RESEARCH & DEVELOPMENT

# Rail Corridor Trespass Severity Assessment

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Abstract

This research project builds on NCDOT RP 2015-18 ("Reduction in Railroad Right-of-Way Incidents"). For NCDOT RP 2015-18, the research team analyzed Federal Railroad Administration (FRA)-reported trespassing incidents along the 174-mile North Carolina Railroad (NCRR)/Piedmont corridor between Raleigh and Charlotte, NC using strike rates, Amtrak train crew surveys, and geospatial methods to identify communities with the highest risk of railroad right-of-way trespass. Since the FRA started geolocating trespass data in July 2011 through June 2016, this corridor had 65 reported trespasser strikes, or an average of one strike for every 677 trains. Based on an analysis of historic trespass strike data, associated environmental features, and survey data provided by Amtrak train crews who travel along the portion of the NCRR under study, the communities with the highest trespass risk were identified as Durham, Mebane, Elon/Burlington, and Greensboro. The rate of strikes from the 5 year study period indicated that these communities have the highest risk corridors. The close proximity of pedestrian generators to the railroad in these areas shows some correlation to the high number of strikes.

The NCDOT Rail Division currently has no baseline data on the universe of trespassing along the railroad right-of-way in North Carolina beyond limited data on trespass incidents resulting in fatalities and injuries as reported by railroads and the FRA. Using the hotspot locations identified in NCDOT RP 2015-18, NCDOT RP 2017-15 ("Rail Corridor Trespass Severity Assessment") seeks to provide an estimate of the universe of trespassing within the Piedmont corridor via a pilot of static and dynamic thermal video detection.


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## 1. BACKGROUND AND RESEARCH NEED

Addressing trespassing along railroad rights-of-way (ROW) is a leading priority for the Federal Railroad Administration (FRA). Trespassing is the leading cause of rail-related deaths in the United States, with 553 trespass-related fatalities reported in 2017 alone compared to 271 highway-rail fatalities for the same period.[1] This represents a 10-year high and an 18.6% increase from the previous year. Based on 2016 FRA statistics, North Carolina ranks the 8th state in the nation for pedestrian rail trespass casualties, with 23 deaths and 12 injuries reported for the year alone out of 994 casualties for the nation in total.[2] For the 5-year period from January 2011 through December 2016, 97 pedestrians have been killed while trespassing along the railroad right-of-way in North Carolina.[3]

This research project builds on NCDOT RP 2015-18 ("Reduction in Railroad Right-of-Way Incidents"). For NCDOT RP 2015-18, the research team analyzed FRA-reported trespassing incidents along the 174-mile North Carolina Railroad (NCRR)/Piedmont corridor between Raleigh and Charlotte, NC using strike rates, Amtrak train crew surveys, and geospatial methods to identify communities with the highest risk of railroad right-of-way trespass. Since the FRA started geolocating trespass data in July 2011 through June 2016, this corridor had 65 reported trespasser strikes, or an average of one strike for every 677 trains. Based on an analysis of historic trespass strike data, associated environmental features, and survey data provided by Amtrak train crews who travel along the portion of the NCRR under study, the communities with the highest trespass risk were identified as Durham, Mebane, Elon/Burlington, and Greensboro. The rate of strikes from the 5 year study period indicated that these communities have the highest risk corridors. The close proximity of pedestrian generators to the railroad in these areas shows some correlation to the high number of strikes.

The NCDOT Rail Division currently has no baseline data on the universe of trespassing along the railroad right-of-way in North Carolina beyond limited data on trespass incidents resulting in fatalities and injuries as reported by railroads and the FRA. Using the hotspot locations identified in NCDOT RP 2015-18, NCDOT RP 2017-15 ("Rail Corridor Trespass Severity Assessment") seeks to provide an estimate of the universe of trespassing within the Piedmont corridor via a pilot of static and dynamic thermal video detection.

From August 2017 through September 2018, static thermal video data collection was conducted a sample of trespassing hot spots along the corridor. The hotspots included those identified in NCDOT RP 2015-18 and were located in the communities of Durham, Elon, Mebane, Greensboro, and Salisbury, NC. At least one week of 24/7 video data was collected in each seasonal quarter at each hot spot. The hot spots were selected based on FRA incident data and Amtrak train crew surveys. The video data were reduced by coding attributes for each trespassing event, including time of day, duration, direction of travel, whether the trespasser is alone or in a group, group size, whether the trespasser crossed the tracks or traveled along the tracks, and basic information about the trespasser's activity (walking, standing, sitting, laying). A notes field captured additional information not covered by the standardized fields, such as whether the trespasser was a child, riding or pushing a bicycle, walking a dog, carrying something, or anything else unusual or of note. Fundamentally, the final dataset provides a count of trespassing events for the data collection time periods and provides an estimate of the trespassing frequency at the hotspots.

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[1] Federal Railroad Administration Office of Safety Analysis. **Trespasser Causalities.** Trespasser fatality data for 2016/2017 retrieved from https://safetydata.fra.dot.gov/officeofsafety/publicsite/query/castally4.aspx.

[2] Operation Lifesaver. **Trespassing Casualties by State.** https://oli.org/about-us/news/statistics/trespassing-fatalities-by-state. Accessed November 7, 2017.

[3] Federal Railroad Administration Office of Safety Analysis. **Trespasser Casualties Query Tool.** https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/castally4.aspx. Accessed November 7, 2017.

A second component of the research involves the development of a dynamic camera system for detecting trespassing events, including near-strike events, from a moving locomotive. The prototype camera system is in the piloting phase. Testing on NC State University's campus and on a controlled corridor in Star, NC owned by Aberdeen, Western, & Carolina Railroad has been completed.

The results of this project can be leveraged at multiple levels. At the local level, data collected at the hot spot locations will provide up-to-date information on the characteristics and frequency of trespassing events. This information can be used by local law enforcement and municipal officials to inform targeted educational initiatives and interventions to prevent trespassing by pedestrians along the railroad right-of-way which will ultimately reduce injuries and deaths that may occur from these events. At the state level, data-driven analyses that describe and estimate trespass events can be used to more accurately estimate costs related to strikes and near-strikes, including maintenance and delays, and to evaluate the effectiveness of NCDOT Rail Division's safety programs, including but not limited to the BeRailSafe program, by informing NCDOT Rail Division staff on when, where, and how trespassing events are taking place. At the national level, this research provides a model for scientifically assessing pedestrian trespassing on the railroad right-of-way by through static and dynamic video detection technology. Overall, the data and guidance that result from this project will be long term resources for educating colleagues, citizens, and public figures on the extent of trespassing along the railroad right-of-way and informing initiatives for reducing its occurrence.

## 2. LITERATURE REVIEW

Addressing trespassing along railroad rights-of-way (ROW) is a leading priority for the FRA. Trespassing is the leading cause of rail-related deaths in the United States, with 553 trespass-related fatalities reported in 2017 alone compared to 271 highway-rail fatalities for the same period.[4] This represents a 10-year high and an 18.6% increase from the previous year. In 2017, the FRA held a Grade Crossing Research Needs Workshop that established five research needs focus areas.[5] The top recommended action for the Community Outreach and Education focus area is trespasser identification, motivation, and messaging.[6] The goal of this action is to provide communities with tools for deterring trespassing, including better targeting of messaging based on demographics, geography, and reasons for trespassing. Achievement of this goal requires identifying types of and reasons for trespassing along with developing modes and methods to test messaging aimed at trespassers. The collection and analysis of quantitative event-based data is an important component for achieving this goal.

The FRA is the primary source for data related to the injury or death of trespassers on the railroad right-of-way. Under Title 49 Code of Federal Regulations (CFR) Part 225, railroad carriers are required to provide the FRA with accurate information concerning the hazards and risks that exist on railroads in the United States so that the FRA can effectively carry out its regulatory and enforcement responsibilities under the Federal railroad safety statutes.[7] Railroads are required to complete reports and records of accident/incidents in accordance with the current FRA Guide for Preparing Accident/Incident Reports.[8]

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[4] Federal Railroad Administration Office of Safety Analysis. **Trespasser Causalities.** Trespasser fatality data for 2016/2017 retrieved from https://safetydata.fra.dot.gov/officeofsafety/publicsite/query/castally4.aspx.

[5] Alibrahim, Sam. (2017). **FRA Grade Crossing Safety Research.** https://www.fra.dot.gov/conference/2017/rnw/pdf/Presentations/Other%20Sessions/FRA%20Accomplishments.pdf.

[6] Federal Railroad Administration. (2017). **Working Group Summary of Top Recommended Actions.** https://www.fra.dot.gov/conference/2017/rnw/pdf/Presentations/Other%20Sessions/Working%20group%20Summaries.pdf.

[7] Federal Railroad Administration. (2011). **FRA Guide for Preparing Accident/Incident Reports.** DOT/FRA/RRS-22.

[8] Ibid.

According to the FRA guide, the following definitions are used in reference to trespassing:

- Trespass: Any vehicle or pedestrian is deemed by the FRA to be trespassing if they are on the part of railroad property used in railroad operation and whose presence is prohibited, forbidden, or unlawful, including if
    - They are in the railroad right-of-way not at a designated crossing
    - They are in the railroad right-of-way at a designated crossing when the gates are down
- Trespass incident: A trespasser is struck or otherwise injured by rail equipment, resulting in a form being submitted to the FRA

While FRA incident reporting potentially provides a near-census of trespasser casualties on railroad right-of-ways in the United States, the dataset does not capture the universe of trespassing activities including those events that do not result in injury or death.

The FRA released a report in 2013[9] as an update to a 2008 study[10] that provided demographic profiles of deceased trespassers based on surveys sent to coroners/CMEs associated with the trespass fatalities. Further, the FRA released a report in July 2018 that presents a baseline measure of FRA trespassing and suicide incident data from 2012-2014 with information on populations and locations deemed at most risk for trespass and suicide.[11] These datasets do not include data for individuals who trespass but were not struck and killed or injured by a train, thus it provides only a partial view of the universe of trespassing activity. Further, since the studies sought national representativeness with demographics provided by FRA Region as the smallest geography, their aggregated results may not reflect local realities and thus may have limited utility for informing local countermeasures.

Some researchers have recognized the need to distinguish between the demographics and behavior of trespassers in general and those who sustain fatal or non-fatal injuries in order to expand the knowledge related to trespassing. One research report from the VTT Technical Research Centre of Finland (VTT) identified trespassing hotspots on Finnish railways by surveying locomotive engineers, investigated trespassing behavior and characteristics at the hotspots by counting and interviewing trespassers, and explored opinions about possible countermeasures.[12] The trespasser interview protocol employed in the study was based on a previous Canadian study[13] and focused on trespassers' movements in the rail right-of-way, their willingness to change their routes, their perceptions of the dangers of trespassing, their knowledge of trespassing laws, and their feedback on what would stop them from trespassing. Notable results from the trespasser surveys included:

- 80% of respondents indicated that the most common reason for trespassing was that the route was the shortest and fastest option
- Most trespassers were going shopping, jogging, or on their way to school or work

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[9] North American Management. (2013). **Rail Trespasser Fatalities: Demographic and Behavioral Profiles.** Report for the Federal Railroad Administration. North American Management (NAM), Alexandria, Virginia.

[10] George, B.F. (2008). **Rail Trespasser Fatalities: Developing Demographic Profiles.** Report for the Federal Railroad Administration. Cadle Creek Consulting, Edgewater, Maryland.

[11] Volpe National Transportation Systems Center. (2018). **Characteristics of Trespassing Incidents in the United States (2012-2014).** Federal Railroad Administration, USDOT. https://rosap.ntl.bts.gov/view/dot/36451/dot_36451_DS1.pdf.

[12] Silla, Anne and Juha Luoma. (2009). **Trespassing on Finnish railways: identification of problem sites and characteristics of trespassing behavior.** European Transportation Research Review. 1(1), 47-53.

[13] Law, W. (2004). **Trespassing on railway lines—a community problem-solving guide.** CD-ROM. In 8th International Level Crossing Symposium & Managing Trespass Seminar. Rail Safety and Standards Board, Sheffield.

- 35% of respondents trespassed daily; over half (67%) of respondents trespassed at least once per week
- Most respondents thought that fencing or an underpass/overpass were the best preventative measures for trespassing

A more recent VTT study took a different approach to understand localized trespassing activity by surveying people who live close to a railway line in an urban area in eastern Finland with high trespassing risk.[14] Findings from the study (n = 502) include:

- 89% of respondents reported that they had seen trespassing in their neighborhood
- 69% of respondents reported they had trespassed themselves, while 84% considered trespassing to be fairly or highly dangerous and 81% assumed it to be illegal
- Most respondents supported countermeasures such as fencing or an underpass and believed that it is possible to resolve trespassing

One component of a recent British study involved focus groups with young people (16-25 year olds) to determine their attitudes towards safety campaign videos that warn about the dangers of trespassing.[15] The findings from the focus groups (n = 117) indicated a general lack of awareness and understanding of the dangers surrounding railways among teenagers and young adults in the sample, including low awareness that trespassing is illegal and punishable by a fine and perceptions that trespass is a 'victimless crime' and 'similar to a road crossing.'

In recent years, researchers have studied and documented railroad trespassing events in various parts of the United States.[16,17] Data collected in these studies used static/fixed-base camera systems to detect pedestrian activity along rail corridors. Thermal/infrared systems can also be used for pedestrian detection including in trespassing scenarios. Thermal or infrared camera systems allow greater detection capability in lower pixel environments because heat signatures are more readily detectable than the color variations of standard cameras.[18]

Based on the literature and the research team's past research experience using various camera systems, the research team concluded that a thermal camera system supplemented with standard digital cameras would work best to optimize our detection capabilities. Additional details on the evaluation of specific detection technology used in this study are provided in the following section.

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[14] Silla, Anne and Juha Luoma. (2012). **Opinions on railway trespassing of people living close to a railway line.** Safety Science. 50(1), 62-67.

[15] Waterson, Patrick, et al. (2017). **Teenage trespass on the railways – a systems approach.** Proceedings of the Institution of Civil Engineers – Transport. 170(5), 287-295.

[16] Savage, I. (2007). **Trespassing on the Railroad.** Research in Transportation Economics: Railroad Economics. Volume 20(1), pages 199-224. Amsterdam: Elsevier Science.

[17] DaSilva, M.; Baron, W.; and Carroll, A. (2004). **Highway Rail-Grade Crossing Safety Research: Railroad Infrastructure Trespassing Detection Systems Research in Pittsford, New York.** Federal Railroad Administration, USDOT. https://trid.trb.org/view.aspx?id=795856.

[18] Torresan, H.; Turgeon, B.; Ibarra-Castanedo, C.; Hebert, P.; and Maldague, X. (2004). **Advanced Surveillance Systems: Combining Video and Thermal Imagery for Pedestrian Detection.** Proceedings Volume 5405, Thermosense XXVI; (/conference-proceedings-of-spie/5405.toc); doi:10.1117/12.548359.

# 3. METHODOLOGY

## 3.1. Static Thermal Detection System

### *3.1.1. Technology Evaluation*

The research team determined that thermal imaging would be necessary in order to capture movement at night and in rain or hazy environments. The team researched several thermal camera options. Only thermal cameras with motion detection capabilities were considered, since the ability to only record motion events would minimize the amount of video that needed to be manually reduced. The camera needed to be able to withstand the elements of being outdoors. The camera also needed to operate with relatively low power consumption, as it would be running off of DC power in the field and likely without the ability to be powered by the grid.

Unfortunately, testing a camera without purchasing it was not possible, so the research team decided on the most affordable camera that came from a recognized vendor – AXIS. AXIS provided technical support and detailed documentation on camera setup and usage that proved useful to the research team.

### *3.1.2. Description of Selected System*

The AXIS cameras selected for trespass detection are lower end thermal cameras with respect to the AXIS lines currently available that have thermal imaging capabilities, which reduced the costs to a small extent. The cameras are approximately 16 inches long when attached to a mount and the diameter of the camera housing is about four inches. The cameras have a weather shield that is attached from the factory to protect it from water and sunlight, although the cameras do have a waterproof rating of IP66. The cameras were strapped to a pole using a power drill and hose clamps that go through the mount.

The cameras can run on PoE (power over Ethernet) or by simply connecting a 12-volt power supply. Originally, a 20-watt solar panel was attached to a double 22 amp-hour battery array in order to keep the batteries charged. However, whereas this setup worked during initial testing in Durham, which was during the summer and on top of a parking deck, the research team quickly learned that this would not suffice during the winter and in areas potentially more obstructed from direct sunlight. Therefore, after trying a setup that included two 20-watt solar panels connected through a solar controller to three batteries, the team eventually chose the current setup of a single 70-watt solar panel attached to a solar controller for power regulation and three batteries.

For remote access to the camera, an Ethernet cable was used to connect the camera to a cellular modem, providing the research team with the ability to closely monitor the cameras as necessary. At project onset, the research team used 3G modems, which allowed for adequate remote viewing, but did not allow the team to quickly download the recorded videos. The research team eventually deployed 4G LTE modems with the camera systems that allow for relatively fast recording downloads and efficient, reliable remote access to the cameras.

All system components except for the cabling and the camera itself were housed in a plastic box that was locked in place during data collection. These components include the three batteries, the solar controller, and the cellular modem. The wires from these devices ran outside of the box and through conduit to the camera (power and Ethernet) and the two cellular antennas. A picture of two typical setups is shown below in Exhibit 1.

**EXHIBIT 1. TYPICAL STATIC THERMAL DETECTION SYSTEM SETUP**

#### *3.1.3. Pilot Testing*

The initial pilot test of the camera system was conducted outside of ITRE offices on NC State University's Centennial Campus on Capability Drive. This location was chosen for its straight line distance, regular presence of vehicles and pedestrians, and its proximity to ITRE offices. During pilot testing, researchers were able to better determine the camera's power consumption and range of detection. Only two 22 amp-hour batteries and a 20-watt solar panel were initially tested to determine how quickly the batteries were drained overnight when not being charged and how much the batteries recovered during the day from the small solar panel. It was determined that the batteries alone could only last about 1.5 days before failing. The addition of the 20-watt solar panel kept the batteries running indefinitely during seasons with longer periods of direct sunlight, such as late spring/early summer, and when it could be placed in direct sunlight. This power array was not sufficient during seasons with shorter periods of direct sunlight. The power array was upgraded to enable adequate power to the camera system throughout the year to account for the seasonal variability in the quantity of sunlight.

#### *3.1.4. Installation and Monitoring Procedures*

After the first few field installations, the research team developed an efficient camera system installation process with setup typically completed within 15 to 30 minutes. Installations were relatively simple and involved attaching the camera and mount to a pole near the observation area before powering up the devices sequentially – first, attaching the batteries to the solar controller, next attaching the solar panels to the solar controller, then powering up the cellular modem, and lastly powering up the camera. The team learned that the batteries must be connected to the solar controller first in order to prevent power surges to the batteries from the solar panels. Likewise, the team learned that the camera and modem would sometimes not communicate properly if the camera was powered on first. The box containing the batteries, cellular modem, and solar controller was locked to the pole using a steel cable and combination lock to complete the installation.

After installing the camera and securing the equipment, the research team inspected the video feed from the camera using the AXIS Companion application that comes with the purchase of an AXIS camera. Use of the application allowed for easy communication without the need for forwarding ports through IP addresses on the modem. Barring any communication errors between the camera and the cellular network, the video feed was viewed using either a mobile device or laptop with the AXIS Companion application. This process was used as needed to adjust the camera to ensure the appropriate viewing window.

The cameras were setup to record only when motion was detected. The preceding 5 seconds and following 30 seconds were also recorded to capture pre-event circumstances and to determine which direction trespassers were coming from and going towards. After installation of the camera system, the research team would use the AXIS Companion software to adjust the camera's exclusion area (Exhibit 2). The exclusion area is the area that the camera ignores when capturing motion events, shown as the area outside of the box shown in Exhibit 2.

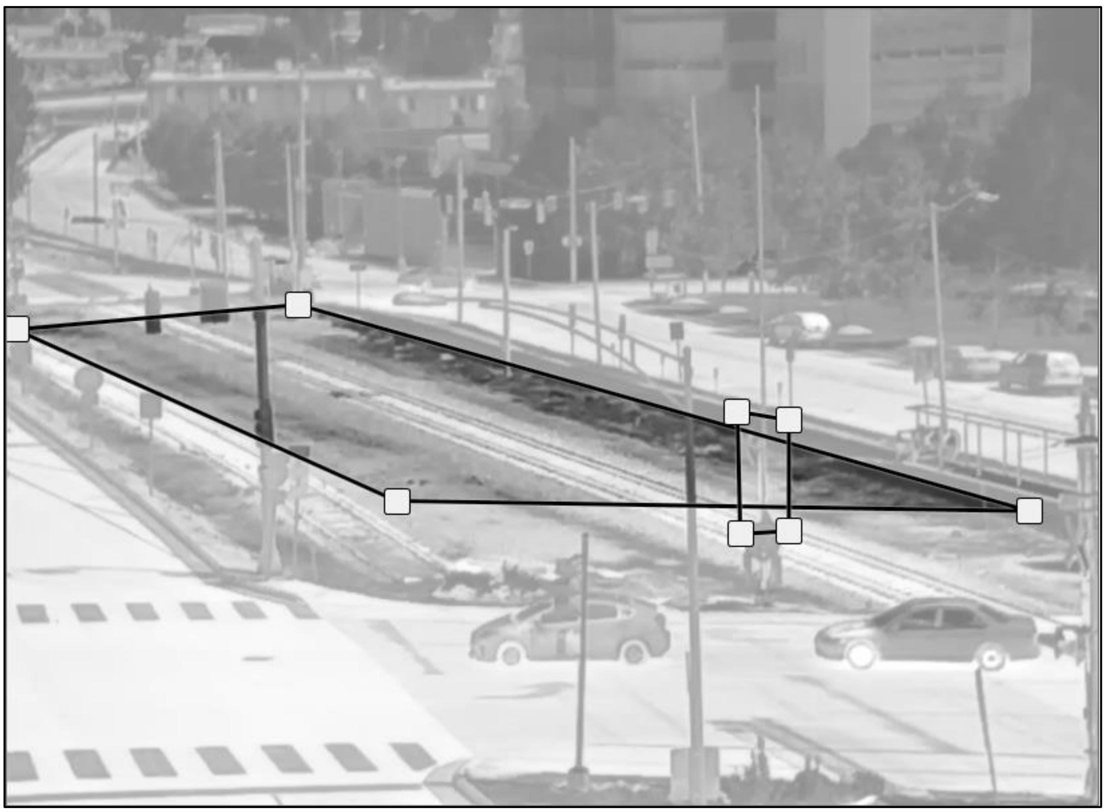


**EXHIBIT 2. EXAMPLE OF EXCLUSION AREAS DEFINED IN AXIS COMPANSION SOFTWARE**

Using the exclusion area setting allowed the team to minimize the area that was being observed for motion, thereby minimizing the amount of video that would have to be manually reduced by the research team after downloading the recorded video. Exhibit 3 provides an example of an event that would be captured (left) based on the exclusion area defined in Exhibit 2 and an event that would be ignored (right).

**EXHIBIT 3. CAPTURED EVENT (LEFT) AND IGNORED EVENT (RIGHT) BASED ON EXCLUSION SETTINGS**

Additional settings were available that are only accessible when directly connected to the camera using an Ethernet cable, but not remotely. These settings include the ability to ignore small objects (like animals), swaying objects (like trees or bushes), and short-lived objects (like birds). The research team chose not to ignore small objects to ensure the recording of people that were farther away, and thereby smaller in the video image. Likewise, the research team chose not to ignore swaying objects to ensure that the camera did not mistake a slow-moving person for a swaying object. However, the team did choose to ignore short-lived objects that were in the frame for less than 1 second since any person entering the railroad right-of-way would reasonably be in the frame for a longer duration.

### *3.1.5. Issues Encountered, Troubleshooting, Lessons Learned*

#### 3.1.5.1. Camera Setup

Early on in the process of setting up the camera for pilot testing, the research team experienced several issues related to direct and network access for the camera. These issues ultimately resulted from a misunderstanding of how the camera operated and the inexperience of the research team with highly complex IP cameras. Because of previous experience with networking using analog video and digital encoders and decoders, the team assumed that ports had to be forwarded through the cellular modem to allow access to the camera remotely. However, the team was unaware of the AXIS Companion software that bypassed this step completely and allowed for simple plug-and-play capability regarding remote access. Further, due to firewall protections that are common at universities, the research team was unable to directly access the camera even through hard-wired access during the first stages of testing. This issue was eventually resolved by utilizing cellular modems and laptops not connected to the university firewall. The final process of connecting either remotely or through hardwiring is very simple and quickly accomplished.

#### 3.1.5.2. Power Array

As mentioned previously, power consumption was initially difficult to accurately assess. As a result, it was difficult to determine the appropriate solar and battery array needed for the system. Through testing, the research team determined that three 22-amp-hour batteries and one 70-watt solar panel along with

10-15watt solar controllers was sufficient for operating the camera even during the winter. In addition, this setup was sufficient when there are several cloudy days in a row.

#### 3.1.5.3. Camera Malfunctioning

During the data collection period, cameras randomly malfunctioned. Malfunctions resulted in the loss of data recorded to the SD card inside of the camera. It is unclear what caused this issue, whether a power surge, inherent wiring issues inside of the camera, or something else. Multiple weeks of data were initially lost, but this problem was detected early enough that the research team was able to recover the data using either digital recovery software or by reinstalling the camera at the locations where the data was lost.

## 3.2. Dynamic Thermal Detection System

### *3.2.1. Technology Evaluation*

While the primary purpose of this research project was the development and deployment of a static, fixed-base thermal detection system, the research team also worked to develop and pilot a dynamic thermal detection system. Unlike the static system, the dynamic system is designed to be installed on a push-pull locomotive in order to capture trespassing events along and on the tracks in front of and behind the train while it moves on the corridor. The data captured from this effort would inform a more accurate estimate of near-strike events on corridors, while the data captured using the static system enables a more accurate estimate of trespassing frequency at hot spot locations.

The research team examined three camera systems for detection capabilities in a dynamic context. An assessment of each is provided in Exhibit 4. Based on a review of literature and past research experience using various camera systems including the development of the static system for trespass detection, the research team concluded that a thermal camera system supplemented with standard digital cameras would best optimize our detection capabilities when the system is attached to moving locomotive.

| Camera Type | Pros | Cons |
|---|---|---|
| **Standard Digital Camera** | • Good color quality<br>• Good resolution<br>• Less expensive<br>• Light | • Can only be used during day<br>• Detecting trespassers during post processing is difficult (especially at night) |
| **IR Camera** | • Can be used during day and night<br>• Less expensive<br>• Light | • Color quality poor during day<br>• Requires IR LED arrays to see in the dark<br>• Detecting trespassers during post processing is difficult |
| **Thermal Camera** | • Videos are captured in heat map format<br>• Detect trespassers with recorded video easier<br>• Can see during day/night<br>• Does not need additional accessories for night vision | • Large range of cost<br>• Large range of size |

**EXHIBIT 4. ASSESSMENT OF THREE CAMERA SYSTEM TYPES**

### *3.2.2. Description of Selected System*

The system concept, shown in Exhibit 5, is composed of a Raspberry Pi that allows several plug-in devices to provide or store data. The Pi is a small microcomputer, approximately 4”x 4” x 1,” which can be easily housed in a small storage container and powered by AC or DC power. A thermal and standard camera are plugged into the device to provide video inputs, and GPS and digital timestamp overlays are applied to the video to provide spatial and temporal data for future analysis. A hard drive is utilized for external storage in our current test that will allow our team to post-process video using various prototype algorithms; however, it is possible that the data will eventually be stored in a cloud-based system. An Arduino is used to transfer the GPS signal into usable data that is then overlaid onto the video. The various hardware components are described in more detail in Exhibit 6.

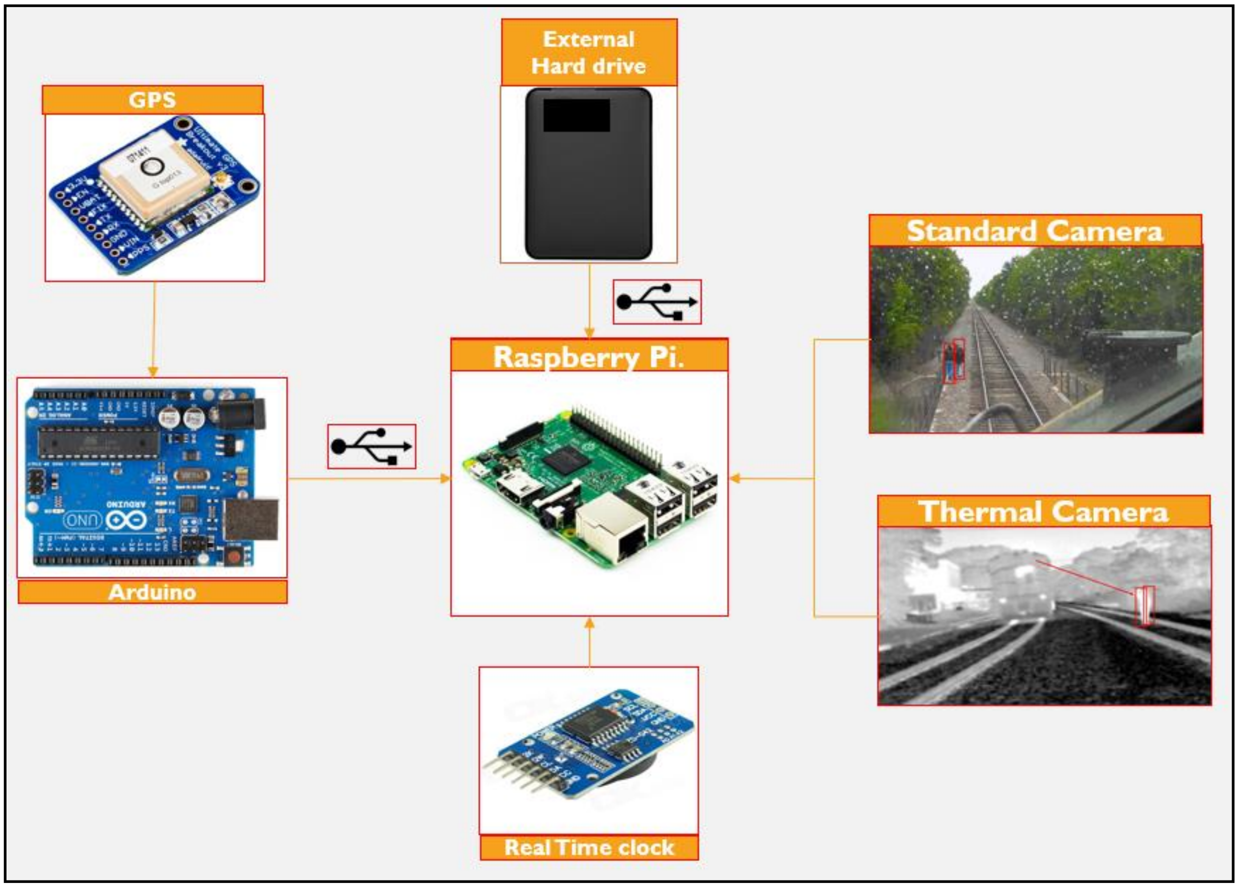



**EXHIBIT 5. DYNAMIC CAMERA SYSTEM COMPONENTS**

| Equipment | Specifications | Description |
|---|---|---|
| Raspberry Pi | • Quad Core 1.2 GHz processor with 1GB RAM<br>• Wireless LAN and Bluetooth Low Energy (BLE) on board<br>• 4 USB 2.0 ports, Ethernet and an HDMI port<br>• Memory size depends on SD card<br>• Can be powered by DC or AC power | • It is a mini computer<br>• It can perform parallel processing<br>• Multiple computer peripherals can be connected such as keyboard, mouse, monitor, etc.<br>• The Pi receives the GPS data through the Arduino and the video data from the camera and stores them in the hard drive |
| Arduino | • 14 digital I/O pins and 6 Analog I/O pins<br>• Memory size is 32KB<br>• Operates at 5y and powered by Pi | • Different sensors can be connected to these digital and analog I/O pins<br>• For example, the GPS mobile is connected to the digital pins |
| GPS | • 10 samples per second (10 Hz)<br>• Provides date, time, latitude, longitude, speed in real time<br>• Connects directly to satellites | • The GPS module connects to the Arduino<br>• Used for determining the location of the train and trespassing event<br>• The GPS data is overlaid on the video in real time |
| Real Time Clock | • Powered by 3V button cell that allows 2y of continuous use<br>• Works at a frequency of 10 Hz<br>• It is a time keeper | • Used to keep track of the Pi time when it is switched off<br>• Updates the system every time the Pi reboots<br>• Time and date is also overlaid on the video real-time |
| Hard Disk | • Memory size is 1TB<br>• Converted to New Technology File System (NTFS) format to store processed video data with overlay | • Connected to the Pi to store video |
| Camera | • 8MP infrared (IR) camera<br>• Wide viewing angle<br>• Maximum resolution of 1080p | • Used to capture trespassing events<br>• Nighttime use requires illumination through IR LEDs |

**EXHIBIT 6. DESCRIPTION OF DYNAMIC CAMERA SYSTEM COMPONENTS**

### *3.2.3. Pilot Testing*

At the time of this interim report, the research team has deployed the prototype system several times from the cab of a passenger vehicle for pilot testing purposes. Exhibit 7 provides the results of overlaying the video imagery with spatial and temporal information. Exhibit 8 shows how the data captured with the GPS is stored in a .CSV file and can be plotted to display the position and movement of the camera. Overall, the system components linked together nicely and are very reasonably priced for a total system cost of less than $500. However, the research team learned that the camera system that is deployed has a wide range of variability in detection.


**EXHIBIT 7. VIDEO IMAGE WITH SPATIAL AND TEMPORAL OVERLAY**

| Date | Time | Latitude | Longitude | Speed |
|---|---|---|---|---|
| 2/15/2018 | 11:28:23 | 35.788645 | -78.648728 | 11 |
| 2/15/2018 | 11:28:24 | 35.78864 | -78.648758 | 6 |
| 2/15/2018 | 11:28:25 | 35.788637 | -78.648773 | 3 |
| 2/15/2018 | 11:28:26 | 35.788635 | -78.648785 | 3 |
| 2/15/2018 | 11:28:27 | 35.78863 | -78.648802 | 5 |
| 2/15/2018 | 11:28:28 | 35.788615 | -78.648822 | 9 |
| 2/15/2018 | 11:28:29 | 35.788582 | -78.648838 | 13 |

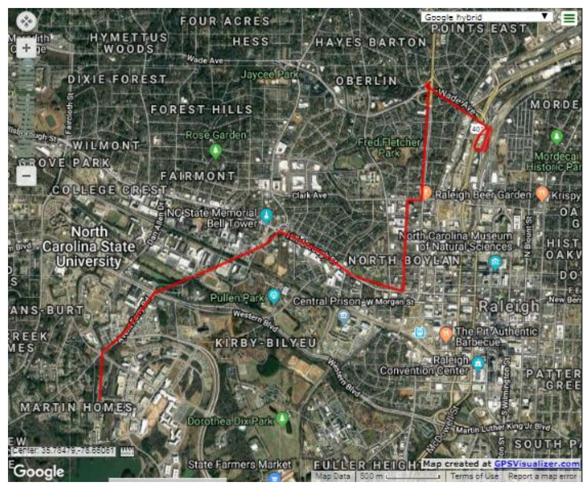



**EXHIBIT 8. GPS DATA STORED IN .CSV FORMAT (LEFT); PLOTTED GPS DATA (RIGHT)**

The ability to capture pedestrian events during day and night without being dependent on light and the possibility of improving the detection algorithm using heat signatures (which are not available in IR or standard cameras) led the research team to test the thermal camera as a stand-alone capturing device. One minor drawback would be the absence of spatial data in the overlay. The research team tested the AXIS camera system used for static detection under dynamic conditions in a variety of scenarios along a two-mile stretch of rail in Star, North Carolina. This test provided a rich video-based dataset with which to develop machine learning algorithms. Exhibit 8 provides a snapshot from both camera views (standard and thermal) for one subject scenario of 32 possible scenarios.

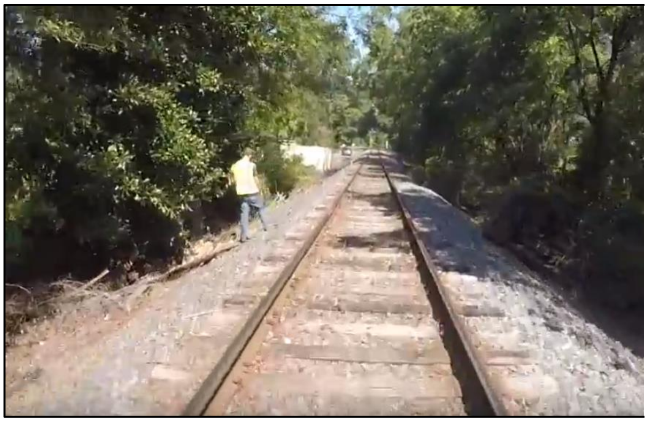



**EXHIBIT 9. FORWARD-FACING VIEW FROM STANDARD CAMERA (LEFT); FORWARD-FACING VIEW FROM AXIS THERMAL CAMERA (RIGHT)**

The research team has future plans to train a pedestrian detection algorithm with the training dataset and validate the algorithm with test data.[19] Through the experiment in Star, NC, the research team gathered the dataset to validate future algorithms being developed. This dataset looks at the factors and associated levels shown in Exhibit 10 for both a forward and rear facing thermal camera arrangement using four subjects along a 2-mile section of rail. As part of future research efforts, the research team intends to collect similar datasets and begin developing the necessary algorithms to capture trespassing events in real time.

| Factor | Levels |
|---|---|
| Direction of travel | Away from Train, Towards Train, Stationary |
| Distance to redirect from travel path | 200’, 600’ |
| Time frame to continue after train passes | 1 second, 5 seconds |
| Direction of travel after train passes | Away from Train, Towards Train, Cross Perpendicular |
| Section type | Straight or Curve |
| Lighting type | Direct sun, shade, nighttime (not included in this dataset but will in later versions) |

**EXHIBIT 10. EXPERIMENT DESIGN FACTORS AND ASSOCIATED LEVELS**

### *3.2.4. Issues Encountered, Troubleshooting, Lessons Learned*

The main reason Arduino was used was due to the poor serial terminal connection that Raspberry possesses. Therefore, the GPS was connected serially to the Arduino and the Arduino was connected to the Pi through USB. The time format from the GPS is in Greenwich Mean Time (GMT), which is then converted into Eastern Standard Time, similarly speed is provided in knots, which is converted to miles per hour (mph). The main drawback of the GPS would be during cloudy days, where the GPS update rates are poor and sometimes it would fail to make a connection/fix with satellites. In addition, the Raspberry pi heats up after an hour or so due to continuous powering of the Arduino and the hard drive, but continues to work. The drawback of the NoIR camera is that it adds another component to the device setup as it requires a large IR LED hub to illuminate the scene in front of the train as the Train head

[19] P. Doll´ar, C. Wojek, B. Schiele, and P. Perona. **Pedestrian detection: A benchmark.** In Computer Vision and Pattern Recognition, 2009. CVPR 2009. IEEE Conference on, pages 304–311. IEEE, 2009

lamp might not give a clear image. With all these above mentioned resolved and unresolved problems, the research team realized that it is important to have a stable and reliable device rather than a low cost system for the pilot deployment of the dynamic thermal detection system. Future efforts will focus on the deployment of a higher end AXIS thermal camera with artificial intelligence (AI)/machine learning applications overlaid. We will revisit the system as a whole at a later date once we confirm AI is possible.

## 3.3. Data Collection

### *3.3.1. Site Selection*

This section of the report documents the methodology and results for identifying and selecting "hot spot" locations for static thermal video detection within the 170-mile Piedmont corridor from Raleigh to Charlotte. Site selection was informed by examining several secondary data sources, including FRA trespasser incident data for the most recent five-year period for the Piedmont corridor, FRA train volume data and U.S. Census Bureau population data to identify high strike rate areas, Piedmont Amtrak train crew surveys administered in May 2015, and environmental characteristics using aerial imagery in a GIS.

This section also summarizes the video data collection plan based on the site selection results. The data collection plan was designed to capture at least one week of 24/7 video data at each site in each season of the year (Winter, Spring, Summer, Fall) and involved rotating the equipment between the "hot spot" locations during the period of study. The "hot spot" locations included in the study were Durham, Greensboro, Mebane, Elon, Charlotte, and Salisbury.

#### 3.3.1.1. Evaluation of Secondary Data Sources

Several data sources were used to identify "hot spot" locations for trespassing along the railroad right-of-way for the entire North Carolina rail network. Federal Railroad Administration (FRA) trespasser incident data for the five-year period from 2013-2017 were downloaded from the FRA's online database.[20] A trespasser incident describes when a trespasser is struck and killed or otherwise injured by rail equipment resulting in an incident report being submitted to the FRA. Any vehicle or pedestrian is deemed by the FRA to be trespassing if: 1) they are in the right of way not at a designated crossing or 2) if they are in the right of way at a designated crossing when the gates are down. Trespasser incidents were extracted from the total incident dataset and those that were identified as being located within 150 feet of the Piedmont corridor were displayed in a GIS to examine geospatial clustering of the incidents (Exhibit 11). A total of 65 trespasser incidents (causalities) were identified for the most recent five-year period at the time of site selection (July 2011-June 2016).

FRA train volume data was used in combination with the FRA trespasser incident data for the five-year period to calculate the strike rate for 1-mile, 3-mile, 5-mile, and 10-mile windows along the Piedmont corridor. Population data by U.S. Census tract from the Decennial Census[21] were used to calculate the number of strikes per 1,000 people living within one quarter mile of the rail. These results were compared to observations from Amtrak Piedmont train crews collected through a survey administered in

[20] Federal Railroad Adminstration Office of Safety Analysis. **Accident Data as Reported by Railroads, 2011-2016.** Retrieved from https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/on_the_fly_download.aspx.
[21] U.S. Census Bureau, Census 2010, Summary File 1, Total Population.

May 2015 and completed by six train crews. In their surveys, the train crews identified areas on the corridor by milepost where trespassing activity has been observed.

Additional geospatial data were gathered for the high strike rate locations from the U.S. Census Bureau, North Carolina county parcels, and FRA datasets, as well as a corridor video review. Count variables such as grade crossings, passenger stations, public schools, colleges/universities, and commercial services were divided by the window length to obtain counts per mile. Detailed data descriptions, analyses, and results are provided in the project final report for NCDOT 2015-18.[22]

Aerial imagery were also used to investigate environmental evidence of trespassing activity at locations where the FRA trespass incidents were clustered. Evidence included desire lines such as informal footpaths along and/or across the railroad right of way, particularly where attractors (e.g., housing, businesses, social/recreational areas) are separated by rail corridors.

Based on the analysis of the historic FRA trespasser incident data/strike rates, associated environmental features, and survey data provided by Amtrak Piedmont train crews, the communities identified with the highest trespassing risk were Durham, Mebane, Elon/Burlington, and Greensboro. Population density and the close proximity of attractors to the railroad track in these areas correlates with higher numbers of strikes.

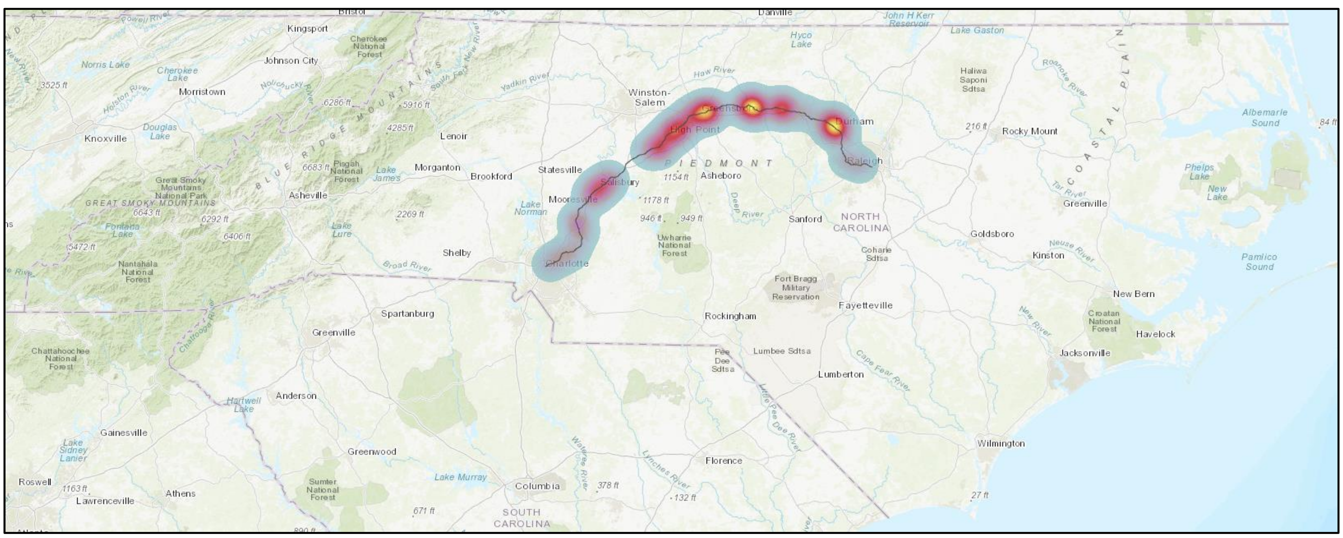



**EXHIBIT 11. FRA TRESPASSER INCIDENTS (2011-2016) HEAT MAP FOR THE PIEDMONT CORRIDOR FROM RALEIGH TO CHARLOTTE, NC**

[22] NCDOT. **Reduction in Railroad ROW Trespassing Incidents.** https://connect.ncdot.gov/projects/research/Pages/ProjDetails.aspx?ProjectID=2015-18.

#### 3.3.1.2. Description of Selected Sites

Based on an evaluation of secondary data sources, ITRE identified six locations on the Piedmont corridor from Raleigh to Charlotte as data collection sites (Durham, Greensboro, Elon, Mebane, Charlotte, and Salisbury). These locations are described below in Exhibit 12.

| Site Number | Latitude | Longitude | Town/ City | Site Description |
|---|---|---|---|---|
| 31-1 | 35.99461 | -78.90190 | Durham | Four historic strikes within 0.25 mi of this location from 2012, 2014, and 2015; marked as a corridor of concern on Amtrak Piedmont train crew surveys; unfenced along entire stretch that bisects downtown Durham. Possibly a short cut to destinations on either side of tracks. |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Marked as a corridor of concern on Amtrak Piedmont train crew surveys; short cut to social services and downtown area from neighborhood to the south; obvious informal path that crosses through the railroad right-of-way. |
| 00-1 | 36.10044 | -79.50804 | Elon | Frequent trespassing activity according to Amtrak Piedmont train crew surveys; low number of strikes according to FRA trespasser incident data; university housing, businesses, and academic buildings are attractors on both sides of the railroad right-of-way. |
| 67-1 | 36.09700 | -79.27110 | Mebane | Four historic strikes within 0.25 mi of this location from 2011, 2014, 2015, and 2016; marked as a corridor of concern on Amtrak Piedmont train crew surveys; short cut from housing to the south to Tommy's MiniMart and downtown Mebane to the north. |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Frequent trespassing activity according to Amtrak Piedmont train crew surveys; three historic strikes within one mile of this location from 2014 and 2015. |
| 59-1 | 35.25822 | -80.77337 | Charlotte | Frequent trespassing activity according to Amtrak Piedmont train crew surveys; no historic strikes within one mile of this location between 2011-2016. |

**EXHIBIT 12. SUMMARY OF SELECTED SITES**

#### 3.3.1.3. Site Visits and Camera Installation Locations

The ITRE research team initially inspected each location in a GIS to determine feasible camera installation locations. The team then visited each of the six locations to further evaluate their viability, including examining environmental conditions and finalizing camera installation points. NCDOT Rail Division staff coordinated with stakeholders in each community to share information about the research project and to secure permissions to install the thermal camera systems. A summary of the camera installation locations for each data collection site is provided below in Exhibit 13.

| Site Number | Latitude | Longitude | Town/ City | Camera Install Location |
|---|---|---|---|---|
| 31-1 | 35.99461 | -78.90190 | Durham | Railing along the south side of the Corcoran Street parking garage roof; camera detected activity south across the corridor between Ramseur Street and Vivian Street. |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Lamp post on the eastern side of the secondary Amtrak platform; camera detected activity down the corridor towards the informal path between E. Washington Street and Plott Street. |
| 00-1 | 36.10044 | -79.50804 | Elon | Rail radar detection pole at the intersection of W. Lebanon Avenue and North Williamson Avenue; camera detected activity west down the corridor towards Church Street. |
| 67-1 | 36.09700 | -79.27110 | Mebane | Rail radar detection pole at the intersection of South Third Street and East Washington Street; camera detected activity west down the corridor towards South 1st Street. |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Lamp post on the south side of the Amtrak platform; camera detected activity south across the corridor towards East Liberty Street. |
| 59-1 | 35.25822 | -80.77337 | Charlotte | Lamp post on the western side of the CATS station platform at Old Concord Road; camera detected activity south down the corridor towards Eastway Drive. |

**EXHIBIT 13. CAMERA INSTALL LOCATIONS BY SITE**

A map of the selected locations overlaid with a heat map of FRA trespasser incidents for the five-year period from July 2011-June 2016 is provided in Exhibit 14.

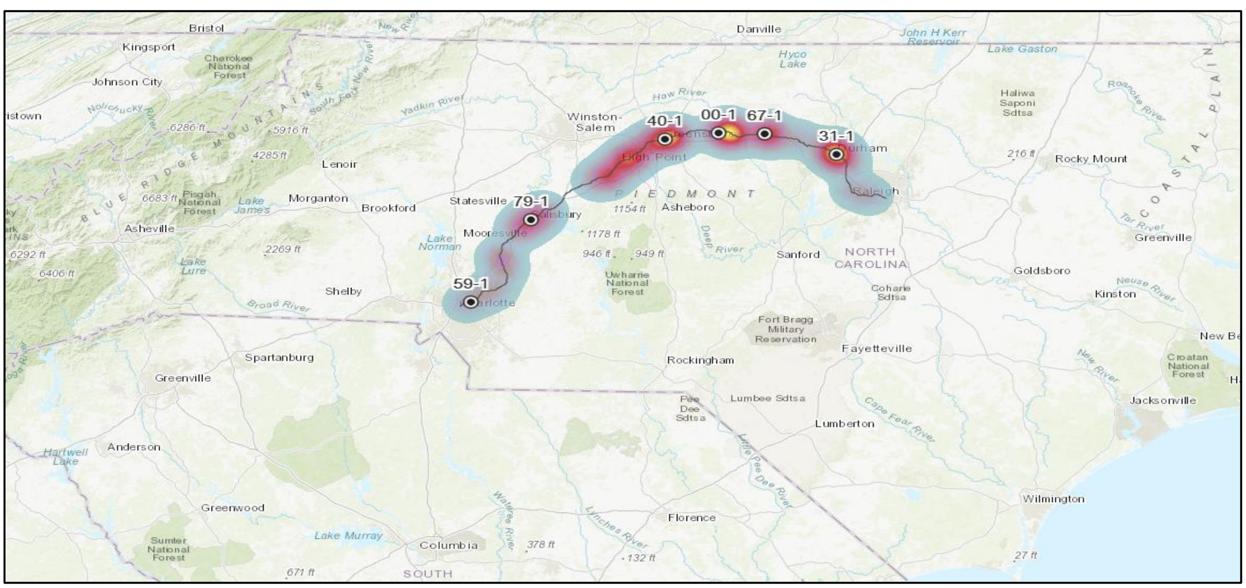



**EXHIBIT 14. SELECTED SITES WITH FRA TRESPASSER INCIDENTS (2011-2016) HEAT MAP AND PIEDMONT CORRIDOR**

### *3.3.2. Sampling Plan and Data Collection Schedule*

The final video data collection dates are provided below in Exhibit 15.

| Site Number | Latitude | Longitude | Town/City | Season | Year | Data Collection Dates |
|---|---|---|---|---|---|---|
| 31-1 | 35.99461 | -78.9019 | Durham | Fall | 2017 | Nov. 3 - Nov. 8; Nov. 30 - Dec. 8; Dec. 10 |
| 31-1 | 35.99461 | -78.9019 | Durham | Spring | 2018 | Apr. 2 - Apr. 11 |
| 31-1 | 35.99461 | -78.9019 | Durham | Summer | 2017 | Aug. 10; Aug. 11; Aug. 21 - Aug. 28 |
| 31-1 | 35.99461 | -78.9019 | Durham | Summer | 2018 | Jul. 31 - Aug. 10 |
| 31-1 | 35.99461 | -78.9019 | Durham | Winter | 2018 | Jan. 6 - Jan. 15 |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Fall | 2017 | Nov. 2 - Nov. 8; Nov. 10; Nov. 30 - Dec. 8; Dec. 10 |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Spring | 2018 | Jun. 11 - Jun. 30 |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Summer | 2017 | Sept. 12 - Sept. 21 |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Summer | 2018 | Jul. 1 - Jul. 11 |
| 40-1 | 36.06946 | -79.78339 | Greensboro | Winter | 2018 | Jan. 7 - Jan. 16 |
| 00-1 | 36.10044 | -79.50804 | Elon | Fall | 2017 | Nov. 11 - Nov. 21 |
| 00-1 | 36.10044 | -79.50804 | Elon | Spring | 2018 | May 22 - May 31; Jun. 1 - Jun. 30 |
| 00-1 | 36.10044 | -79.50804 | Elon | Summer | 2018 | Aug. 20; Aug. 21; Aug. 27 - Sept. 4 |
| 00-1 | 36.10044 | -79.50804 | Elon | Winter | 2018 | Jan. 19 - Jan. 31; Feb. 1 - Feb. 6; Mar. 1 - Mar. 30 |
| 67-1 | 36.097 | -79.2711 | Mebane | Fall | 2017 | Oct. 12 - Oct. 22; Nov. 11 - Nov. 21 |
| 67-1 | 36.097 | -79.2711 | Mebane | Spring | 2018 | May 3 - May 11 |
| 67-1 | 36.097 | -79.2711 | Mebane | Summer | 2018 | Jul. 11 - Jul. 20 |
| 67-1 | 36.097 | -79.2711 | Mebane | Winter | 2018 | Jan. 16; Jan. 18 - Jan. 31; Feb. 1 - Feb. 7 |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Fall | 2017 | Oct. 24 - Nov. 1 |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Spring | 2018 | May 11 - May 22 |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Summer | 2018 | Aug. 10 - Aug. 20 |
| 79-1 | 35.66734 | -80.46552 | Salisbury | Winter | 2018 | Feb. 9 - Feb 16 |
| 59-1 | 35.25822 | -80.77337 | Charlotte | Fall | 2017 | Oct. 23 - Nov. 1; Dec. 11 - Dec. 20 |
| 59-1 | 35.25822 | -80.77337 | Charlotte | Winter | 2018 | Feb. 8 - Feb. 14 |

**EXHIBIT 15. FINAL VIDEO DATA COLLECTION RESULTS BY SEASON WITH DATES**

Based on the site selection results, the ITRE research team created a video data collection plan. The data collection plan was designed to be cost-effective and time-efficient relative to the testing of the camera equipment and the rotation of the equipment between several locations during the period of study. Two camera systems were deployed to collect data for at least one week of 24/7 data collection at each site in each season (Winter, Spring, Summer, Fall).

Adequate time was budgeted between seasonal installs to allow for time to evaluate the data and to troubleshoot the camera systems, if needed.

### *3.3.3. Data Sources*

#### 3.3.3.1. Data Processing

Videos were downloaded from the static thermal detection systems remotely using AXIS Companion software at the end of each seasonal data collection period. The video clips were organized in folders on secure servers by date, season, and location. The video clips were also catalogued in an inventory file which documents and tracks the recording and data status (Exhibit 16).

| Recording Status | | | | | | | | | Data Status | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Angle | Season | Month | Camera | On Drive? | On SD Card? | Recovered? | Video Lost? | Analyzed? | Data Lost? |
| Durham | 1 - DPAC | Summer 2017 | August | 1 | Y | N | - | N | Y | N |
| | | Fall 2017 | November | 1 | Y | N | - | N | Y | N |
| | | | December | 1 | Y | N | - | N | Y | N |
| | | Winter 2018 | January | 1 | Y | N | - | N | Y | N |
| | | Spring 2018 | April | 1 | N | N | N | Y | Y | N |
| | | Summer 2018 | August | 2 | N | Y | - | N | Y | N |
| | 2 - ATT Deck | Summer 2017 | August | UK | Y | N | - | N | Y | N |
| | | | September | UK | Y | N | - | N | Y | N |
| Greensboro | 1 - Path | Summer 2017 | September | 1 | Y | N | - | N | Y | N |
| | 2 - AWOL | Summer 2017 | September | 1 | Y | N | - | N | Y | N |
| | | Fall 2017 | November | 2 | Y | N | - | N | Y | N |
| | | | December | 2 | Y | N | - | N | Y | N |
| | | Winter 2018 | January | 2 | Y | N | - | N | Y | N |
| | | Spring 2018 | April | 2 | N | N | N | Y | N | Y |
| | | | June | 2 | N | Y | - | N | Y | N |
| | | Summer 2018 | July | 2 | N | Y | - | N | Y | N |
| Elon | 1 - Tree | Summer (battery issues) | | 1 | Y | N | - | N | Y | N |
| | | Fall 2017 | October | 1 | Y | N | - | N | Y | N |
| | 2 - Radar pole | Fall 2017 | November | 2 | Y | N | - | N | Y | N |
| | | Winter 2018 | January | 1 | N | N | N | Y | Y | N |
| | | | February | UK | N | N | N | Y | Y | N |
| | | | March | 1 | N | N | N | Y | Y | N |
| | | Spring 2018 | May | UK | N | N | Y | N | Y | N |
| | | | June | 1 | N | Y | - | N | Y | N |
| | | Summer 2018 | August | 2 | N | Y | - | N | Y | N |
| | | | September | 2 | N | N | - | Y | Y | N |
| Mebane | 1 - Radar pole | Fall 2017 | October | 1 | Y | N | - | N | Y | N |
| | | | November | 1 | Y | N | - | N | Y | N |
| | | Winter 2018 | January | 2 | Y | N | - | N | Y | N |
| | | | February | 2 | Y | N | - | N | Y | N |
| | | Spring 2018 | May | 1 | N | Y | - | N | Y | N |
| | | Summer 2018 | July | 2 | N | Y | - | N | Y | N |
| Salisbury | 1 - Amtrack Station | Fall 2017 | October | 2 | Y | N | - | N | Y | N |
| | | Winter 2018 | February | 1 | Y | N | - | N | Y | N |
| | | Spring 2018 | May | 1 | N | Y | - | N | Y | N |
| | | Summer 2018 | August | 2 | N | Y | - | N | Y | N |
| Charlotte | 1 - CATS Station | Fall 2017 | October | 1 | Y | N | - | N | Y | N |
| | | | December | 1 | Y | N | - | N | Y | N |
| | | Winter 2018 | February | 2 | Y | N | - | N | Y | N |

**EXHIBIT 16. INVENTORY FILE FOR TRACKING RECORDING AND DATA STATUS**

#### 3.3.3.2. Data Coding

Once the video clips were downloaded, organized, and cataloged, trained data coders reduced the videos into individual trespassing events and their associated characteristics in a data coding workbook using the protocols in Exhibit 17.

# Rail Trespass Static Thermal Video Camera Data Coding: Quick Reference Guide

**For ITRE Project Team Members (updated: 11/13/2017)**

## 1 Locate Assigned Video Files

Each team member is assigned a batch of video files to code. Assignments are recorded and updated in a data entry log file located on the server: *\\Hwy348\hwystorage348\02_Videos\01_NCDOT\Rail Trespass* – file name:

**Rail Trespass Video Data Entry Log.xls**

Video files are in the same location on the server and are organized in subfolders by site name (Durham, Greensboro, Elon, Mebane, Charlotte, or Salisbury):

*[file pathway to video storage location]*

- **Review List of Assigned Videos:** Your supervisor will assign a set of video files for each team member to code. Each set of video files will be for one site/one camera angle/one season/one week of data.
- **Locate Assigned Video Files:** Locate your assigned video files in the appropriate subfolder by **site name>>>camera angle>>>season>>>date.**

## 2 Locate Data Coding Workbook

Each team member is provided a data coding workbook to record their coded observations. Data coding workbooks are located on the server: *H:\01-Projects\1-NCDOT\1808_Rail Trespass 2\05 - Data\Analysis Files* – file name:

**Rail Trespass_Static Data_*[data coder name]*.xls**

**Rail Trespass_Static Data_*[data coder name]*.xls**

**Rail Trespass_Static Data_*[data coder name]*.xls**

## 3 Open Assigned Video Files

The VLC Media Player is the most convenient program to view assigned video files. Add the video files for one day into a playlist using the following steps:

1. Open the VLC Media Player
2. Go to View>>>Playlist
3. Select all video files for a day from the appropriate folder on the server and drag/drop into the playlist box
4. Select the first video in the playlist
5. Click the Play button
6. The first video should begin playing; use the Pause, Skip Forward, and Skip Backward buttons in the lower left to navigate through the video clips

### ➤ Trespasser Event Coding

Each trespasser, whether traveling alone or in a group, should recorded in a separate row.

- Do not record pedestrians that cross at the legal at-grade crossing, if visible
- Assign each trespasser an appropriate Group ID **even if a trespasser is traveling alone**
- **Do not leave any field missing**

## 4 Update Data Entry Log

When you have finished your data coding work for the day, please update and save the data entry log with your progress.

- Enter your name and highlight yellow if the entry status for the data is **In Progress**
- Enter your name and highlight green if the entry status for the data is **Completed**

**EXHIBIT 17. DATA CODING PROTOCOLS FOR RAIL TRESPASSING EVENTS**

Descriptions for the fields captured from the video clips are provided in Exhibit 18.

➤ Data Coding Field Descriptions

The data coding workbook contains the following fields to be captured from the video files:

| Field Name | Field Description | Data Type |
|---|---|---|
| Site | Location name (Durham, Greensboro, Elon, Mebane, Charlotte, or Salisbury) | String |
| Camera Angle | 1 or 2 | Numeric |
| Date | Date of video (mm/dd/yyyy) | Date |
| Group (Y/N) | Is trespasser in a group? (Y/N) | String |
| Group ID | Numeric group ID beginning at 1 and continuous within site; every trespasser including single trespassers is assigned a group ID | Numeric |
| Enter ROW | Time that trespasser enters the railroad right-of-way (military time; hh:mm:ss) | Time |
| Enter Tracks | Time that trespasser enters the railroad tracks with boundary defined by the top of the rock bed (military time; hh:mm:ss) | Time |
| Exit Tracks | Time that trespasser exits the railroad tracks with boundary defined by the top of the rock bed (military time; hh:mm:ss) | Time |
| Train Arrival (If Applicable) | Time that train arrives (military time; hh:mm:ss); code NA if not applicable | Time |
| Exit ROW | Time that trespasser exits the railroad right-of-way (military time; hh:mm:ss) | Time |
| Activity | Trespasser activity coded as 1 (yes) or 0 (no); one or more may be applicable | Numeric |
| Direction Traveled | Direction that trespasser traveled coded as N (north), S (south), E (east), or W (west) | String |
| Crossed Tracks? | Did the trespasser cross the railroad tracks? (Y/N) | String |
| Travel Along Tracks? | Did the trespasser travel along the tracks? (Y/N) | |
| Min Distance from Tracks (Top of Rock Bed) | The minimum distance in feet that the trespasser was located from the tracks; code as 0 if the trespasser crossed the tracks | Numeric |
| Notes | Record any additional information about the trespasser that may be useful for characterizing their activity | String |

**EXHIBIT 18. DATA CODING FIELD DESCRIPTIONS**

One of the fields captured from the video clips denotes the minimum distance in feet that the trespasser in an event was located from the tracks. Acetate overlays with measured distances from the tracks in feet were provided to data coders to facilitate capturing data for this field. An example is provided in Exhibit 19.


**EXHIBIT 19. EXAMPLE OF DISTANCE OVERLAY FOR CAPTURING MINIMUM DISTANCE FROM TRACKS (IN FEET)**

### 3.4. Data Analysis

For the purposes of this interim report, a preliminary analysis was performed based on the trespassing event data captured over the period August 2017 – August 2018 for sites in Durham, Greensboro, Elon, Mebane, and Salisbury. Data collected at the Charlotte site was excluded from the analysis due to the impact of light rail track construction and associated fencing along the corridor which limited access to the railroad right-of-way. Data was also collected during an initial testing period in Summer 2017 in Durham and Greensboro that utilized different camera placements and angles than the primary placements and angles used for the official data collection period. These data are not included in the analysis.

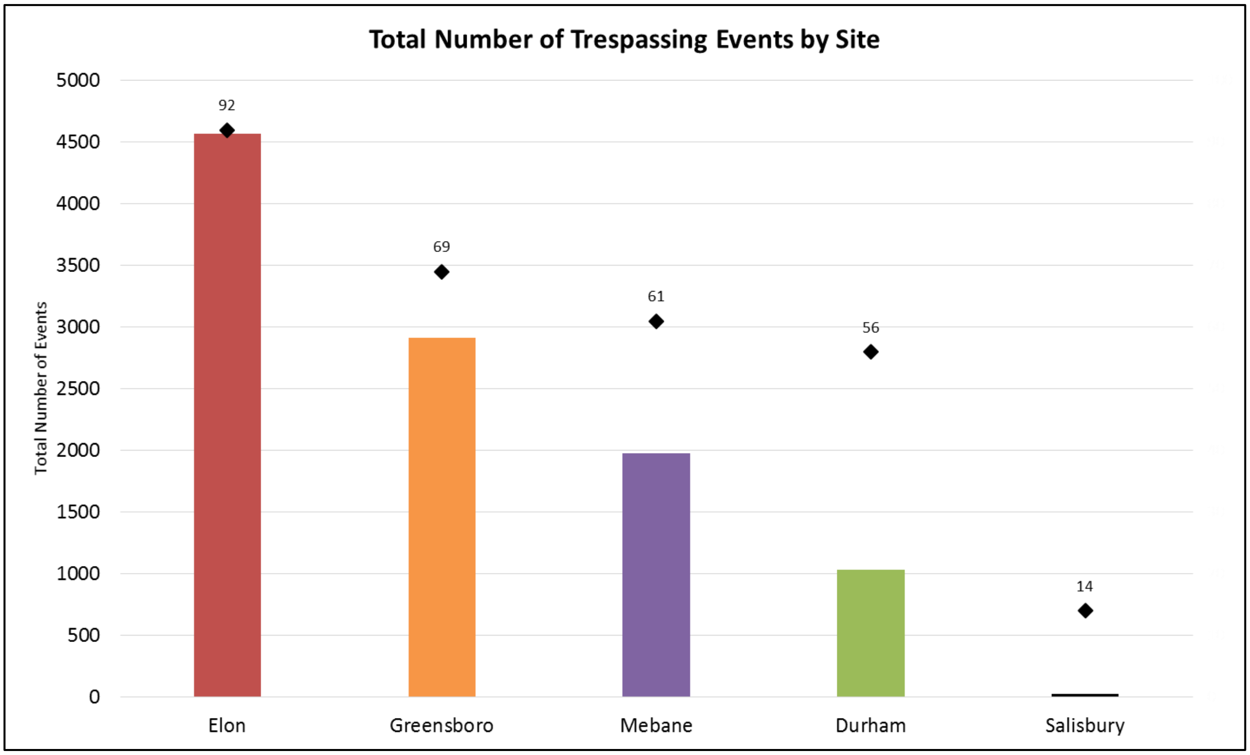
Exhibit 20 provides still images of typical trespassing behaviors that were captured at the data collection locations. A descriptive summary of trespassing characteristics by site is provided in Exhibit 21. The majority of events across all sites (97%) involved crossing the tracks. Only 3% of events involved activity in the right-of-way without crossing the tracks, and less than 2% of events involved riding or carrying a bicycle. Less than 1% of events across all sites included the presence of a train. The median amount of time on the tracks was 3 seconds.

**EXHIBIT 20. TYPICAL TRESPASSING ACTIVITIES AT GREENSBORO (TOP LEFT), ELON (TOP RIGHT), MEBANE (BOTTOM LEFT), AND SALISBURY (BOTTOM RIGHT) SITES**

| | Durham | Greensboro | Elon | Mebane | Salisbury |
|---|---|---|---|---|---|
| **Who** | Mostly small groups and individuals | Mostly individuals; small groups to/from business near tracks | Some days all groups; some days mixed; huge groups on Veteran's Day may be outlier | Mostly individuals; some groups | Mostly individuals; very low activity |
| **What** | Nearly all crossing | Nearly all crossing | Nearly all crossing | Nearly all crossing; some dog walkers parallel to tracks | No crossing except for one event barely outside at-grade crossing |
| **When** | Throughout the day to/from parking areas; minimal activity late at night | Consistently throughout the day; low to no activity from 11pm-5am | Consistently throughout the day; higher in evening/late night on some days may be related to university schedule | Consistently throughout the day | All during the day |
| **How** | Mostly pedestrians | Even split between pedestrians and bicycles; some dog walkers | All pedestrians; no bicycles | Mostly pedestrians; few bicycles; some dog walkers | All pedestrians; one left platform to track to retrieve fallen item |

**EXHIBIT 21. SUMMARY OF TRESPASSING CHARACTERISTICS BY SITE**

Additional summary statistics are provided in Exhibits 22-25. The average number of trespassing events per day across all sites was 36 with variation between sites shown in Exhibits 23 and 24. The site at Elon University is the most different from the other sites included in the sample. This site experiences the highest average number of trespassing events which typically ramp up on the weekend during months when the university is in session. There is a marked decrease in activity during the summer months when the university is not in session. In addition, the height of fencing along the corridor under observation was changed from 3’ to 6’ in June 2018, which resulted in an overall decrease in trespassing events when classes resumed for the semester.




| Site Number | Latitude | Longitude | Town/City | Number of Events | Number of Dates with Events | Number of Dates with No Events | Total Dates | % of Dates with Events |
|---|---|---|---|---|---|---|---|---|
| 00-1 | 36.10044 | -79.50804 | Elon | 4,569 | 92 | 19 | 111 | 83% |
| 40-1 | 36.06946 | -79.78339 | Greensboro | 2,912 | 69 | 9 | 78 | 88% |
| 67-1 | 36.09700 | -79.27110 | Mebane | 1,978 | 61 | 0 | 61 | 100% |
| 31-1 | 35.99461 | -78.90190 | Durham | 1,032 | 56 | 1 | 57 | 98% |
| 79-1 | 35.66734 | -80.46552 | Salisbury | 28 | 14 | 37 | 51 | 27% |
| Grand Total | | | | 10,519 | Average No. Events per Day: 36 | | | |

**EXHIBIT 22. TOTAL NUMBER OF TRESPASSING EVENTS AND DATES OBSERVED BY SITE**

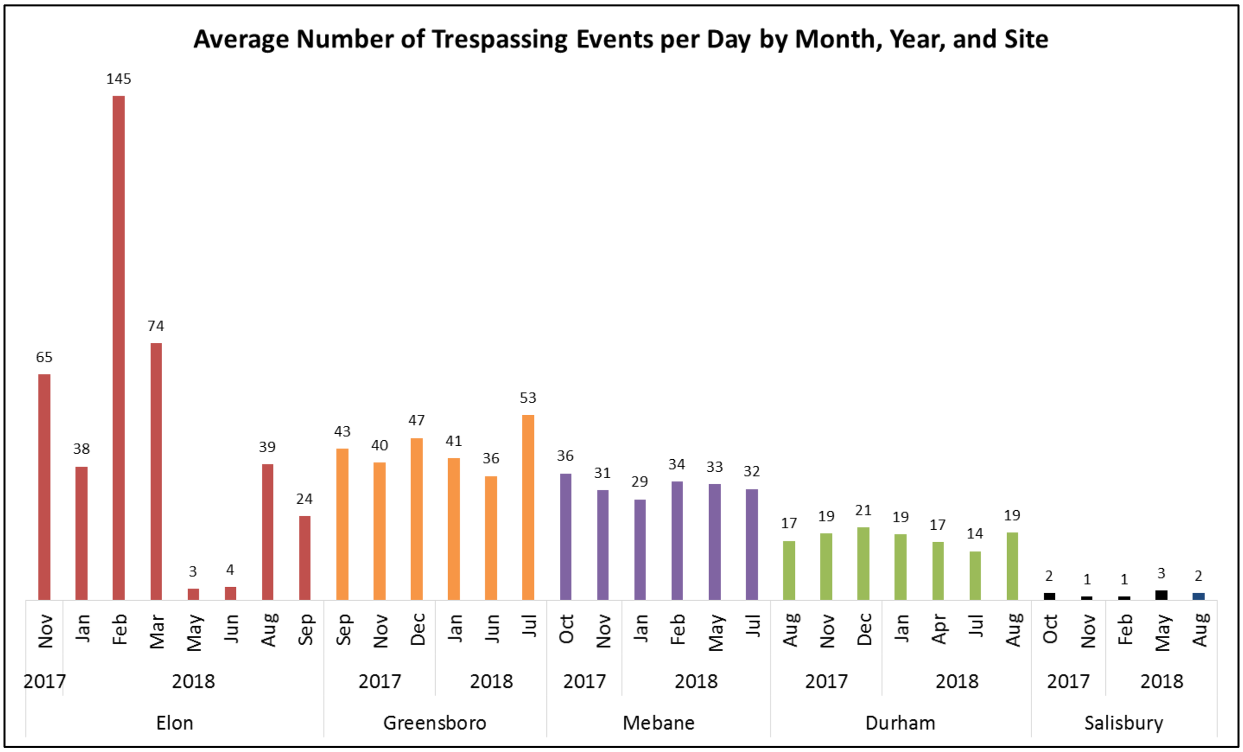



**EXHIBIT 23. AVERAGE NUMBER OF TRESPASSING EVENTS PER DAY BY MONTH, YEAR, AND SITE**

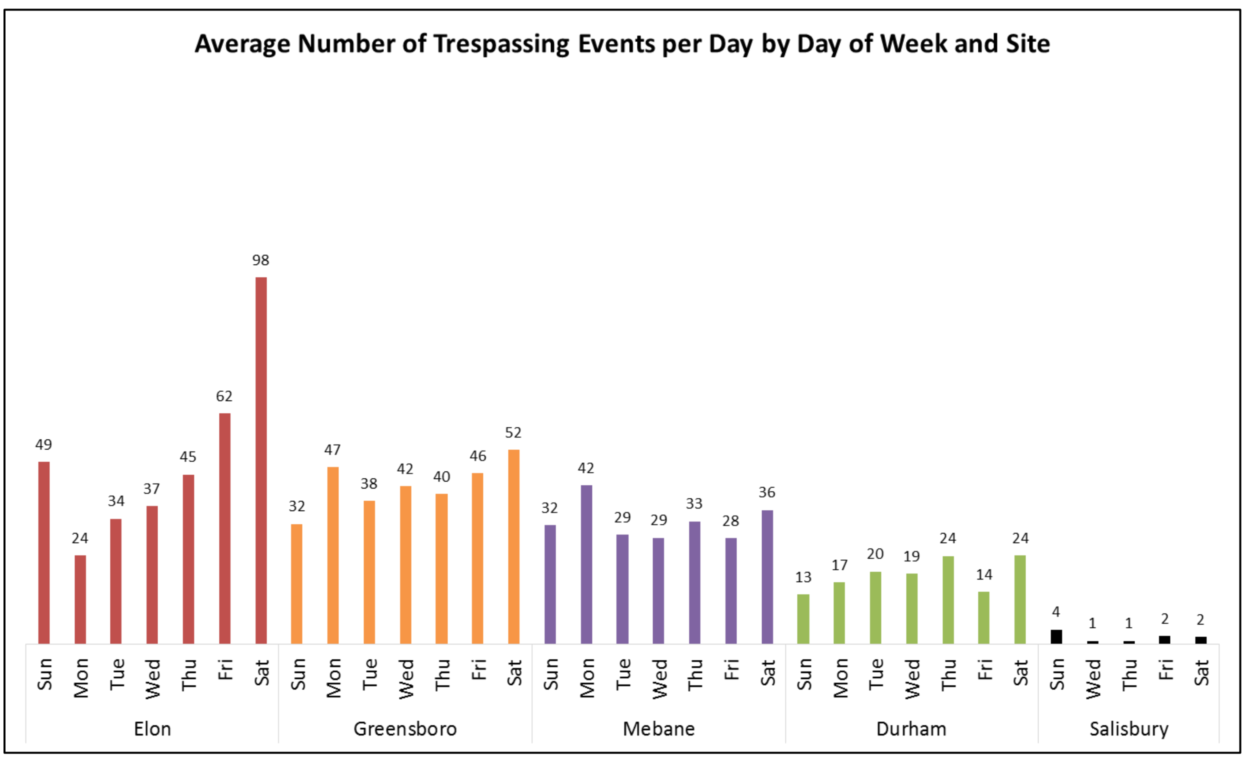



**EXHIBIT 24. AVERAGE NUMBER OF TRESPASSING EVENTS PER DAY BY DAY OF WEEK AND SITE**

| Site | Proportion of Trespassing Events by Hour of Day - All Dates | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** |
| Elon | 13% | 11% | 5% | 2% | 0% | 0% | 0% | 0% | 1% | 2% | 3% | 2% | 3% | 3% | 3% | 4% | 6% | 7% | 5% | 4% | 4% | 5% | 9% | 9% |
| Greensboro | 2% | 2% | 1% | 2% | 2% | 3% | 3% | 6% | 6% | 6% | 5% | 5% | 6% | 6% | 7% | 5% | 6% | 6% | 4% | 5% | 5% | 4% | 3% | 2% |
| Mebane | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 3% | 4% | 4% | 5% | 6% | 6% | 6% | 7% | 9% | 9% | 10% | 6% | 6% | 6% | 4% | 4% | 1% |
| Durham | 2% | 1% | 1% | 0% | 0% | 0% | 2% | 1% | 3% | 4% | 5% | 7% | 6% | 8% | 7% | 9% | 9% | 7% | 5% | 5% | 5% | 6% | 4% | 3% |
| Salisbury | 18% | 0% | 7% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 4% | 7% | 4% | 0% | 18% | 11% | 0% | 7% | 11% | 7% | 0% | 0% | 0% |

**EXHIBIT 25. PROPORTION OF TRESPASSING EVENTS BY HOUR OF DAY**

The study location at Elon University is also unique from the other sites relative to the distribution of trespassing events across the hours of the day (Exhibit 25). Considering all data collection dates, 52% of trespassing events at the Elon site occur from 9 pm – 2 am (compared to 17% at the Durham site, 14% at the Greensboro site, 9% at the Mebane site, and 25% at the Salisbury site).

### 3.5. Preliminary Modeling

The research team is currently developing preliminary predictive models to estimate and forecast trespassing events based on the event-based thermal video data from the hot spot locations along the Piedmont corridor. The research team is also collecting additional data in 2019 from hot spot locations on the wider NC rail network that were identified in additional ongoing research under NCDOT RP 2019-08. Preliminary modeling results based on the Piedmont corridor data collection will be provided in the reporting for NCDOT 2019-08.

## 4. DISCUSSION

The research documented in this report includes the testing and deployment of a static thermal detection system for capturing trespassing events at hot spot locations along the Piedmont corridor from Raleigh to Charlotte, NC and initial piloting of a dynamic thermal detection system. The preliminary results from the event-based data collected at the Elon, Greensboro, Mebane, Durham, and Salisbury sites indicate that 1) the magnitude of trespassing at hot spots along the corridor is much greater than indicated by FRA incident reporting and Amtrak train crew surveys, 2) the majority of trespassing events are short in duration and involve crossing the tracks rather than movement along the right-of-way, 3) variability in time-of-day/day-of-week/month-of-year patterns appear to be influenced by local environmental and population factors, such as the case of the Elon site where university academic and athletic schedules appear correlated with trespassing activity, and 4) the profile of the average trespasser represented in the event-based data may not be consistent with the profile as defined with FRA incident data, particularly when analyzed at the local level rather than as a regional or state level aggregate. Additional analysis of the event-based data including model development will be provided in the reporting for NCDOT 2019-08. Further testing of the dynamic thermal detection system is ongoing and will be completed in a separate effort.