Enhanced Safety Vests (worn by responders) • Enhanced safety vest lighting makes responders more visible to oncoming motorist(s) • Enhanced safety vest lighting does not distract or inhibit the oncoming motorist(s) from driving safely	Evaluators, as passengers in vehicles approaching simulated roadway incidents, assessed the conspicuity of ADRAS for four different roadway geometries, with varying noise level conditions. Additionally, evaluators assessed the visibility of the enhanced safety vest using a darkened classroom.
Functionality for Responder(s)	• Enhanced safety vest lighting and vibration are sufficient to alert responders of approaching vehicle • Loudspeaker volume is sufficient to alert a responder of approaching vehicle	Evaluators assessed the lighting, vibration and loudspeaker features of the system using simulated roadway incidents on four roadway geometries.
Deployability	• ADRAS can be deployed by responder(s) without impeding their emergency response activities • With minimal training, responders can quickly establish threshold speeds before deploying ADRAS • Video recorded by ADRAS can be easily viewed by responder(s) if needed	Evaluators deployed ADRAS and set threshold values to assess ease of use. Additionally, evaluators watched video recordings in a classroom to assess the camera's ability to capture images of the roadway, and oncoming vehicles, from both the front and back of ADRAS.
Usability	• Donning of the enhanced safety vest does not impede emergency response operations • Wearing of the enhanced safety vest does not impede emergency response activities	Evaluators donned enhanced safety vests for simulated emergency response operations to assess its impact on responder activities.

1.5 SYSTEM DESCRIPTION

The vehicle-mounted component of ADRAS (Figure 1-1) consists of a telescoping mast with loudspeakers, a radar system, a low frequency tone siren, and two video cameras. It integrates existing technologies into a single platform and is designed to be deployable by a single responder. The mast can be raised, lowered and rotated on the roof of the vehicle using a controller (Figure 1-2, left). A second controller (Figure 1-2, right) is used to power on the radar and loudspeakers, and to set a threshold speed ranging from 25 to 65 miles per hour (mph). This controller also has a test button that allows responders to hear the system alerts at a lower volume.

Figure 1-1 ADRAS Vehicle Mounted Deployment
Courtesy of ARA

The second component of ADRAS, the enhanced safety vest (or network of multiple vests), is an American National Standards Institute standard safety vest that has been equipped with LED lights and a small oscillatory motor on the left shoulder that provides tactile warning inside the vest (Figure 1-3). The enhanced safety vest is paired with the vehicle mounted system through a ZigBee® radio intended for low-power, low data rate, close proximity (estimated at about 50 meters) wireless networks. The LED lights and oscillatory motors are activated when an oncoming vehicle does not heed the alert to slow down provided by the vehicle mounted system.

Figure 1-2 ADRAS Controllers
Courtesy of DHS S&T (Left Image) and ARA (Right Image)

ADRAS is intended to provide an early audible warning of an upcoming traffic incident area to approaching motorists, instructing them to slow down or take the necessary actions to safely avoid the scene. Once activated, ADRAS's radar detects the speed of oncoming vehicles. If the speed exceeds the responder-set threshold, a first audible alert initiates a siren and can include a message through the loudspeaker. Audible messages can be pre-set or changed prior to deployment. If the system's radar detects a vehicle that fails to slow down, the audible message increases in intensity and the responder's enhanced safety vest will illuminate, providing the responder a visual warning of a possible threat and making the responder more visible to motorists. If the vehicle continues to pose a threat by failing to slow down or change lanes as it comes closer to the ADRAS, the enhanced safety vest will flash and vibrate, and the vehicle mounted system will sound a loud warning to alert the responders. In addition, ADRAS has the capability to continuously record video once it is deployed, which may be useful in accident investigations. This feature can be disabled, or omitted entirely, if not required or desired by the responder agency.

Figure 1-3 ADRAS Enhanced Safety Vest
Courtesy of ARA

2.0 OPERATIONAL FIELD ASSESSMENT DESIGN

2.1 EVENT DESIGN

For this OFA, six responders from the law enforcement, roadway incident management and operations and emergency medical service disciplines served as evaluators to assess the functionality, capability and usability of the system. The OFA was conducted at FLETC in Cheltenham, Maryland, where evaluators participated in various activities (Table 2-1) at four sites: a classroom located in Building 3 and three simulated roadway incident sites with various roadway geometries (Figure 2-1). Evaluators were grouped into pairs and a data collector from NUSTL was assigned to each pair. The data collectors facilitated the test activities, recorded observations and comments during each activity and gathered feedback from each evaluator following the completion of all activities at each site using a questionnaire. Following the operational activities, a group debrief was held to solicit additional feedback from the evaluators. Observers from federal agencies watched the OFA activities and provided feedback during the group debrief session.

Figure 2-1 Map of OFA Activities

2.2 SCOPE AND LIMITATIONS

The OFA consisted of the following components:

- Classroom Presentation and Technology Familiarization: The OFA began with an introductory session providing participants with an overview of the R-Tech program, the schedule and planned activities for the OFA and a site safety briefing. ARA provided an overview of ADRAS in the classroom, which included background on the development of the technology and previous testing conducted. This overview was followed by a familiarization session outdoors on the driving track (Figure 2-2) where evaluators learned to power on, deploy and stow the ADRAS mast, power on the system, set speed thresholds and use the test functionality.

Figure 2-2 OFA Participants Attending the Familiarization Session

- Assessment Activities: After the familiarization sessions, the evaluators performed the activities listed in Table 2-1 at Sites 1 through 3 and inside the classroom. After completing the activities at each site and in the classroom, evaluators provided direct feedback to NUSTL data collectors. NUSTL data collectors also recorded any feedback and comments during the activities. Full details of the event design are described in the Automated Driver and Responder Alert System Operational Field Assessment Plan (U.S. Department of Homeland Security (DHS), Science and Technology Directorate, August 2018).

Table 2-1 Assessment Activities

Number	Activity Title	Activity Description	Purpose
1	Vest	Evaluators don enhanced safety vests and perform actions typical of their response operations at a roadway incident	To assess the system's ability to notify responders about an approaching vehicle and to assess the usability of the enhanced safety vest to ensure it does not impede evaluators' normal wear and use of uniforms and PPE.
2	Partner	Evaluators act as the response partner to evaluators in Activity 1 and observe activities	To assess the system's ability to notify responders about an approaching vehicle; and to assess the usability of the enhanced safety vest to ensure it does not impede evaluators' normal wear and use of uniforms and PPE.
3	Motorist	Evaluators act as motorists	To assess the system's effectiveness for motorists on different roadway geometries.
4	Deployment	Evaluators deploy ADRAS at the scene of a roadway incident	To assess the ease of setting up and configuring ADRAS.
5	Night Use	Evaluators don the safety vest in darkened room	To assess the enhanced safety vest's lighting system and its visibility in no or low light conditions.
6	Video	Evaluators watch video replay of roadway activities	To assess if this feature is effective for responders for capturing the scene, scene reconstruction and other post-incident uses.

- Debrief: A debrief session, facilitated by the NUSTL OFA Test Director, was held at the conclusion of all activities with all OFA participants.

As described in the test plan, the OFA had several limitations in the design and execution of the assessment, including:

- Effectiveness of the Loudspeaker: The OFA was held on a closed test site, where the drivers and evaluators were all knowledgeable about the technology and its intended purpose to alert drivers; therefore, the effectiveness of ADRAS's loudspeaker for unknowing drivers in varying environments was not assessed.

- Season, Weather, and Time of Day: The OFA was held in August in Maryland during traditional work hours. Based on the time of sunrise and sunset, the OFA did not fully assess ADRAS in all light levels nor did it assess ADRAS under various weather conditions such as rain or fog. Classroom activities aimed to mimic conditions of low-and no-light.

2.3 DEVIATIONS FROM THE TEST PLAN

There were several deviations from the test plan, including:

- Speed of Vehicles on Tracks 1, 2a and 2b: During set-up the day before the OFA, speed limits for three of the driving tracks were adjusted to accommodate for roadway conditions and placements of ADRAS. Adjustments are shown in Table 2-2 below.

Table 2-2 Vehicle Speeds Adjusted for OFA

Track Label	Description	Test Plan: Estimated Speed of Vehicle	OFA: Estimated Speed of Vehicle
Track 1 (Blue)	Straightaway	65 mph	55 mph
Track 2a (Green)	Mild curve	55 mph	45 mph
Track 2b (Yellow)	Large curve	35 mph	25 mph
Track 3 (Orange)	90-degree turn	25 mph	No change

- Addition of Activity 3 (Motorist) at Site 2a: The test plan did not call for evaluators to execute Activity 3 (motorist) on Track 2a. Based on time and availability of evaluators during the OFA, evaluators performed Activity 3 on all four tracks. However, feedback from Activity 3 was combined for Tracks 2a and 2b as Site 2 feedback.

- Number of Runs at Each Site: The test plan had prescribed a limited number of runs at each site which took a shorter amount of time to complete than initially anticipated. As such, additional time was available and used to fulfill specific requests from evaluators for the vehicle to travel at other speeds and in different lanes than dictated in the test plan. This flexibility allowed evaluators to get a stronger understanding of the system's components.

- Additional Vehicle: During activities at Site 2a, an additional FLETC vehicle became available on the track, as shown in Figure 2-3. Evaluators and observers requested this additional vehicle drive past ADRAS in separate lanes, at various speeds and distances from the other vehicle on the track to see how the system works with multiple vehicles. Feedback from evaluators was incorporated into overall feedback provided in the questionnaire and allowed evaluators to gain a stronger understanding of the technology.

Figure 2-3 ADRAS Vehicle Mounted System under Evaluation with Two Test Vehicles

- Activity 5 (Night Use): The test plan called for this activity to take place in a darkened classroom so observers could also see the lights on the enhanced safety vest in low- and no-light conditions. The classroom could not be darkened, so this activity was conducted in a smaller utility closet next to the classroom. All evaluators participated in this activity[iii].

[iii] Some of the other OFA participants chose not to observe this activity.

3.0 RESULTS

This section contains feedback from the evaluators' questionnaires and group discussions. Section 3.1 summarizes the results of the evaluator feedback during activities that inform how effective ADRAS is for responders. Section 3.2 summarizes the results of the evaluator feedback during activities when evaluators were acting as motorists. Section 3.3 summarizes the feedback received during the familiarization session and during the group debrief session. This feedback includes evaluator feedback on possible operational scenarios where the technology may be best employed, enhancements to the vehicle-mounted and enhanced safety vests components and additional areas for innovation that may improve the technology's operational use.

3.1 EFFECTIVENESS FOR RESPONDERS

Five of the activities were designed for responders to understand how ADRAS could enhance their safety and to determine if ADRAS would impede their normal activities while responding to a roadway incident:

- Activity 1: Evaluators donned the enhanced safety vests and performed actions typical of their response operation at a roadway incident to assess the system's ability to notify responders about an approaching vehicle and to assess the usability of the enhanced safety vest to ensure that it does not impede evaluators' wear and use of their uniforms and PPE.
- Activity 2: Evaluators acted as the response partner to evaluators in Activity 1 and observed activities to assess the system's ability to notify responders about an approaching vehicle and to assess the usability of the enhanced safety vest.
- Activity 4: Evaluators deployed ADRAS at the scene of a roadway incident to assess the ease of setting up and configuring the vehicle-mounted component of ADRAS.
- Activity 5: Evaluators donned the enhanced safety vest in a darkened room to assess the lighting system and the ability to operate in no- or low-light conditions.
- Activity 6: Evaluators watched video replay of roadway activities to assess the effectiveness of the camera in capturing the scene for scene reconstruction and other-post incident uses.

Sufficiency of Alerts for Responder Action

During Activities 1 and 2, the six evaluators were asked the same questions regarding the sufficiency of the audible alerts from the loudspeakers and the low frequency tone siren as well as the enhanced safety vest vibrations, from the perspective of both a responder and a second responder observing activities of their partner.

All evaluators either agreed or strongly agreed that the volume of the loudspeaker and low frequency tone siren were sufficient to alert them of an approaching vehicle, that both alerts gave them sufficient time to react or respond to the notification and that the vibration added to the enhanced safety vest was sufficient to alert them that a vehicle was approaching. These results are shown in Figure 3-1.
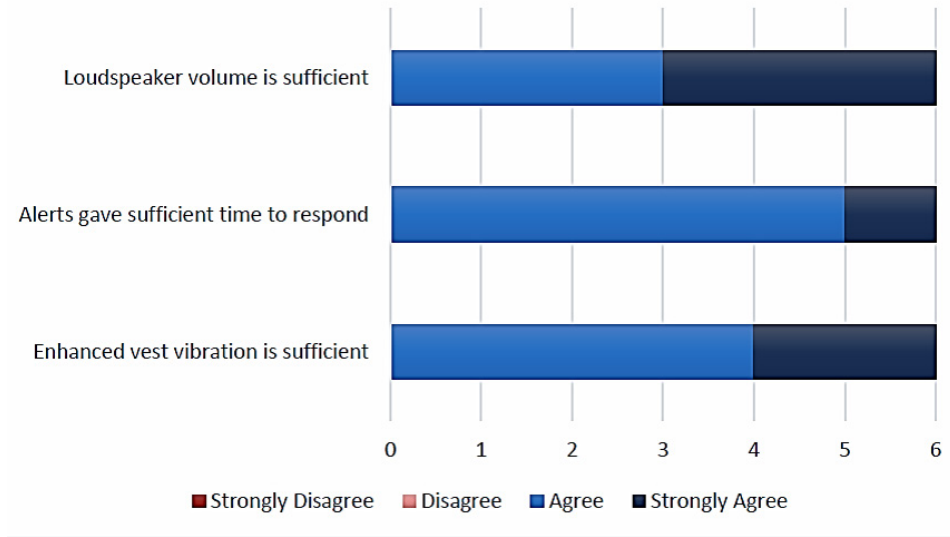
Sufficiency of Alerts for Responder Action

Figure 3-1 Sufficiency of Alerts for Responder Action

One evaluator noted that additional testing on the suitability of the enhanced safety vest vibration would be required for responders who wear heavier PPE, such as firefighter turnout gear, and warming layers during colder times of the year because thicker layers may inhibit their ability to feel the small vibration. Another evaluator noted that an unintended consequence of the high volume of the low frequency tone siren and loudspeaker volume could be that responders may not be able to hear each other while working on an incident scene or hear the public they are interacting with on the roadway.

Deployability of ADRAS and Impact on Roadway Operations

Evaluators were asked to provide feedback on the deployment of the vehicle-mounted system (Activity 4) and if the enhanced safety vests would impede their activities (Activities 1, 2). All evaluators either agreed or strongly agreed that deployment of the vehicle-mounted system was simple and that establishing wanted threshold speeds for passing traffic was easy. Additionally, all evaluators either agreed or strongly agreed that the enhanced safety vests would not impede the activities they needed to complete when responding to a roadway incident. However, responses varied on whether the deployment of the vehicle-mounted system would interfere with duties. Three evaluators—from roadway incident management and law enforcement—did not believe they could deploy the system without interfering with their duties. During the debrief session, evaluators and observers noted that the time required for raising and lowering the mast of the vehicle-mounted component, approximately 30 seconds, may impede law enforcement operations on a roadway in cases such as speeding infractions and/or erratic driving. The results on the system's deployability and its impact on operations are shown in Figure 3-2.
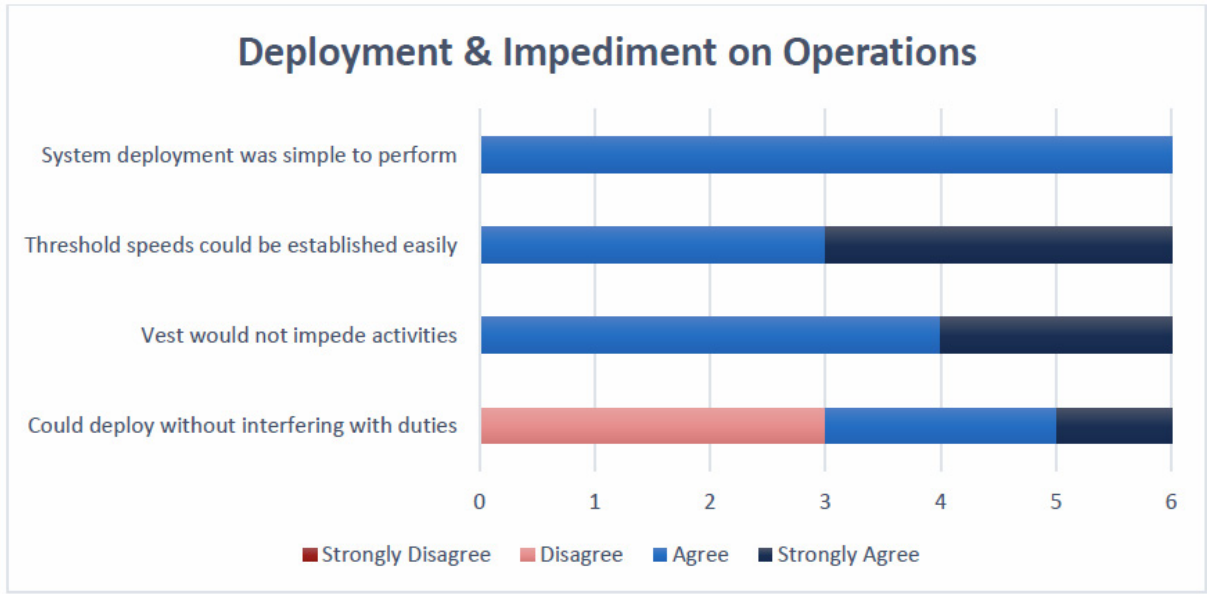
Figure 3-2 Deployment of ADRAS and Impact on Roadway Operations

Effectiveness During Nighttime Operations

During Activity 5, evaluators were asked to evaluate the enhanced safety vest lighting in a darkened room to assess its potential effectiveness during nighttime operations. Four of the evaluators either agreed or strongly agreed that the enhanced safety vest lighting would not impede their duties at night, nor would the lights be distracting while performing duties. Two of the evaluators answered not applicable as to whether the enhanced safest vest lighting was distracting during nighttime operations because they did not think the testing environment of a quiet, darkened room was representative of a nighttime roadway environment. The results for potential effectiveness of the enhanced safety vest during nighttime operations are shown in Figure 3-3. A photo of the enhanced safety vest lighting in a darkened room is in Figure 3-4.
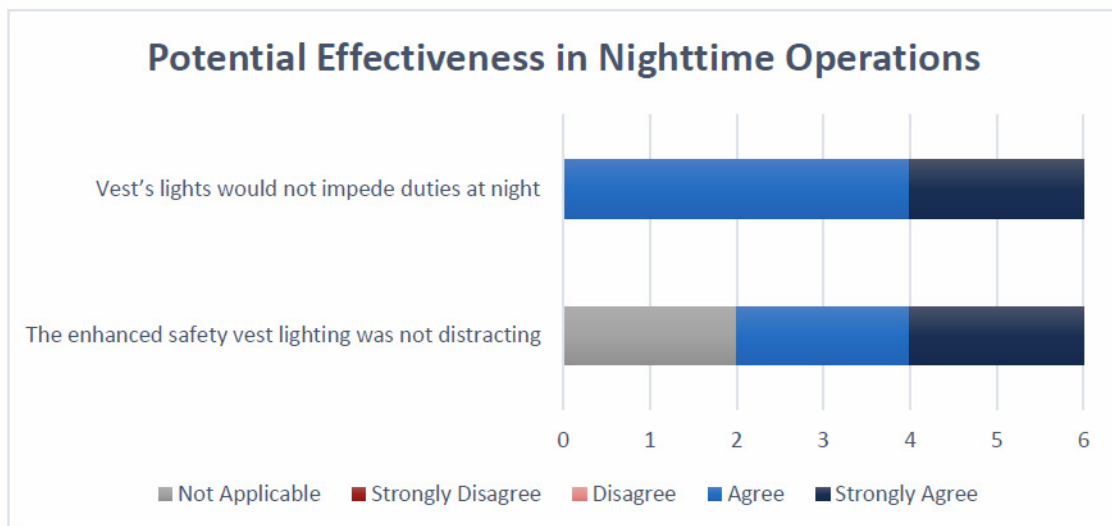
Figure 3-3 Potential Effectiveness of Enhanced Safety Vest Lighting during Nighttime Operations

Figure 3-4 An Evaluator Demonstrates the Enhanced Safety Vest Lighting Feature

Usability of Videos and Radar Data for Post-Incident Activities

During Activity 6, evaluators reviewed video camera images taken during the other activities. Evaluators had the opportunity to view several files—a "rear" camera image, facing the front of the vehicle that ADRAS is installed on and a "front" camera image, facing the back of that vehicle. Additionally, evaluators viewed a metadata file produced by the system, which could be used to view vehicle speeds captured by the radar and how the system was configured during operations. This log could be used after an incident to confirm measured vehicle speed or diagnose why the system did or did not trigger. Evaluators reviewed and provided feedback on several videos from Sites 1, 2 and 3. Overall, evaluators concurred that it was easy to obtain and review the videos from ADRAS. Evaluators' opinions varied on the value of the video in supporting their operations. The results are shown in Figure 3-5.
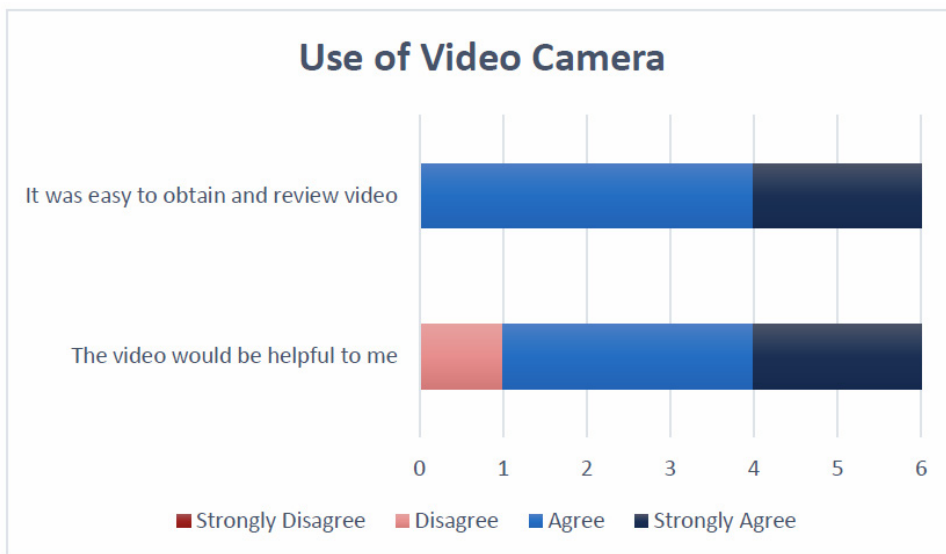
Figure 3-5 Usability of Videos for Post-Incident Activities

During the debrief, evaluators expressed concerns with data management requirements of the video images, such as having to download, file, store and account for copious amounts of data, and the concept of operations required for it to be effectively used by responder agencies, such as ensuring that responders have appropriate protocols for turning on and off the cameras and downloading the data. Figure 3-6 shows screen shots of video recordings from the two cameras installed in the vehicle-mounted system, and Figure 3-7 is a screenshot of the metadata collected by the system which may be reviewed as part of accident investigations. Note that after the system sat outside overnight, the video image quality was diminished by water on the lens (Figure 3-6, left), likely due to rain or dew and to the fact that this ADRAS prototype does not contain a waterproof camera. Metadata is recorded each time ADRAS alerts, and records the alert type, date, time, speed setting and estimated speed of the passing vehicle.

Figure 3-6 "Front" (Left) and "Rear" (Right) Images Taken from the ADRAS Video Cameras

Figure 3-7 Screenshot of Sample Meta Data File

3.2 EFFECTIVENESS FOR MOTORISTS

In Activity 3, evaluators acted as motorists to assess the warning system's effectiveness on different roadway geometries. This activity was completed with the vehicle-mounted system at three different drive-by locations under two different conditions—(1) with loud music playing in the vehicle and (2) with light conversation or a quiet car. The level of music or amount of conversation were not prescribed during the assessment; evaluators were instructed to play the music at levels they would normally use while driving and were instructed to converse normally as they would while driving or being a passenger in a vehicle.

A baseline run was conducted for the evaluators to observe no audible alert. In both conditions as well as the baseline run, all windows in the vehicle were closed. The drive-by sites were used to depict varying roadway geometries and operational implementation of ADRAS. Site 1 was intended to be a straightaway at high speeds, similar to a two-lane highway. Site 1 had the highest speeds for the oncoming vehicle and the greatest distance between where the vehicle started and where the ADRAS was located. Site 2 included two tracks, a mild curve with an obstructed downhill view and a large curve, representing an interchange or ramp between roadways. Site 2 had slower speeds than Site 1 and a shorter distance between the oncoming vehicle and the ADRAS than Site 1. Site 3 was a 90-degree turn, representing an urban area with obstructed views (trees). Speeds were the slowest for Site 3, and the distance between the oncoming vehicle and the ADRAS the shortest. These descriptions are included in Table 2-1.

As stated in Section 2.2, the results on the effectiveness for motorists are limited as all evaluators were familiar with the technology and thus anticipated hearing the audible alerts and seeing ADRAS placed on the simulated response vehicle. Figure 3-8 shows Activity 3 at Site 3.

Figure 3-8 ADRAS Vehicle under Evaluation at Site 3

Ability for Passing Motorists to Hear Loudspeaker

For quiet car situations at the three sites, most evaluators agreed they could clearly hear the audible alert (loudspeaker), though in a few cases, evaluators strongly disagreed or disagreed. With music playing, the evaluators mostly disagreed they could hear the audible alert. These results are shown in Figure 3-9 and Figure 3-10 as overall feedback across all three sites. One evaluator indicated they had limited hearing in one ear at the start of the OFA activities.
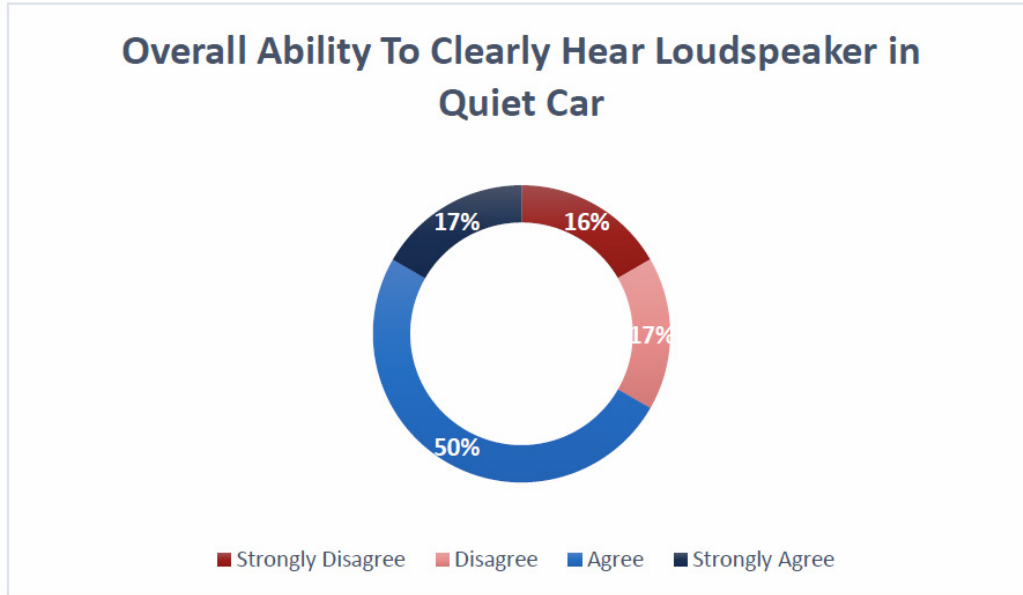
Overall Ability To Clearly Hear Loudspeaker in Quiet Car

- Strongly Disagree: 16%
- Disagree: 17%
- Agree: 50%
- Strongly Agree: 17%

Legend: ■ Strongly Disagree ■ Disagree ■ Agree ■ Strongly Agree

Figure 3-9 Overall Ability of Evaluators to Hear Loudspeaker in Quiet Car across all Sites

Overall Ability To Clearly Hear Loudspeaker in Loud Car

- Strongly Disagree: 28%
- Disagree: 50%
- Agree: 5%
- Strongly Agree: 17%

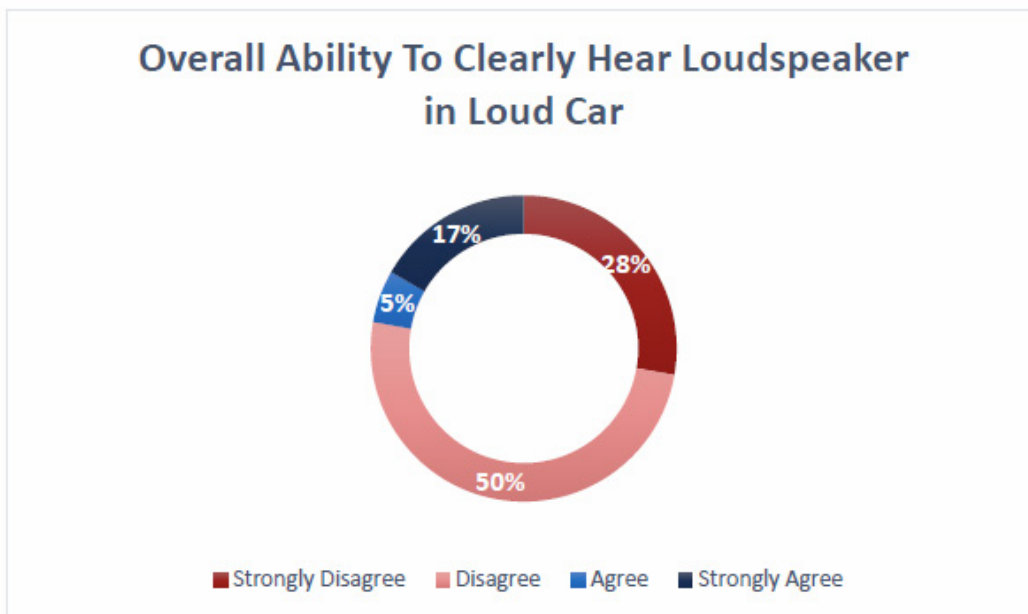**Legend:** ■ Strongly Disagree ■ Disagree ■ Agree ■ Strongly Agree

Figure 3-10 Overall Ability of Evaluators to Hear Loudspeaker in Loud Car across all Sites

Looking across the three sites, evaluators were able to hear the loudspeaker better in a quiet vehicle, over a vehicle with loud music playing. Additionally, as the vehicles got closer to the roadway incident sites where the ADRAS was located and speeds lowered (Site 1 being the furthest away and fastest speeds and Site 3 being the closet and slowest speeds), the ability to hear in a quiet car and with music playing did improve. These results are shown in Figure 3-11 and Figure 3-12.
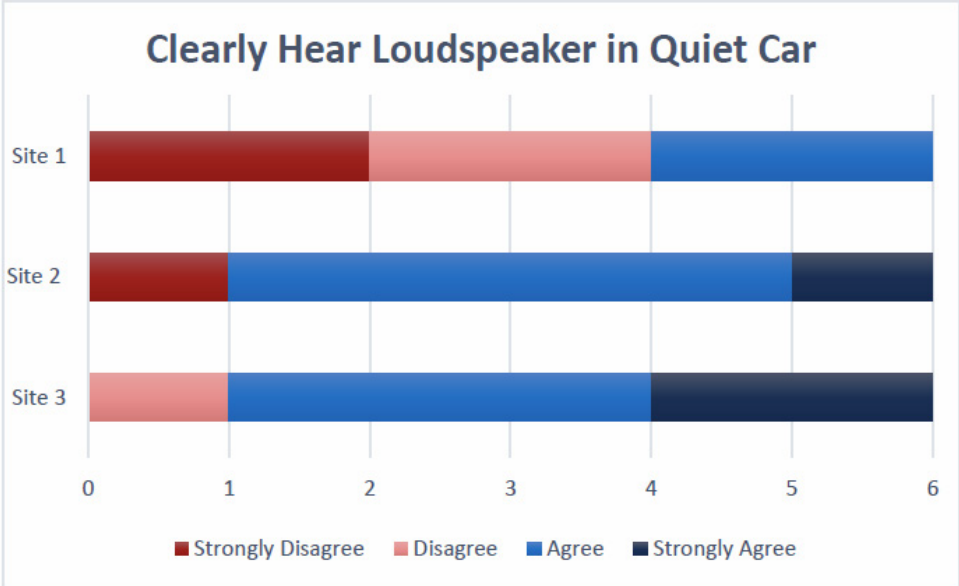

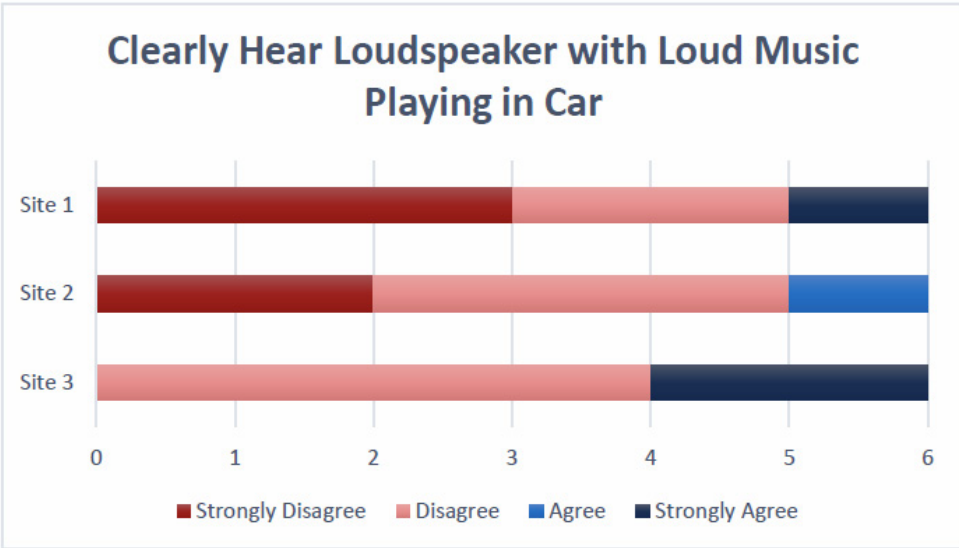Figure 3-11 Ability of Evaluators to Hear Loudspeaker in Quiet Car by Site

Figure 3-12 Ability of Evaluators to Hear Loudspeaker in Loud Car by Site

Effectiveness of Audible Alerts for Motorist Action

At all three sites, evaluators either agreed or strongly agreed that the loudspeaker would not distract them while they were driving. These results are shown in Figure 3-13. However, at all three sites, evaluators had differing opinions as to whether instructions provided by ADRAS were clear and easy to follow. That is, while the evaluator may have heard the alerts and some messaging, they may not have heard the instruction, "slow down" or "slow down, now," in a manner that would have allowed them to change their behavior. More evaluators agreed (though some still disagreed) that the instructions were easier to follow at Site 3, where the speeds were the lowest and evaluators started closer to the vehicle-mounted system. These results are shown in Figure 3-14.
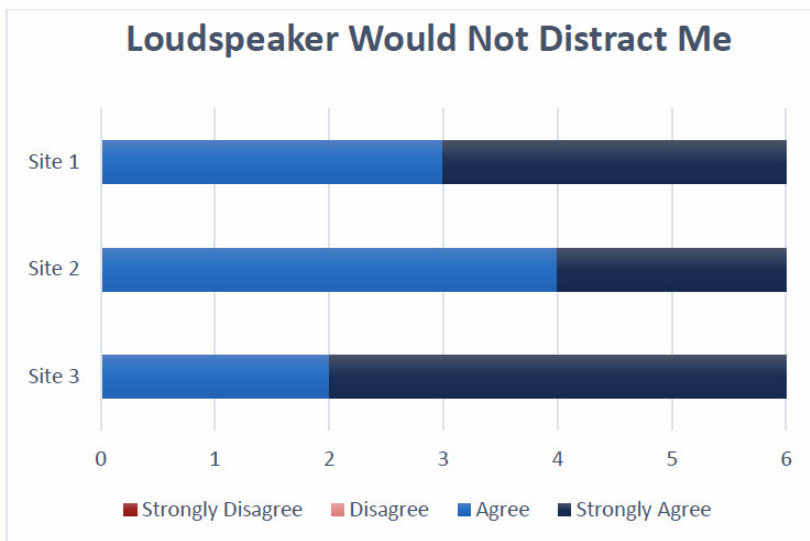
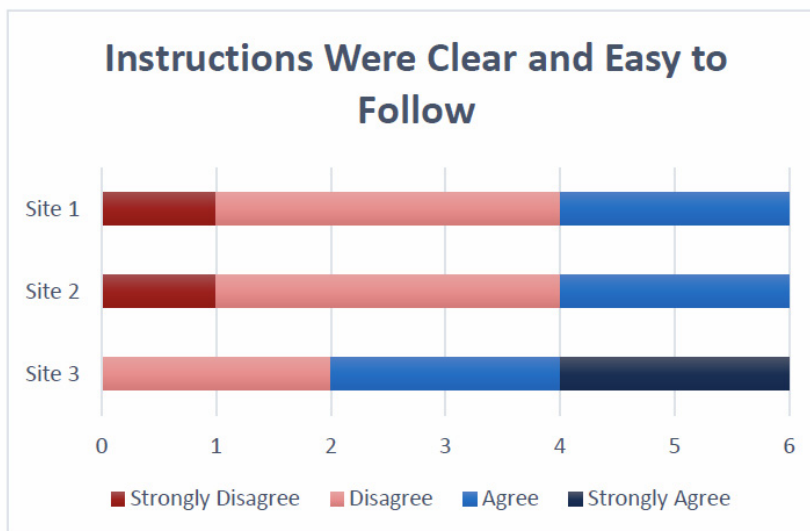

Figure 3-13 Ability of Loudspeaker to Distract Motorists

Figure 3-14 Clarity of Instructions Provided to Motorists by Site

Increased Conspicuity of Response Vehicle and Responders

Lastly, evaluators were asked to assess if the ADRAS vehicle-mounted system would increase the conspicuity of the emergency response vehicle and if the enhanced safety vest lighting would increase the conspicuity of the responder. Across the three sites, evaluators mostly disagreed that the enhanced safety vest lighting made the responder more noticeable; however, evaluators noted that this was based on daylight conditions. Most responders declined to answer if the enhanced safety vest lighting was distracting because of the operational and light environment. Results from these three indicators are shown in Figure 3-15. Overall, across the three sites, evaluators agreed that the telescopic mast made the vehicle more noticeable. Note that during the OFA, the vehicle-mounted system was placed on a mini-van, as shown in Figure 1-1.

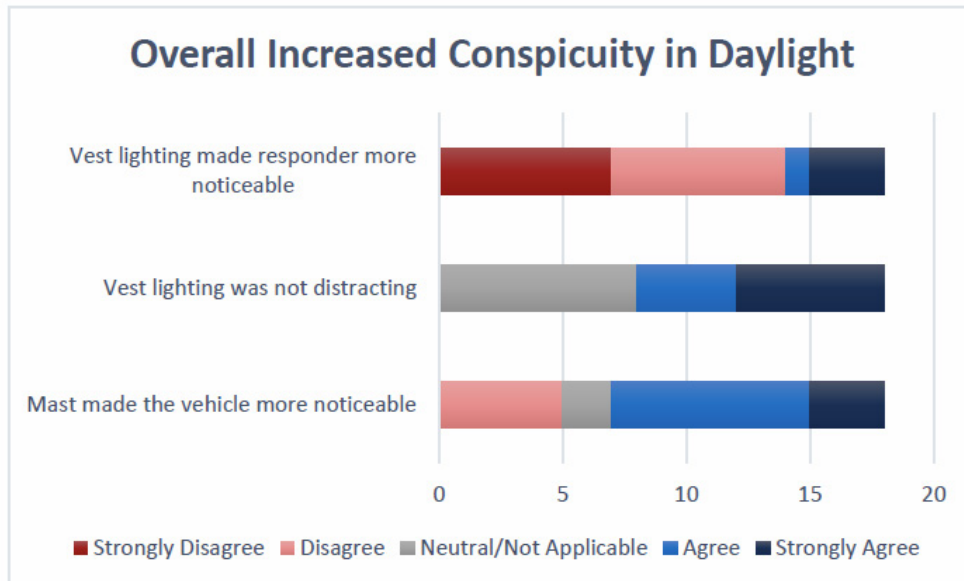Figure 3-15 Conspicuity of Responders and Responder Vehicles on Roadway in Daylight

Overall, across all three sites, evaluators all agreed or strongly agreed that the two-component system would not be distracting to motorists. This includes their feedback on both the loudspeaker and the enhanced safety vest. This is shown in Figure 3-16.
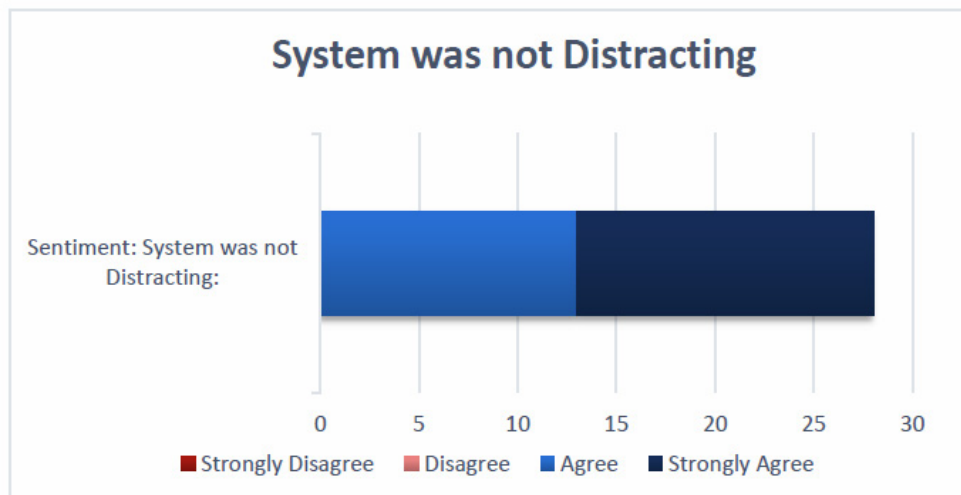

Figure 3-16 Overall Conspicuity of Responders and Responder Vehicles on Roadway

3.3 OTHER FEEDBACK

Additional information was provided by the evaluators during the familiarization session and the debrief. Overall, the evaluators noted that ADRAS would be a valuable addition to existing safety mechanisms and technologies for responders on the roadway (such as cones and other markings that alert motorists to their presence) but not something that would be used as a stand-alone tool. One evaluator used the analogy of a seatbelt and air bags for motorist safety, by saying that airbags do not replace the safety need of wearing a seatbelt, but instead together seatbelts and airbags improve the safety of motorists.

3.3.1 USE CASES

For law enforcement use cases, evaluators expressed that ADRAS would be useful in urban and rural settings for crime scene investigations or crash reconstruction teams, where high-speed traffic volume is limited. Additional use cases may include traffic management and post-accident situations. Evaluators and observers with law enforcement experience noted that this technology would not applicable for traffic stops because the requirement of stowing the mast before driving would impede an officer's ability to pursue a car fleeing the scene. An evaluator noted that this system may not require a mast, depending on the vehicle on which it was installed (i.e., a vehicle already equipped with radar and loudspeakers).

For traffic incident management use cases, evaluators indicated that ADRAS would be useful as an advance warning signal during incidents in rural settings and also for lane closures. Evaluators would not solely want to use ADRAS, but instead would use it as part of their existing tools to manage incidents and alerts motorists about activities on the roadway. One evaluator noted that cue warnings, (e.g., variable message and electronic signs that are routinely used to alert drivers to construction activity on the roadway) decrease secondary accidents, and ADRAS may be useful in that capacity. Another evaluator noted that rural usages might pose noise issues among neighbors if the system is consistently alerting on speeding traffic.

For emergency medical services, an evaluator noted that ADRAS would be useful in incidents where extractions are needed, where the responders' focus would primarily be on the patient they are tending to, and during late-night scenarios, which are the most dangerous based on limited visibility.

An evaluator noted that tow-truck drivers have the highest rate of death on the roadway from being struck by vehicles (Bergal, 2015), but integration of additional technology may not be practical to these applications as many tow-trucks are privately owned and operated. Lastly, an evaluator noted that another use case for the technology could be with the Corrections departments, where in some jurisdictions, inmates perform trash collection in medians and on shoulders.

3.3.2 ADJUSTMENTS TO ENHANCE SAFETY VEST

Evaluators indicated that increasing the vibration in the enhanced safety vest to both shoulders to add more points of contact and/or to a more sensitive area such as the back of the neck would increase the effectiveness for responders wearing it. Additionally, evaluators commented that battery management in the enhanced safety vests would be needed, noting that during the OFA the two AAA batteries used to power the vest drained between the dry-run conducted the day before and the actual event the next day. It was recommended that an "off" or "sleep" function for the enhanced safety vests be included to preserve battery life. Evaluators noted that responders may have a false sense of security that there was no risk if their vests did not light up/vibrate, but it may be a battery issue.

ARA-provided specifications indicated an approximate range of 50 meters for the ZigBee®; however, OFA participants observed a range of approximately 75 meters. Evaluators noted this range may be limiting, and suggested that a range of approximately 200 meters would be ideal in all directions from the incident. Figure 3-17 shows evaluators in safety vests on the very far left side (in the background of the image) assessing the range in distance of ADRAS.

Evaluators noted that a network calibration for the vests would be ideal to ensure all responders vests are activated at the same time. A best practice would need to be developed for responders at the start of their shift to ensure connectivity. Lastly, the enhanced safety vests that were used during the OFA did not include side tear-aways (Velcro strips on the side of safety vests from the arm-pit down to the bottom of the vest that allow for the vest to be easily torn off a responder if the safety vest becomes attached to something, such as a moving car). Multiple evaluators noted that tear-away safety vests were required for their agencies.

Figure 3-17 Evaluators, Wearing Safety Vests (on far left side in yellow circle), Test the Range of the Vests

3.3.3 ADJUSTMENTS TO VEHICLE-MOUNTED SYSTEM

Evaluators suggested that the vehicle-mounted system could be offered in a "menu of options" for customization to responder organizations, as some organizations already use some of the components, such as the low frequency tone siren. This customization would allow for various configurations that may be optimal for different use cases. Evaluators noted that some components of the system could be integrated directly into the responder vehicle, so that the radar, loudspeaker and camera would be the only items needed outside the vehicle. Additionally, evaluators suggested that a single, combined controller, which could be activated from inside the emergency vehicle, possibly from the dashboard, would be useful. ARA noted that plans were already underway for this change. Discussion on the mast, as noted before, focused on its deployability. An evaluator noted that an alert should be provided to responders if they begin to drive with the mast still deployed. Figure 3-18 shows the telescopic pole as its being raised or lowered—it is neither stowed nor operational as it is shown in this image.

Figure 3-18 Telescopic Mast with Radar and Loudspeakers is Halfway Raised during Testing

Differing opinions emerged on the type and range of the radar. One evaluator noted that a two-panel radar may provide additional range. This evaluation was noted after evaluators completed Activity 4 (Deployment) and intentionally placed the radar in a non-line of sight angle to see if ADRAS was triggered (it was not). However, other evaluators noted that it would be preferable if the system only concerned one or two lanes of traffic to minimize false alerts. It was suggested a lidar would be better because lidar has better bearing resolution, allowing it to better distinguish which lane a vehicle is in.

As noted in Section 3.1, evaluators had mixed responses to the inclusion of the video cameras. Evaluators noted that requirements for records retention and data management differ by organization, and applicable laws and regulations may require organizations to have procedures and policies before they could integrate this into their operations. ARA noted that the recording capabilities could easily be removed from the system by simply taking out the USB where videos are saved and, if ADRAS was customizable, the camera could be optional.

3.3.4 ADDITIONAL ENHANCEMENTS

Evaluators noted that an additional feature that would benefit both motorists and responders would be connecting the deployment of the mast to mapping services, such as Waze or Google Maps, which would notify motorists of an incident scene as well. One evaluator noted that the audible alerts could also be integrated into upcoming "smart highway" projects that would air alerts through radios in personal vehicles. Evaluators also noted that additional technology and alerts could be added to the system, such as an alert from a lightning detection device to protect responders on the roadway from lightning strikes. While not noted by evaluators, the developer plans additional weather proofing of the camera lens and system connections based on their experience from the OFA. Lastly, it was noted that any new equipment would need to fall within a category of the Federal Emergency Management Agency Authorized Equipment List to facilitate responder purchasing.

4.0 CONCLUSIONS

The objectives of the OFA were to obtain responder feedback on ADRAS's effectiveness, functionality, deployability and usability.

Overall, evaluators agreed on the effectiveness of the technology in alerting responders through both audible, visible and tactile notifications in the vehicle-mounted system and the enhanced safety vest. However, some evaluators noted the technology would not be applicable to all operational use cases, specifically for law enforcement, and may impede their ability to conduct their operations while responding to roadway incidents.

When evaluators assessed the effectiveness of the system as occupants of a vehicle driving by a scene, they found that it was easier to hear the loudspeaker in a quiet car over a car with loud music playing, when cars were traveling at slower speeds and when in closer proximity to the incident scene. Evaluators varied on their ability to understand the instructions to the passing vehicle provided during the test; however, all evaluators concluded that it would not be distracting to motorists. In this test, the evaluators were familiar with the technology and expected to hear the audible alerts and see ADRAS placed on the simulated response vehicle; reactions of drivers not anticipating the warnings may differ.

Evaluators offered several ideas for enhancing the technology to make it more effective and useable. They concurred that the components of ADRAS should be offered as a "menu of options" for responder organizations to pick and choose from based on their existing equipment and response needs. They suggested increasing the usability of the vehicle-mounted system through the use of different radar options, a single (one-piece) controller or integrating ADRAS controls into the vehicle dashboard and adding alerts to notify responders that the telescopic-mast is deployed before they begin to drive again. Evaluators varied in their feedback on the usefulness of the video camera systems, primarily due to the concerns associated with varying data management policies.

Overall, evaluators found that ADRAS would be beneficial as part of the suite of tools at their disposal for improving safety of responders on the roadway.

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