#1141

U.S. Department
of Transportation
**Federal Railroad
Administration**

Vehicle Proximity Alert System: Prototype 3

Office of Research and
Development
Washington, D.C. 20590

Prepared by:
Scott E. Gage and
Stanley T. Gurule
Association of American Railroads
Transportation Technology Center
Pueblo, Colorado

LETTER REPORT
October 1995

DISCLAIMER

This report is disseminated by the Association of American Railroads (AAR) and the Department of Transportation (DOT) for informational purposes only and is given to, and is accepted by the recipient at the recipient's sole risk. The AAR and DOT make no representation or warranties, either expressed or implied, with respect to this report or its contents. The AAR and DOT assume no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential, or any other kind of damages resulting from the use or application of this report or its contents. Any attempt to apply the information contained in this report is made at the recipient's own risk.

PREFACE

As part of Task Order 114, AAR is to provide letter reports following the testing of each prototype VPAS system. These reports are soley for the purpose of summarizing the testing with a brief discussion of the results. No analysis or conclusions on the results of the testing are included in these reports. A full analysis of each system and conclusions based on the results of this analysis will be included in the final report for Task Order 114.

1.0 INTRODUCTION

As part of FRA Task Order 114, the Association of American Railroads (AAR) Transportation Technology Center (TTC), Pueblo, Colorado, completed testing of Vehicle Proximity Alert System (VPAS) Prototype System 3. VPAS systems are designed to give priority vehicle operators (emergency, police, school buses, hazmat) advanced warning of the approach and/or presence of a train. These are stand alone systems that do not rely on the activation of conventional highway-rail grade crossing warning/protection devices.

This letter report is an overview of the testing that was performed for VPAS System 3 and does not include any detailed analysis of the data or draw conclusions based on that data. A more detailed analysis will be included in the final report for Task Order 114.

2.0 SYSTEM OVERVIEW

All railroads are required to signal their approach to a public highway-rail grade crossing by blowing the horn on the locomotive.* The standard approach signal for all railroads is two long horn blasts, a short horn blast, and another long horn blast. This horn cycle continues until the train fouls the crossing. Most Class I railroads require locomotive engineers to begin the approach warning (regardless of speed) at whistle boards, which are generally placed 1,500 feet in advance of the crossing, although some local and state governments have regulations that may limit this distance.

VPAS System 3 is a one-point system that uses an acoustic recognition design developed by Early Alert Response System (EARS), Inc. The one point consists of a microphone transducer mounted outside the vehicle and a digital signal processor inside the vehicle, although the horns on a locomotive could be considered a second (transmitting) point.

*Except where specifically prohibited by local ordinance

System 3 uses a technology that is designed to detect the frequency-time patterns generated by blowing a train horn. System 3 accomplishes this by using a digital signal processing algorithm to analyze the frequency content of audio signals received by the microphone transducer. If the appropriate frequencies are recognized by the EARS system, a visual and audio warning is transmitted to the vehicle operator. This system is designed to give a train approach warning and not a train occupancy warning, since locomotive engineers only blow the horn until the train fouls a crossing.

3.0 PROCEDURES

VPAS testing is broken down into four phases.

Phase I - System installation, calibration and check-out
Phase II - System performance and repeatability
Phase III - Maximum system performance limits
Phase IV - System response to adverse conditions

The following sections outline the testing that was performed under each phase.

3.1 PHASE I

Phase I testing consisted of system installation, calibration, and initial check-out. Installation was performed by a representative of EARS Systems, Inc. under the supervision of TTC personnel on February 13, 1995. The system was delivered ready to install. The receiver in the vehicle was supplied 12 VDC. Although the EARS system does not require the installation of any device on the locomotive, for the purpose of monitoring the train horn, a magnetic valve was installed on the locomotive.

The initial system check-out was performed with both the vehicle and locomotive stationary. The vehicle was placed 500 feet perpendicular to the track. The locomotive was placed at the crossing and two horn cycles were transmitted. The locomotive was then backed down the track 500 feet and another two horn cycles transmitted. This was repeated until the EARS system could no longer detect the train horn. The maximum distance, given the weather conditions that day, was 1,500 feet.

With the vehicle remaining stationary at 500 feet, several passes at varying speeds (40 mph max) were then made with the locomotive. The results from Phase I indicated that System 3 was operating properly and Phase II testing was ready to begin.

3.2 PHASE II

The objective of Phase II testing was to test system performance and repeatability in a simulated revenue service environment on a sustained basis. This phase of testing involved repeated actuation of the vehicle receiver by a passing train traveling at 40 mph. The vehicle remained stationary at 500 feet perpendicular to the simulated crossing for the entire duration of Phase II. A single approach warning horn cycle was initiated on each train pass when the locomotive was approximately 1,750 from the crossing. This horn cycle lasted from the time of initiation until the locomotive fouled the crossing (approximately 30 seconds). The following table summarizes train passes made during Phase II for VPAS System 3:

Table 1. Phase II Train Passes

DATE	TRAIN DIRECTION	TRAIN PASSES	SYSTEM OPERATION TIME (hrs)
3/15	CCW	30	2.15
3/16	CCW	76	5.50
3/17	CCW	52	3.75
3/19	CCW	65	4.65
3/20	CW	113	8.10
3/21	CW	109	7.80
3/22	CW	59	4.2
	TOTAL	504	36.15

As stated earlier, each train horn cycle consisted of four horn blasts (two long blasts, a short blast, and another long blast). The complete cycle was set up to give a 30 second approach warning. Figure 1 is a time history of a single horn cycle as generated by the data collection system.

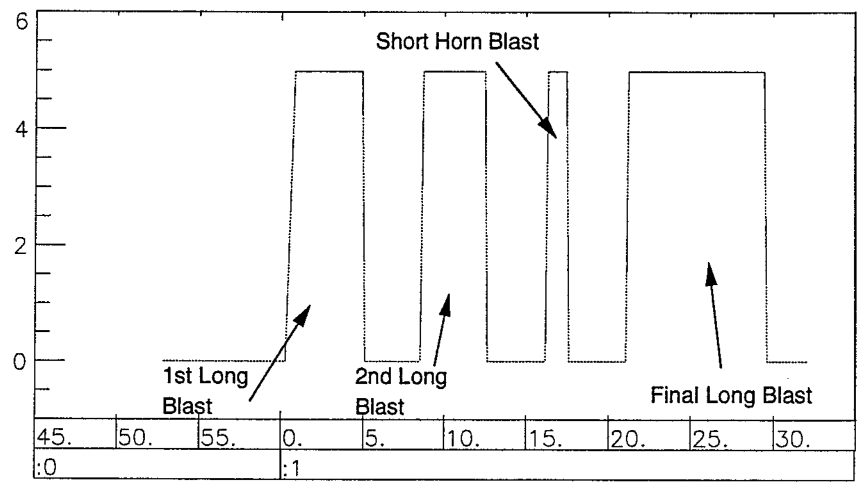

Figure 1. Single Train Horn Approach Warning Cycle

VPAS System 3 can receive multiple warning signals during a single train pass. For the purpose of evaluating the repeatability and performance when System 3 received the initial detection of an approaching train, Phase II data was categorized into which horn blast the initial detect was received. By categorizing the data in this fashion, an approximation of the warning time and its consistency can be made for each train pass. If the VPAS system was unable to detect any of the given horn blasts during a train pass, it was categorized as a "no detect." Table 2 summarizes the results of this evaluation.

Table 2. Phase II Initial Detection

		Single Train Horn Cycle				
DATE	Total Passes	1st Long Blast	2nd Long Blast	Short Blast	Final Long Blast	NO DETECT
3/15	30	0	1	0	14	15
3/16	76	14	7	6	35	14
3/17	52	8	4	0	38	2
3/19	65	22	18	8	17	0
3/20	113	51	22	13	26	1
3/21	109	58	17	19	8	7
3/22	59	8	22	8	20	1
	504	161	91	54	158	40

Table 2 shows there was a large variability in train approach warning time from train pass to train pass. Mean warning time for the 504 train passes was 15.26 seconds with a standard deviation of 9.13. The suspected causes of this variability were wind speed, wind direction, and background noise.

3.3 PHASE III

The purpose of Phase III testing was to determine the maximum performance limits of the VPAS System 3. To determine system design limits, testing was conducted with either the locomotive or vehicle stationary under good conditions.

3.3.1 RTT Testing

The first segment of Phase III testing was performed on the Railroad Test Track (RTT) which has a simulated crossing located at post R-14 (Figure 1). Before actual test runs were made, an initial measurement was made to determine reasonable test zone boundaries. This initial measurement was performed with both the locomotive and vehicle stationary. The vehicle was stationed adjacent to the crossing, approximately 15 feet from the track, and positioned so that the microphone transducer was facing the locomotive. The vehicle remained in position while the locomotive was stopped at 1,000 foot increments from the crossing and the horn was sounded to determine a distance at which the VPAS system in the vehicle could no longer detect the sound of the train horn. This initial examination showed that the VPAS system was able to detect the train horn when the locomotive was within the range of 2,500 feet and 3,000 feet from the crossing.

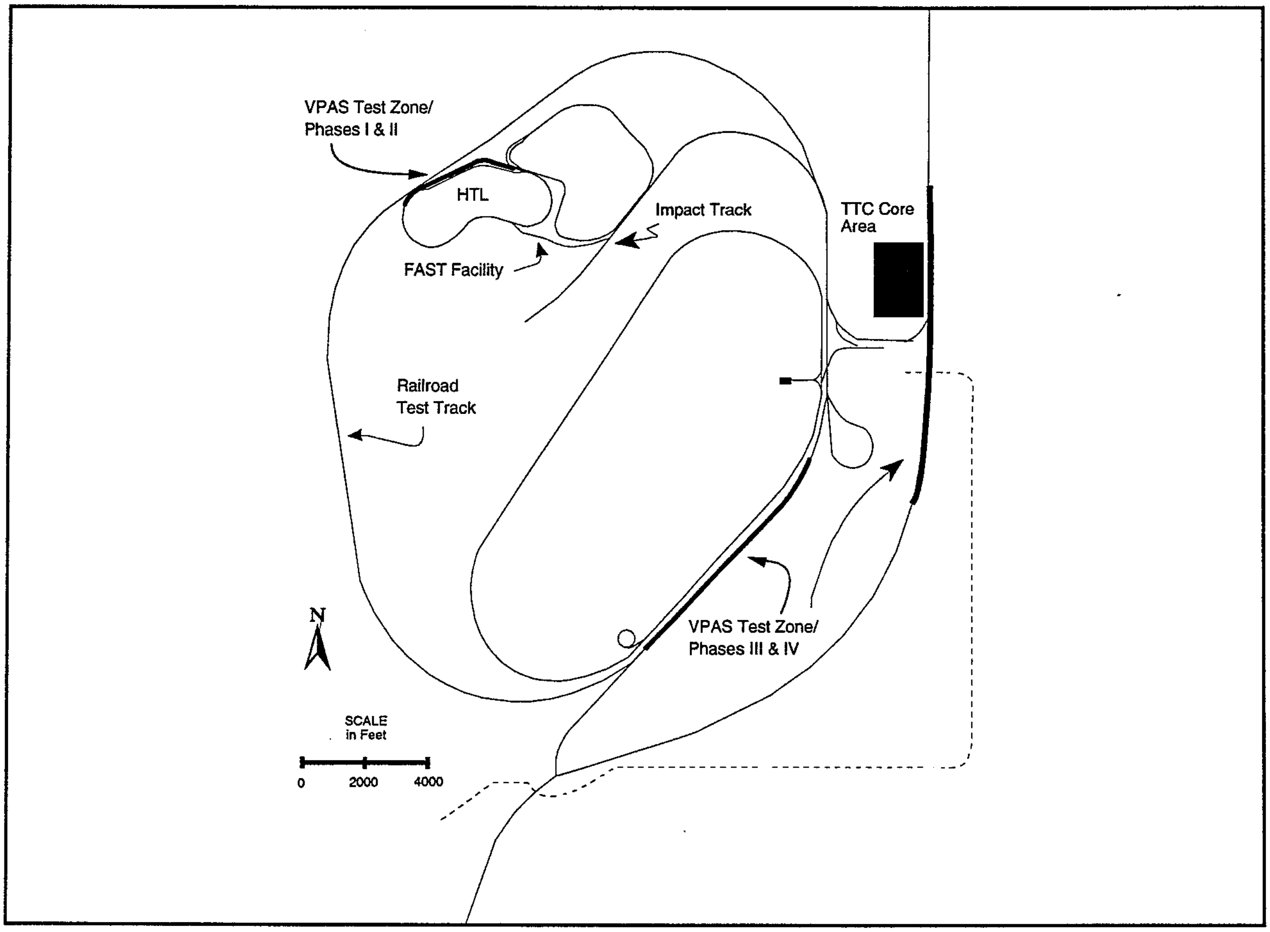

Figure 2. TTC Site Map / VPAS Test Zones

The next series of runs was performed with the vehicle remaining stationary, at set distances perpendicular to the track, while the locomotive approached at varying speeds. The data collection systems were turned on 1000 feet prior to initiating the first horn cycle. The horn cycle was triggered repetitively until the train reached the crossing. Table 3 summarizes the results of each run, focusing on the distance of the locomotive from the crossing at the time the VPAS system received its initial detect.

Table 3. Phase III, Stationary Vehicle

Run No.	Vehicle Distance from Crossing (feet)	Loco Speed (mph)	Comments
01	At crossing	10	Initial detect occurred when locomotive was ~2000 feet from crossing.
02	At crossing	10	Initial detect occurred when locomotive was ~2000 feet from crossing.
03	At crossing	30	Initial detect occurred when locomotive was ~2000 feet from crossing.
04	At crossing	30	Initial detect occurred when locomotive was ~1800 feet from crossing.
05	At crossing	60	Initial detect occurred when locomotive was ~1000 feet from crossing.
06	At crossing	60	Initial detect occurred when locomotive was ~1500 feet from crossing.
07	1000	10	Initial detect occurred when locomotive was ~2800 feet from crossing.
08	1000	30	Initial detect occurred when locomotive was ~2300 feet from crossing.
09	1000	60	Initial detect occurred when locomotive was ~1000 feet from crossing.
10	2000	10	No Detect
11	2000	30	No Detect
12	2000	30	Turned vehicle around so microphone was facing the track. Initial detect occurred when locomotive was ~1500 feet from crossing.
13	1500	10	Initial detect occurred when locomotive was ~2000 feet from crossing.
14	1500	30	No Detect
15	1500	60	No Detect

3.3.2 Impact Track Testing

A second segment of Phase III testing was performed on the Impact Track (Figure 1). This particular track has a paved road crossing, essential for mobile vehicle testing, that intersects perpendicular to the track. Markers were set on the road every tenth of a mile for one mile. For this portion of testing, the locomotive remained stationary at set distances from the crossing while the vehicle approached the crossing at varying speeds. Table 4 summarizes the test results for this segment of Phase III testing:

Table 4. Phase III, Mobile Vehicle Tests

Run No.	Vehicle Speed	Locomotive Distance	Comments
29	Stationary @ crossing 500 ft and 1000 ft	100	Stationary checkout. 2 horn cycles. Initial detects on, first blast of first horn cycle at crossing, third blast of second horn cycle at 500 feet, and no detect at 1000 feet.
30	Stationary @ crossing and 500 ft	100	Stationary checkout. Locomotive in 6 throttle. Initial detects on, first blast of first horn cycle at crossing and no detect at 500 feet.
31	30	100	Horn blowing when vehicle is 1500 feet from crossing. No detect.
32	30	100	Horn blowing when vehicle is 1500 feet from crossing. No detect.
33	30	500	Invalid run. Data collection system went down.
34	30	500	Horn blowing when vehicle is 1500 feet from crossing. No detect.
35	20	Stationary	Vehicle traveling head-on towards locomotive from 1500 feet. Repetitive horn cycles. Initial detect when vehicle was ~50 feet from locomotive.
36	20	Stationary	Vehicle traveling head-on towards locomotive from 1500 feet. Repetitive horn cycles. Initial detect when vehicle was ~30 feet from locomotive.

3.3.3 Post 100 Testing

The previous runs were performed as the vehicle approached from up-wind of the impact track crossing. Conversely, the performance was examined traveling down-wind towards the Post 100 crossing (Figure 1). During the entire duration of the following test runs, wind speed was between 4 and 7 miles per hour out of the East. Table 5 summarizes the results of these test runs:

Table 5. Phase III, Wind Effects

Run No.	Vehicle Speed	Locomotive Distance	Comments
37	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 500 feet from crossing.
38	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 500 feet from crossing.
39	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 700 feet from crossing.
40	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 800 feet from crossing.
41	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 500 feet from crossing.
42	30	500	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 450 feet from crossing.
43	50	500	Vehicle down-wind from locomotive. No Detect.
44	50	500	Vehicle down-wind from locomotive. No Detect.
45	30	1000	Vehicle down-wind from locomotive. No Detect.
46	30	1000	Vehicle down-wind from locomotive. No Detect.
47	30	100	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 550 feet from crossing.
48	30	100	Vehicle down-wind from locomotive. Initial detect when vehicle is ~ 550 feet from crossing.

3.4 PHASE IV

The next series of runs were performed to examine the effects of interference that may be caused by the locomotive engine noise. This was accomplished by having the locomotive in 6 throttle, while maintaining speed through the test zone during mobile locomotive runs. The vehicle remained stationary for these runs. The following table summarizes the results of this series.

Table 6. Phase IV, Background Noise Interference

Run No.	Vehicle Distance from Crossing (feet)	Loco Speed (mph)	Comments
16	At Crossing	Stationary @ Crossing	Loco in notch 6. Two horn cycles. No Detect.
17	At Crossing	Stationary @ 1000 feet from crossing	Loco in notch 6. Two horn cycles. Initial detect at beginning of second horn cycle.
18	At Crossing	Stationary @ 2000 feet from crossing	Loco in notch 6. Two horn cycles. No Detect.
19	At Crossing	Stationary @ 1500 feet from crossing	Loco in notch 6. Two horn cycles. No Detect.
20	1000	10	Loco in 6 throttle 6. Repetitive horn cycles. Initial detect occurred when locomotive was ~100 feet from crossing.
21	1000	30	Loco in 6 throttle 6. Repetitive horn cycles. Initial detect occurred when locomotive was ~500 feet from crossing.
22	1000	30	Loco idling through zone @ 30 mph. Repetitive horn cycles. Initial detect occurred when locomotive was ~100 feet from crossing.
23	500	10	Loco in 6 throttle 6. Repetitive horn cycles. Initial detect occurred when locomotive was ~600 feet from crossing.
24	500	30	Loco in 6 throttle. Repetitive horn cycles. Initial detect occurred when locomotive was ~500 feet from crossing.
25	500	60	Loco in 6 throttle 6. Repetitive horn cycles. Initial detect occurred when locomotive was ~500 feet from crossing.
26	500	60	Loco idling. Repetitive horn cycles. Initial detect occurred when locomotive was ~500 feet from crossing.
27	500	Stationary @ Crossing	Loco idling. 2 horn cycles. Initial detect on first blast of first horn cycle.

In runs 49 thru 54, the vehicle was positioned stationary in various locations around the TTC "core" area (Figure 3). Table 7 lists the test runs that were make to check for interference from obstacles such as buildings and bridges.

Table 7. Phase IV, Obstacle Interference

Run No.	Vehicle Distance from Crossing (feet)	Loco Speed (mph)	Comments
49	200	30	Vehicle positioned south of bridge (figure X). Locomotive traveling North to South. Initial detect @ ~300 feet.
50	200	50	Vehicle positioned south of bridge (figure X). Locomotive traveling north to south. Initial detect @ ~50 feet.
51	200	30	Vehicle positioned south of bridge (figure X). Locomotive traveling north to south. Initial detect @ ~100 feet.
52	200	30	Vehicle positioned between RDL and CSB (figure X). Locomotive traveling north to south. Data collection system down. No data.
53	200	30	Vehicle positioned between RDL and CSB (figure X). Locomotive traveling north to south. Initial detect @ ~550 feet.
54	200	30	Vehicle positioned between RDL and CSB (figure X). Locomotive traveling north to south. No detect.

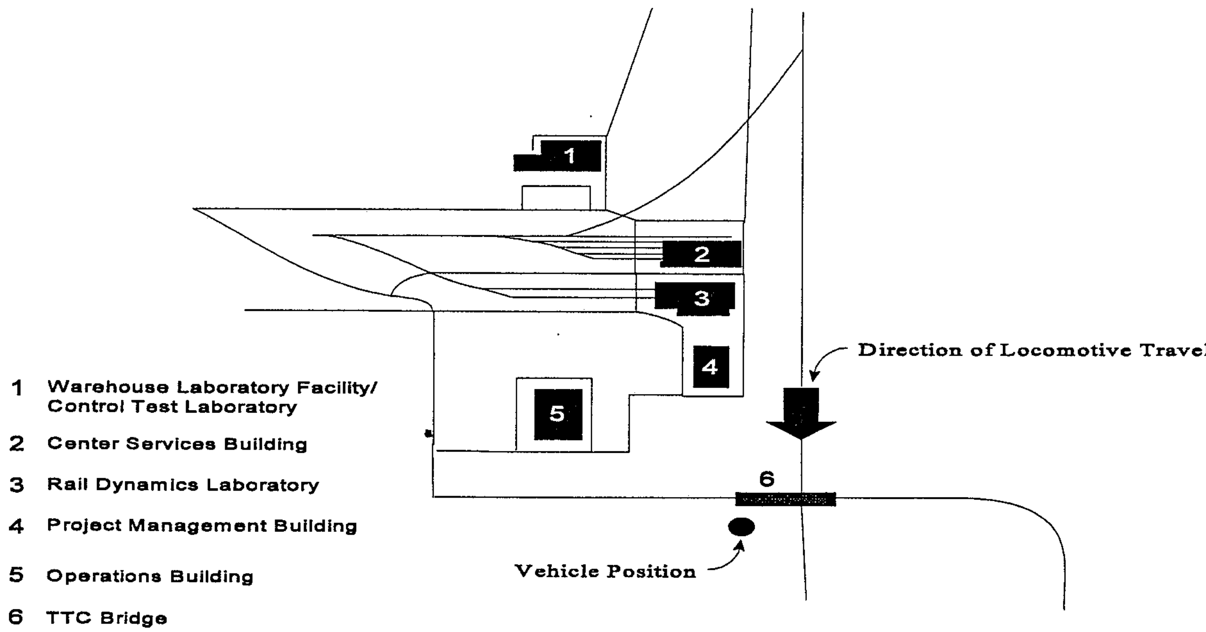

Figure 3. TTC Core Area - Stationary Vehicle Position Behind TTC Bridge