U.S. Department of
Transportation

**Federal Railroad
Administration**

Office of Research,
Development and Technology
Washington, DC 20590

Trespasser Detection Systems on Railroad Rights-of-Way

DOT/FRA/ORD-20/34

Final Report | August 2020

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
27-01-2020	Technical Report	September 2016 – January 2020

4. TITLE AND SUBTITLE	
Trespasser Detection Systems on Railroad Rights-of-Way	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) William Baron ORCID 0000-0001-9601-6725 Marco daSilva ORCID 0000-0001-8081-6250	**5d. PROJECT NUMBER** RR97A8
	5e. TASK NUMBER TC967
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology John A. Volpe National Transportation Systems Center 55 Broadway, Cambridge, MA 02142	DOT-VNTSC-FRA-20-04
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Federal Railroad Administration Office of Railroad Policy and Development Office of Research, Development and Technology Washington, DC 20590	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)** DOT/FRA/ORD-20/34

12. DISTRIBUTION/AVAILABILITY STATEMENT

This document is available to the public through the FRA eLibrary.

13. SUPPLEMENTARY NOTES

Safety of Highway-Rail Grade Crossing series

FRA COR: Francesco Bedini Jacobini

14. ABSTRACT

The U.S. Department of Transportation's Volpe Center, under the direction of DOT's Federal Railroad Administration Office of Research, Development, and Technology, conducted a research study to evaluate the effectiveness of trespass detection technology on rail property linked to and controlled by a local police department. The system was operated for several years, while different communications and sensor technologies were tested for their abilities to overcome shortcomings. Researchers found that wireless broadband service in this area was insufficient in providing uninterrupted high-resolution video from multiple cameras, and while TV white space transceivers had adequate bandwidth, their short transmission range limited their usefulness. Providing live video directly to the local police department resulted in quick response to trespassing events; however, dispatchers were particularly unhappy with false alarms.

15. SUBJECT TERMS

Highway-rail, grade crossing, humped crossing, photogrammetry, LiDAR

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			William Baron
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U		24	(617) 494-2540

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0	1	2	3	4	5

Centimeters	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures.
Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

Acknowledgements

The U.S. Department of Transportation Federal Railroad Administration (FRA) Office of Research, Development, and Technology (RD&T) sponsored the work leading to this report. The authors would like to thank Sam Alibrahim, Chief, FRA RD&T's Train Control and Communication Division, and Francesco Bedini Jacobini, Program Manager, FRA RD&T Train Control and Communication Division; and Tarek Omar, Michail Grizkewitsch, and Norma Griffiths of FRA for their guidance during various phases of the project.

The authors would like to thank Jeffrey Pitcher and Julia Picard of the Maine DOT, which owns the railroad property; Tim Kunzler of Pan Am Railways, which operates the railroads in Brunswick; and Tony Padilla of Secure Integrator and Alan Kauffman of Strongbridge LLC for their contractual support in deploying and maintaining the trespasser detection system.

The authors would also like to thank the Brunswick Police Department, in particular Commander Thomas Garrepy, Sonia Moeller, and Arthur Frizzle for their extensive support in hosting this system and their efforts in helping it reach its potential, and to Bryan Cobb of the Town of Brunswick for support in obtaining and enhancing network connectivity for the system.

Contents

Illustrations

Tables

Executive Summary

The Federal Railroad Administration (FRA) Office of Research, Development and Technology tasked the John A. Volpe National Transportation Systems Center (Volpe) with developing and evaluating a system to detect trespassers on a railroad right-of-way. This project builds off a previous effort that began in 1999 in Pittsford, New York, where Volpe developed a similar system. This time, FRA wanted Volpe to work directly with a cooperative municipal law enforcement agency to integrate the system into its dispatch facility to enable real-time responses to trespassing events. Working with the FRA, Volpe identified the town of Brunswick, Maine as being supportive of hosting the system.

Volpe researchers deployed test cameras in selected locations throughout the Brunswick area to better understand the places where trespassing occurs. Volpe then contracted the design and deployment of an integrated trespasser detection system, commissioned in January 2016. Camera stations were deployed at three selected locations with demonstrated trespassing issues.

Many lessons were learned in the areas of communications, video transmission, and sensor technology. The Volpe team found that in these locations, the cellular infrastructure was not sufficient to provide uninterrupted high-definition video from multiple cameras. TV white space technology, intended to provide non-line-of-sight wireless network connectivity, does not provide the range required by this project, but nonetheless has utility in a system such as this. The Volpe team encountered false alarms with the video motion detection component of the system, and similar challenges were found with other types of sensors.

Volpe researchers found that integrating rail trespassing detection into a police dispatch center had mostly positive effects, including rapid response and constant oversight over the right-of-way. The recorded video was sometimes used by the police in forensic investigations.

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe) provides technical support to the Federal Railroad Administration (FRA) on grade crossing safety and trespass prevention research. This support includes key research associated with railroad rights-of-way (ROW), including highway-rail intersections (HRI) and trespass issues.

In 2018, there were 841 rail-related fatalities in the United States.[1] Of these, 541 resulted from trespassing incidents,[2] and 255 of these were determined to be suicides.[3] With the preponderance of railroad fatalities in the U.S. each year involving trespassing activity, FRA is evaluating approaches aimed at addressing this problem.

In 2013, Volpe was tasked by the FRA Office of Research, Development, and Technology (RD&T) with developing and evaluating a system to detect trespassers on a railroad ROW. This project builds off a previous effort that began in 1999 in Pittsford, New York, where Volpe developed a similar system. This time, FRA wanted Volpe to work directly with a cooperative municipal law enforcement agency to integrate the system into its dispatch facility to enable real-time responses to trespassing events. Working with the FRA, Volpe identified the town of Brunswick, Maine as being supportive of hosting the system.

1.1 Background

This report details the Volpe research team's findings in assessing the performance of a prototype trespass detection system. A contractor designed and deployed this system using functional specifications developed by FRA and Volpe. As Volpe discovered shortcomings in various components, the team either reconfigured them or replaced them to find optimal functionality and performance.

1.1.1 Test Site

Volpe and FRA identified Brunswick, Maine as a test location for this project. Brunswick is one endpoint for the Amtrak *Downeaster;* the other is Boston's North Station. Amtrak currently runs five round trips per day. Freight rail on the same line is operated by Pan Am Railways, which is responsible for maintaining the tracks, signals, and grade crossing safety equipment. The railroad property is owned by the Maine Department of Transportation (MDOT), and a spur which crosses Jordan Avenue is maintained by Central Maine and Quebec Railway.

Brunswick, Maine is located on the seacoast about 25 miles northeast of Portland and 130 miles from Boston. Brunswick is home to Bowdoin College, so there is a large number of students living in the area. Key to the selection of this site was the support and cooperation of the Brunswick Police Department (BPD), which offered to host and operate the trespasser detection

---

[1] "4.12–Casualties By State/Railroad," Federal Railroad Administration, Office of Safety Analysis, accessed August 30, 2019, https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/CasualitiesReport.aspx.
[2] "2.07–Trespasser Casualties," Federal Railroad Administration, Office of Safety Analysis, accessed August 30, 2019, https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/castally4.aspx.
[3] "4.11–Suicide Casualties By State/Railroad," Federal Railroad Administration, Office of Safety Analysis, accessed August 30, 2019, https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/suiabbr.aspx.

system, and provide feedback on its functionality. BPD provides dispatch services for the adjacent Town of Freeport under a cooperative agreement, so elements of the trespasser detection system were also installed in Freeport.

1.1.2 Past Research

In 1999, Volpe and FRA began working with CSX Railroad to deploy a trespasser detection system in Pittsford, New York. This location was selected due to a fatal accident in 1997, when trespassers were caught on a trestle that crossed the Erie Canal and were struck by a train. The system, which initially predated high-speed internet connectivity, transmitted video via modem to a contracted alarm services company. That system provided the security company staff the capability to speak to trespassers and warn them off the tracks.

In 2002, cable service providers in Pittsford began offering high-speed internet service, which was then used to provide the video transmission, which improved the performance of the system and made it easier to use. Volpe also developed a train-masking system to reduce the number of alarms triggered by passing trains. There were several instances where trespassers were warned off the tracks just moments before a train passed. The pilot project ended in 2004, and the system was transferred to CSX. That project yielded many lessons, including the need to record video and for first responders to receive the video directly to improve response times. The findings of that study are provided in an FRA report, "Railroad Infrastructure Trespassing Detection System Research in Pittsford, New York."[4]

1.2 Objectives

The objectives of this research included:

- Test new technology for trespasser detection, video transmission and recording.
- Create a platform that allows for a variety of cameras, sensors and methods of connectivity.
- Integrate the system directly into a local police dispatch center.

1.3 Overall Approach

Volpe began this project in 2013 by discussing the problem of railroad trespassing with representatives from Pan Am Railways, Amtrak, MDOT, and Brunswick and Freeport police to target places believed to have a trespassing issue. Volpe then set up temporary video cameras for several weeks to verify that trespassing activity was actually occurring. Figure 1 shows the locations of the temporary cameras installed by the Volpe research team.

---

[4] Marco P. DaSilva, William Baron, and Anya Carroll, "Railroad Trespassing Detection Systems Research in Pittsford, New York" (DOT/FRA/ORD-06/03) (Washington, DC: Federal Railroad Administration, 2006), available at https://rosap.ntl.bts.gov/view/dot/8901.

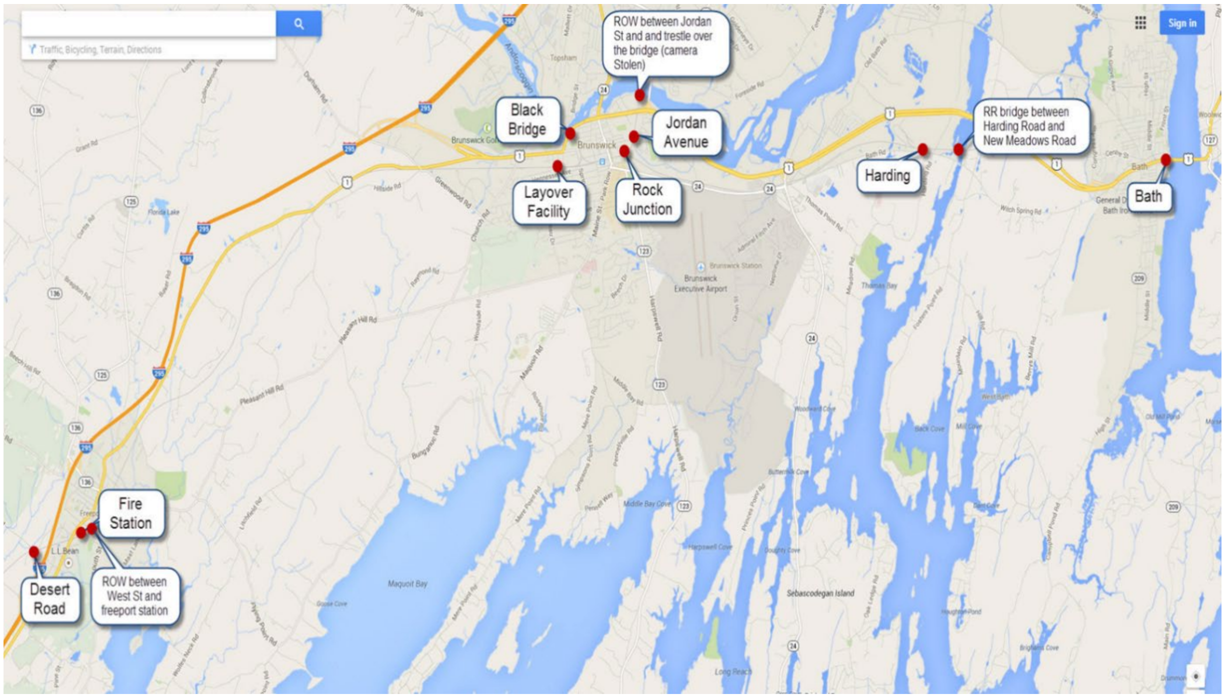

Figure 1 – Temporary Camera Locations

Some locations proved to have little or no trespassing activity, while others had frequent activity. Figure 2 shows examples of some of the activity captured by the temporary cameras.

Figure 2 – Examples of Trespassing Captured by Temporary Cameras

At one location north of Jordan Avenue, trespassing activity was determined to have taken place – since the temporary camera was stolen. A summary of Volpe’s analysis of the temporary camera data is shown in Table 1 below.

Table 1 – Trespass Summary from Temporary Cameras

Locations	Data Analysis Period	Average Trespass Events per Day	Total Trespassing	Train Operation
Desert Road	9/26/13 – 10/05/13	None	None	Yes
Fire Station	9/26/13 – 10/17/13	1.5	47	Yes
Layover Facility	11/5/13 - 11/8/13	1.8	7	Yes
Black Bridge	9/8/13 – 9/18/13	1.1	15	No
ROW west of Freeport station	9/8/13 – 9/18/13	1.3	15	Yes
Rock Junction	9/25/13 - 10/5/13	2.1	35	Yes
Jordan Avenue	5/28/13 – 6/13/13	1.5	33	No
ROW between Jordan Ave. and trestle	No Data – Camera Stolen			
Harding	9/26/13 – 10/17/13	0.3	11	Yes
Railroad Bridge between Harding Rd. and New Meadows Rd.	5/28/13 – 6/13/13	None	None	Yes

Using this data, Volpe and FRA initially decided the trespasser detection system should have four fixed camera sites: Rock Junction, Jordan Avenue, the town of Freeport (west of the station) and Harding Road (near the Bath Iron Works facility). It was later determined that getting reliable power and connectivity at Harding Road was too challenging, so this site was dropped. In 2014, Volpe issued a request for proposals (RFP) for a "Rail Trespassing Video Monitoring and Alarm System." Although this RFP yielded six proposals, none were deemed both acceptable and within budget. At the same time, Volpe negotiated a memorandum of understanding with MDOT (the owner of the railroad property in Brunswick and Freeport) that allowed Volpe to install and maintain the trespasser detection system.

In 2015, Volpe refined the statement of work and issued a sole source contract to Secure Integrator Corporation of Manassas, Virginia. The contract was awarded in August 2015 and installation began in October 2015. Installation and configuration was completed and the BPD server and dispatch monitoring station was activated on January 15, 2016.

1.4 Scope

This study investigates the effectiveness of a trespasser detection system that was integrated into a municipal police dispatch center. This system was intentionally designed to be modular, so that various components for detection, video capture, and transmission could be replaced and assessed. As a result, this project spanned several years in which various elements were integrated and assessed.

1.5 Organization of the Report

This report is organized as follows:

- Section 2 describes the trespasser detection system and Volpe's evaluation of the components.
- Section 3 presents the conclusion of the study.
- Section 4 provides the references used in the report.

2. Trespasser Detection System

The system as delivered by the contractor provided BPD with multiple video feeds from each camera site. It was based on an AXIS Camera Station enterprise video surveillance platform. Large screen monitors were set up in the BPD dispatch center, as shown in Figure 3, as was a workstation from which dispatchers could control or move cameras and respond to alarms. The video was recorded on an AXIS rack mount hard drive array, with the server hosted on a Dell rack mount server, both of which were located in the BPD radio room.

Figure 3 – Trespass Detection Monitors in the BPD Dispatch Center

Live streaming video was transmitted from the Jordan Avenue and Rock Junction sites via wireless broadband service provided by Verizon Wireless. Video from Freeport was transmitted via a Comcast broadband connection provided by the Town of Freeport. The contractor provided video motion detection as a sensor, with the ability to add external sensors later if needed. Automated vehicle location (AVL) software for patrol vehicles, shown in the screen at the bottom center of Figure 3, was also purchased under this program.

Each camera site had two fixed cameras (AXIS Q1765) and one pan-tilt-zoom camera (AXIS Q6045) on a 12-foot pole. Also, each pole had an AXIS P8221 audio control unit, along with a speaker and microphone that allowed dispatchers to speak and listen to trespassers. At Rock Junction, power was provided from the Pan Am bungalow. At Jordan Avenue, the town had power inside an adjacent flashing school zone sign that was turned off when the school was permanently closed. At Freeport, power was run from the station to the pole through existing conduit. Power and communications equipment was contained in a small enclosure near the top of each pole. The Freeport equipment was located on a light pole on the station platform. Since the internet connection was located at the nearby Chamber of Commerce building and could not be physically connected, an FM-PONTE-50 wireless bridge provided a connection to the cameras and audio devices. Each of the camera sites are shown in Figure 4, Figure 5, and Figure 6 below.

Figure 4 – Rock Junction Camera Pole

Figure 5 – Jordan Avenue Camera Pole

Figure 6 – Freeport Camera Pole

2.1 Performance Issues

Several problems were encountered early on. Even before the Freeport cameras were connected to the internet, the Town of Freeport believed the system was responsible for degrading their internet service. They also became uneasy of future use because they were planning to convert all of their municipal telephone service to an internet-based service, and did not want to risk telephone outages due to our video transmission system.

At the same time, the Town of Brunswick saw the internet service at the police headquarters become heavily impacted. It turned out the town was only contracting for 10 Mbps internet service, and the new cameras were demanding nearly half of this on a constant basis.

Figure 7 below shows the network utilization at BPD before and after the commissioning of the trespasser detection system on January 15, 2016. Incoming network traffic, which often runs near zero percent of capacity, suddenly never went below 35 percent, and was often above 90 percent, at which point commonly-used web services often fail to load.

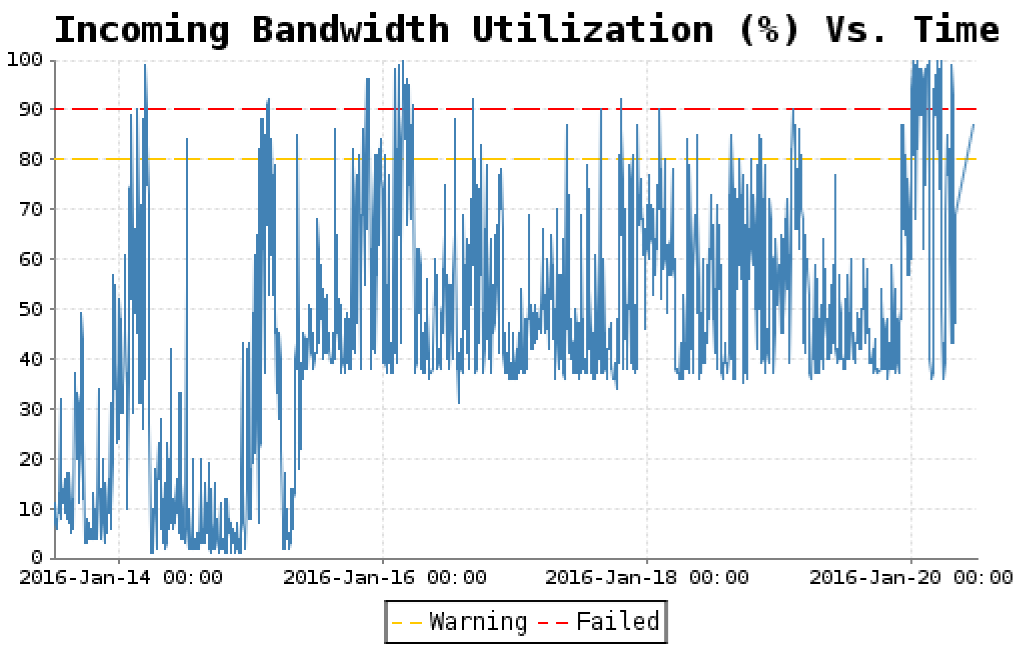

Figure 7 – BPD Network Activity Before and After System Commission

Attempts were made to "throttle down" some of the cameras by manually reducing the resolution and frame rate, but this had little effect since the quality of the video had already been reduced by each camera's transmission protocol due to bandwidth limits in the wireless broadband service. It became clear that BPD would need a higher capacity internet service in order for the trespasser detection system and other BPD systems to function properly. Volpe and the Town of Brunswick agreed to share the cost to upgrade the BPD service to 100 Mbps for the first year, until town officials could add the upgraded service to their annual budget.

Shortly after the upgrade in BPD's internet service, a new anomaly was discovered. While the video streams from the Rock Junction and Jordan Avenue cameras were steady during the overnight hours, they became intermittent during the daytime. This was despite the fact that Volpe was utilizing wireless broadband service under DOT's contract with Verizon Wireless that should have provided unlimited internet service. After discussions with Verizon Wireless representatives and other wireless experts, it was determined that the wireless infrastructure in Brunswick was limited, with only one tower in the area (which was located on the Bowdoin campus). As the daytime demand for wireless broadband services increased each morning, Verizon Wireless automatically shared the available bandwidth with each of the requesting systems and devices. Once it reached capacity, all users experienced a degradation in service. Devices that were browsing the internet may not have noticed the difference, as web pages were loaded with a delay. However, systems that streamed video experienced interruptions in the video stream, which was problematic since live video was required in order to detect and track trespassers.

2.2 BPD Utilization of the System

BPD utilized the system in many ways, some of which were unrelated to trespasser detection. On several occasions, BPD reviewed recorded video to better understand other law enforcement activity that occurred on or near the tracks. For example, a tall truck on Jordan Avenue was recorded striking the railroad bridge. On another occasion, video was reviewed to find evidence of a person of interest in a police investigation. Finally, BPD may expand the system in the future by adding additional cameras.

2.3 Communication Modifications

In 2016, due to the challenges caused by the limited wireless bandwidth and to address the Town of Freeport's concerns, Volpe researchers reviewed three alternatives:

- **Dual SIM card modems –** This involved upgrading the wireless modems to some that support SIM cards from two different wireless broadband service providers. Systems like these are used in disaster areas and at times of crisis, when wireless broadband networks are prone to failure or operating near their maximum capacities. They can switch cellular networks when service on one network is disrupted. However, these modems require that cellular service be obtained from multiple providers, which involves multiple monthly bills for each site.
- **Transmit video via the Bowdoin fiber network –** Volpe and BPD initiated discussions with Bowdoin College to link cameras to a nearby student dormitory, where the video streams could then be routed to BPD via the Bowdoin fiber network. This option only applied to the Rock Junction cameras.
- **Terrestrial internet service –** Volpe became familiar with commercial wired (cable and fiber optic) internet options in the Brunswick area following the upgrade of BPD's internet service. Service from Comcast was available at both Jordan Avenue and Freeport, and offered superior bandwidth at a competitive price.

Volpe pursed both the second and third options. Working with Bowdoin College was particularly attractive since it did not involve ongoing monthly charges. Although the student dormitory was less than 100 yards from the Rock Junction cameras, it was too far to connect using only the Bowdoin Wi-Fi. Volpe, BPD, and FRA met with Bowdoin officials, who refused to allow Volpe to use the same FM-PONTE-50 wireless links that had proven successful in Freeport, citing concerns of potential interference with their Wi-Fi routers. Instead, they agreed to allow Volpe to hardwire a network cable from the cameras to the dormitory, entering the building via an existing underground conduit. However, after the meeting, Bowdoin officials changed course and asked that we enter via the opposite end of the conduit, located at a telephone pole on Federal Street. Running the cable to this pole involved trenching up the hill and cutting through a municipal sidewalk. Volpe was informed that the town of Brunswick would not allow us to simply patch the sidewalk, and that we would have to hire a paving company to fix the cut. At this point, this option was dropped due to the growing cost of implementation.

Follow-up communications with Bowdoin resulted in a new alternative. Volpe could use a microwave link to connect Rock Junction to the Bowdoin dormitory. Volpe purchased a Ubiquiti 24 GHz wireless link. However, the installation guide revealed that these systems are designed to transmit data over miles, not feet, and it warned of potential equipment damage if used in close range. Volpe decided to return the Ubiquiti system.

Volpe acquired cable internet service from Comcast at both Jordan Avenue and Freeport. This enabled Volpe to complete at least part of the trespasser detection system with continuous video feeds. Volpe would then look to link the Rock Junction cameras to BPD via another method. Volpe tested an FM-PONTE-50 system between Rock Junction and Jordan Avenue, but with leaves on the trees between the two sites, the signal strength was too weak to establish a connection.

Discussions with various experts in wireless networking revealed that a new alternative was emerging: TV white space devices. Part of the radio frequency spectrum that was freed up when the Federal Communications Commission converted from analog to digital television broadcasting in 2009 was now being reused in new wireless networking equipment. The difference between traditional wireless links and TV white space is that these frequencies don’t require line-of-sight, enabling wireless connections across towns over hills and through trees.

After a review of potential providers, Volpe identified devices available from Carlson Wireless (Eureka, CA) as meeting system requirements. System manuals and specifications indicated their RuralConnect product line could connect network devices over distances of up to 3 miles, which would be sufficient to cover the distance between BPD headquarters and Rock Junction (less than 1 mile). Volpe purchased a RuralConnect transmitter, receiver, and a variety of antennas and installed them in June 2017 at BPD headquarters. An omnidirectional antenna was mounted on the radio tower and the base station receiver placed in the radio room. Figure 8 shows the installation of the antenna on the BPD radio tower.

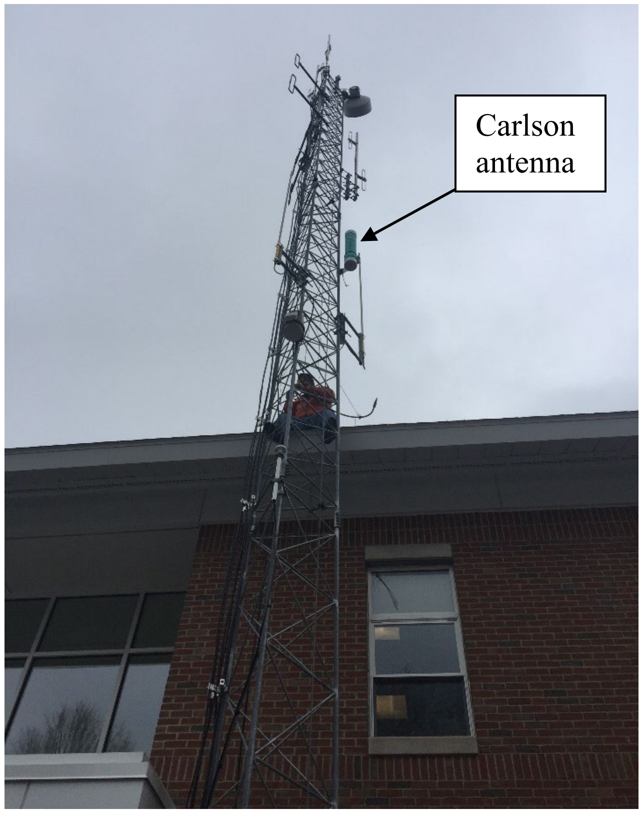

Figure 8 –Carlson Receiver Antenna on BPD Radio Tower

Unfortunately, Volpe was unable to establish a link between the two sites on any frequency. Volpe took down the transmitter from Rock Junction and set it up in various locations throughout Brunswick to determine the actual range of this environment. It was determined that distances much beyond one-half mile resulted in limited connectivity with frequent outages.

Volpe removed the TV white space receiver and antenna from BPD and traded in the receiver module for an “up-tower” receiver so that it could be deployed at on the pole at Jordan Avenue, which is only 1,000 feet away from Rock Junction. The transmitter was reinstalled at Rock Junction with the antenna pointed toward Jordan Avenue. Video from Rock Junction was then transmitted to BPD with the Jordan Avenue video via the Comcast service. This configuration, combined with improved communication protocol settings, resulted in good performance for over a year.

In 2019, to prepare the system for turnover to BPD, Volpe wanted to eliminate the Comcast service. The Town of Brunswick did not want to incur ongoing internet charges, so the decision was made to remove the Freeport cameras. Since the Brunswick Town Hall had a direct fiber link to BPD, it was determined that the TV white space receiver could be relocated there with an antenna on the roof. This would be capable of receiving data from both Rock Junction and Jordan Avenue. In 2019, Volpe purchased a second Carlson transmitter and antenna and installed it at Jordan Avenue, then moved the receiver from Jordan Avenue to Brunswick Town Hall. The Volpe research team encountered issues with the reliability of this second transmitter, which was returned to Carlson for repair, resulting in a delay in completing this project.

2.4 Sensor Modifications

The trespasser detection system relied on video motion detection (VMD) to detect ROW trespassers. The VMD software allows users to create “detection zones” in the camera’s field of vision (see Figure 9). Trespass alarms would be sounded when movement was detected in those zones. However, the AXIS system generated numerous false alarms.

Figure 9 – AXIS VMD Configuration for Jordan Ave. North

Analysis by Volpe and BPD determined the fixed cameras had an anomaly that produced the false alarms. Every few minutes, each camera would adjust its aperture, temporarily darkening and lightening its image. All of the cameras were prone to false alarms to some degree. Volpe speculated this anomaly could be due to power fluctuations. Volpe considered the following potential solutions:

- Deploy a power conditioning system to each of the camera sites.
- Replace the cameras with fixed aperture cameras.
- Choose and install a different type of sensor.

Volpe opted for the third option, to select and install different sensors, since it was not certain that power fluctuations were the cause of the aperture adjustments. Also, even if power fluctuations were the cause, some false alarms would likely remain due to camera shake (the poles were not as rigid as expected and they tended to sway in the wind). In addition, vegetation along the ROW grew each season, and either the vegetation had to be cut back, or the detection zones be redrawn as it grew. Instead, Volpe decided to purchase different trespasser detection sensors and deploy them to determine the effectiveness of each.

At Jordan Avenue, Volpe deployed two sensors from Optex: the SIP-100 and the SIP-5030. These outdoor passive infrared sensors were essentially the same, combining a close-range sensor with a mid-range sensor. The SIP-100 also included a third, long-range sensor that could detect objects up to 100 feet away. The long range sensor's field of view was also only 10 feet wide. Figure 10 shows the Jordan Avenue equipment pole with the Optex sensors installed.

Figure 10 – Jordan Avenue Pole with Optex Sensors

In spite of repeated tuning and adjusting, these sensors also produced false alarms at a rate similar to the VMD sensors (at least several times per hour). Volpe then considered using a sensor similar to that used in the Pittsford project, which was shown to produce fewer false alarms. In the end, BPD expressed a disdain for any false alarms in their dispatch center, and expected they would continue to mute the alert for all sensors, so Volpe did not continue further sensor testing.

2.5 Mobile Cameras

One of the shortcomings identified with this trespasser detection system is that the cameras and sensors were in fixed locations, which could not detect trespassers traveling elsewhere along the tracks. To address this concern, FRA and BPD decided to test the concept of a mobile camera. The Volpe research team purchased an unmanned aerial vehicle (UAV) (a "drone") and trained BPD officers in its use. Shortly afterward, FRA decided to break out UAV trespass detection as a separate research effort; results of that work will be provided in a recent FRA report, "Trespasser Detection on Railroad Property Using Unmanned Aerial Vehicles."

2.6 Equipment Summary

Table 2 below lists the equipment and services tested at each of the selected locations over the course of this project. In some cases, more than one technology was tested.

Table 2 - Equipment at Each Remote Location

Location	Rock Junction	Jordan Avenue	Freeport Station ROW
Cameras	•(2)-AXIS Q1765 fixed •(1)-AXIS Q6045 PTZ	•(2)-AXIS Q1765 fixed •(1)-AXIS Q6045 PTZ	•(2)-AXIS Q1765 fixed •(1)-AXIS Q6045 PTZ
Two-way audio	AXIS P8221	AXIS P8221	AXIS P8221
Microphone	ETS SM1-WBE	ETS SM1-WBE	ETS SM1-WBE
Speaker	Speco SPC-10	Speco SPC-10	Speco SPC-10
Mounting	New 12' pole	New 12' pole	Exiting light pole
Power source	Pan Am bungalow	Municipal sign pole	Freeport station
Connection to network	• Verizon Wireless • Carlson RuralConnect to Jordan Avenue's internet • Carlson RuralConnect to Town Hall fiber	• Verizon Wireless • Comcast internet • Carlson RuralConnect to Town Hall fiber	• Town-shared cable internet • Project-dedicated cable internet
Connection between cameras and internet router	Direct Cat5 cable	Direct Cat5 cable	FM-PONTE-50 wireless bridge
Trespasser detection sensors	• Video motion detection	• Video motion detection • Optex SIP-100 • Optex SIP-5030	• Video motion detection
Delivery of video to Brunswick PD	• Oxford Networks cable internet • Town of Brunswick fiber	• Oxford Networks cable internet • Town of Brunswick fiber	• Oxford Networks cable internet

3. Conclusion

The trespasser detection system Volpe deployed in Brunswick and Freeport, Maine yielded several findings in current wide-area surveillance technologies, including:

- The wireless broadband communications module initially used in this system did not have the bandwidth required for transmitting full high-definition video from multiple cameras during all times of the day. Even after limiting the resolution and frame rate, there were disruptions at times due to high utilization of limited local wireless capacity by the general public. It was not known if this condition would occur in other locations with different cellular infrastructure.
- There was still no ideal outdoor sensor for detecting trespassers. Video motion detection and passive infrared both had limitations and produced false alarms. Sensor deployment at any location requires tuning and adjusting devices to minimize false alarms, and some may require the masking of alarms caused by trains.
- Terrestrial high-speed internet service (in this case from a local cable television provider) provided the most reliable connectivity for high-bandwidth devices located in remote locations where there is no line-of-sight.
- TV white space technology, designed for providing network connectivity where there is no line-of-sight, currently has limited range but works reliably within one-half mile.
- The current state-of-the-art in closed circuit television is full high-definition 1080p streaming video from IP-based network cameras. The cameras used in this project worked reliably in places where there was access to high-speed networks.

Integrating the trespasser detection system into a police dispatch center had both pros and cons over integrating it with a private security monitoring service, as was done in the Pittsford trespass detection project. Pros included a more rapid law enforcement response and better technical support for the system. Cons included a lower tolerance for false alarms than private security services, resulting in a tendency for alarms to be muted when they became too frequent.

4. References

DaSilva, M.P., Baron, W., and Carroll, A. Railroad Infrastructure Trespassing Detection Systems Research in Pittsford, New York [DOT/FRA/ORD-06/03]. Washington, DC: U.S. Department of Transportation.

Federal Railroad Administration, Office of Safety Analysis. Accident Data as reported by Railroads. Accessed January 23, 2020.

Abbreviations and Acronyms

Abbreviation or Acronym	**Name**
AVL	Automated Vehicle Location
BPD	Brunswick Police Department
FRA	Federal Railroad Administration
GHz	Gigahertz
HRI	Highway-Rail Intersection
Mbps	Megabits per second
RD&T	Research, Development and Technology
ROW	Right-of-Way
SIM	Subscriber Identification Module
UAV	Unmanned Aerial Vehicle
VMD	Video Motion Detection
Volpe	John A. Volpe National Transportation Systems Center