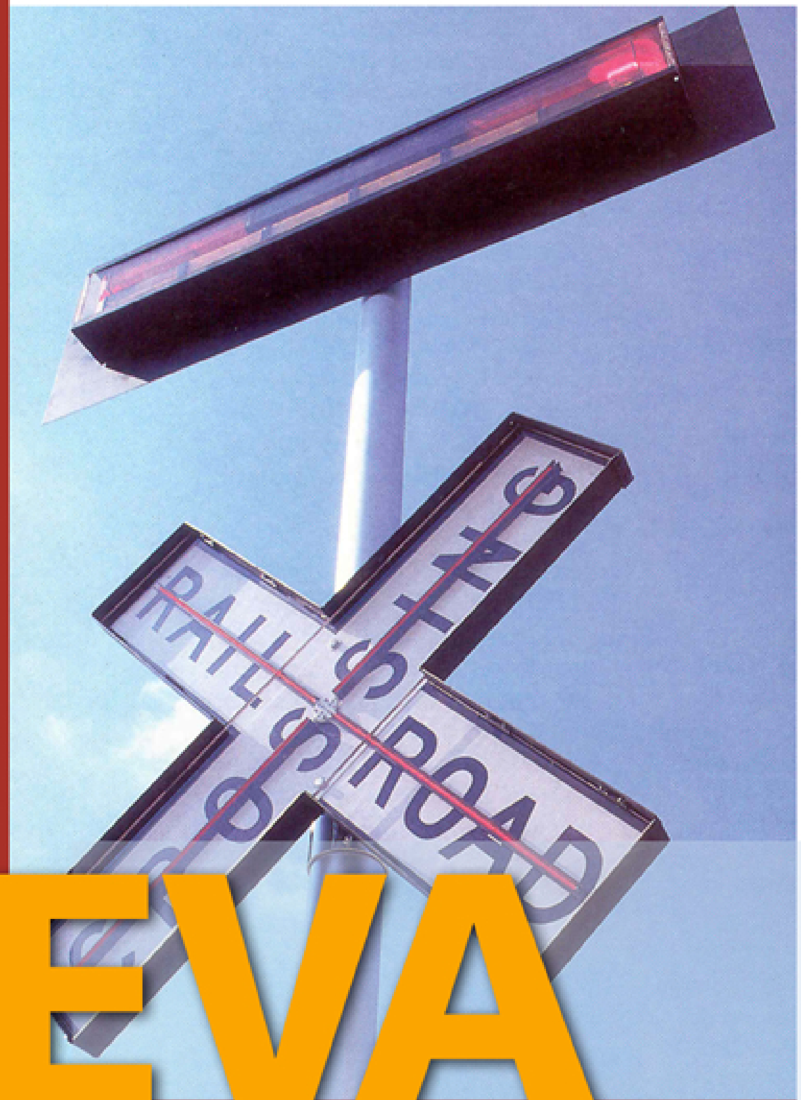


# EVA

## Signal System Report

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Lyndo Tippett, Secretary
Rail Division, North Carolina Department of Transportation

NCDOT

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## Executive Summary

This report examines an exploratory project in North Carolina intended to test an innovative, cost-efficient railroad crossing signal system manufactured by EVA Corporation of Omaha, Nebraska. While the EVA signal system had been installed at three other sites across the nation, North Carolina was the first official test site for the Federal Highway Administration (FHWA). The system was installed on an incremental basis between August 13 and September 28, 2001. The North Carolina Department of Transportation Rail Division (NCDOT Rail Division, the North Carolina and Virginia Railroad Company (NCVARR) and EVA Corporation entered into an agreement to field test the experimental system. At the outset, all parties agreed that if the EVA Signal System performed satisfactorily and is approved to be included the Manual of Uniform Traffic Control Devices (MUTCD), the signals would remain in place with railroad approval. The length of the test project was to be three (3) years – one (1) year of intensive monitoring and evaluation and two additional years with six month evaluations. If for any reason it was decided to remove the EVA signal system before the planned period, standard signals and gates would then be installed within three (3) months following the cessation of the experiment.

From the outset, the EVA System was plagued with a number of problems; both systemic and weather-related. Eventually, a newer, more updated system was installed, but because of the excessive time involved and the costs associated with the project, the State of North Carolina decided to terminate the experiment.

This report describes in detail the EVA Signal System, the process required to employ the system and the methodology devised to evaluate system effectiveness. Moreover, the report provides a detailed description of system effectiveness and deficiencies, as well as what went wrong, from both the point of view of the State of North Carolina and the EVA Corporation.

## Introduction

Over the past several years the North Carolina Department of Transportation's Rail Division (NCDOT Rail Division) has undertaken an active research and development program that utilizes a combination of new and existing technologies to enhance safety on the railroad and at highway-rail crossings.

As an integral part of the overall crossing safety program, the Rail Division routinely evaluates alternative technology applications, typically experimental in nature. This report examines one such experimental project. The project involved the deployment and testing of a new innovative, cost-efficient, highway/rail crossing signal system manufactured by EVA Signal System Corporation headquartered in Bennington, Nebraska. The EVA Signal System uses lighted crossbucks coupled with a red strobe light bar to alert motorists of approaching trains. Unlike other systems, the EVA signal system uses "off the track" detection that reduces dependence on overcrowded rail circuitry. Additionally, the system was thought to be ideally suited to rural crossings because of the battery operated and solar-recharging abilities, although, the solar recharging system was not available, when this test location was installed.

In mid-2001, the NCDOT Rail Division received permission from FHWA to field test the EVA Signal System. EVA Corporation had previously been given the go-ahead to field-test its system by FHWA. The NCDOT Rail Division, NCVARR and EVA Corporation contractually agreed to field test the signal system and actual testing began in early October of 2001. Initial plans called for research to be conducted by the Institute for Transportation Research and Education (ITRE) at North Carolina State University. The nature of the research was to determine the reliability of the system and driver response to it. It should be noted that while the EVA signal system had been installed at three other sites across the nation, North Carolina was the first official test site for the Federal Highway Administration (FHWA). At the outset, all parties, including FHWA, agreed that if the EVA Signal System performed satisfactorily and was approved for inclusion in the Manual of Uniform Traffic Control Devices (MUTCD), the signals would remain in place if approved also by the railroad. If for any reason it was decided the EVA signal system needed to be removed, standard signals and gates would then be installed within three (3) months following the cessation of the test.

The testing took place at an at-grade crossing in Northampton County at State Route 1521 (Lovers Lane Road) on the NCVARR tracks near Rich Square, N.C. The precise location is crossing No. 630 260G, milepost 75.88. The location is a rural, passive highway/rail crossing over which runs a single track, low density rail line. The crossing has minimal vehicular traffic and the timetable track speed is 25 mph through the crossing. Although there were other sites considered during the germinal stage of the project, the final decision was made in favor of the Lovers Lane Road location. NCDOT Rail Division selected the location because the crossing did not otherwise meet the Rail Division's prioritization procedures for upgrade to signalization, and it was determined that conducting the experiment at the particular location constituted minimal safety risk.

The division of labor for the project was as follows: EVA Corporation would provide the equipment and would replace any failed or damaged components of the EVS Signal System for the duration of the Project, NCVARR and EVA would jointly install the equipment, and the NCDOT Rail Division would be responsible for conducting a study to determine the reliability of the equipment and assessing public reaction to the experimental devices.

## EVA Signal System

The EVA Railroad Crossing Signal System was selected because it was considered less costly than other systems and it contained a number of innovative features. The traditional crossbuck sign is animated with flashing red light emitting diodes (LEDs); a strobe light bar is positioned five feet above the crossbuck; a Train Directional Advisor (TDA) directly under the strobe bar indicates the direction of train travel; a magnetic train detection system utilizes sensor probes located outside of the ballast line; and the system is controlled by a microprocessor based Logic Control Center buried in an adjacent underground vault. The system is battery powered by three 12-volt batteries, with an optional solar recharging system, making installation feasible in areas where electric utility power is unavailable or too expensive.


**Figure 3.1 – EVA Signal System**

The visual warning provided to the highway user is accomplished through the use of a standard crossbuck but with the addition of 336 kilo bright light emitting diode (LED) strips aligned atop the crossbuck and forming a large “X” when activated. The red kilo bright LED lights are highly visible during the daylight and evening hours. The stated life expectancy of these lights is around 100,000 hours although during the test, some bulbs failed within three (3) months. The LED strips are protected from vandalism by a covering of ½ inch LEXAN® covering the entire face portion of the crossbuck.

The EVA Signal System provides a much more dynamic warning than traditional signal systems. A flashing LED array in an “X” pattern enhances the standard reflectorized crossbuck, and the flashing strobe bar provides additional clarity. The direction of approach of a train is indicated by the TDA, which consists of six yellow halogen lights sequentially activated to indicate the direction of approach.

An audible warning to the motorist is achieved through the use of a standard railroad crossing bell.

The EVA Signal System’s Off-Track Train Detection System detects trains by means of six magnetometer sensors on each approach and buried in the right of way. The first and second magnetometers calculate the speed of the train, train movement is verified at the fourth probe and island type activation is performed by the sixth probe. The third and fifth probes function in back up mode which occurs for five minutes after an activation caused by the other four probes. Magnetometers sense changes in the ambient magnetic field such as the changes caused by the large mass of iron of an approaching train. A series of sensors placed along the track allows estimation of both the location of the approaching train and its speed. This enables the provision of approximately constant warning time for motorists and pedestrians near the crossing. In addition, the EVA system confirms the presence of the train at the crossing with a set of infrared (IR) detectors mounted on steel posts at the crossing. The IR detectors are positioned to direct beams across the tracks diagonally from one quadrant of the crossing to the opposite quadrant. A train on the track interrupts the IR beams, ensuring that the system continues to detect the train's presence.

**Figure 3.2 – Installed Magnetometer**

The EVA Signal System is managed by a microprocessor-based logic center with relays controlling the high-power lamp circuits. A data-logger monitors operation of the entire system including internal diagnostic signals such as temperature and battery voltage. At the passing of a train the system records date and time as well as the train's length, speed, and a number of other parameters useful for routine system maintenance. Storage is available to record up to 90 days of train and system data. A backup microprocessor monitors system operation to enhance overall reliability. The Logic Control Center (the main processor and standby battery power supply) is normally housed in a buried fiberglass/epoxy vault approximately 5 feet deep by 6 feet wide to help maintain a consistent operating environment and provide physical security. The Logic Control Center was easily accessed through the vault's entryway at ground surface, but it was designed so as to be secured.

The underground vault had a number of advantages over conventional above ground containment. It provided a controlled environment for the solid state components used by the main processor. Moreover, its location was out of harms way from automobiles, etc., which might diverge from the roadway.

One disadvantage was quickly discovered when the underground vault flooded from the conduit feeding it and eventually caused officials to reinstall the equipment cabinet above ground.

**Figure 3.3 – Vault filling**

## Test Objectives

The three main objectives of this test were to:

1. Test the ability of the EVA 1000 system to detect trains reliably and accurately in both the long and short terms. After installation was complete, the system was to be evaluated for period of three (3) years as per agreement with FHWA.

2. Test the systems' ability to communicate effective warnings to motorists.

3. Study the reaction and behavior of the public to the experimental signal.

## Test Procedure

In order to accomplish the test objectives, the following tasks were performed:

a) A suitable location at the site was chosen for an automated video camera to videotape drivers' reactions to the experimental system and train movements.

b) A video sequence of each signal activation and each train movement, was recorded at the test site to record reliability of the EVA sensors for train events and public reaction and behavior associated with the EVA Signal.

For the protection of the motoring public it was necessary to stagger the installation of the sensor and control equipment and the installation of the signals and signs at the crossing. Phase one included the installation of the sensor control system to monitor the train detection system prior to installation of the above ground hardware. This phase was completed in August 2001 and was monitored for about four (4) weeks thereafter. Monitoring was accomplished largely through video surveillance. In late September 2001, the second phase of the project, the installation of the signals and the signal hardware was completed.

The video surveillance system for the test was installed and powered-up concurrently with the installation of the sensor control system in August of 2001. The process of video monitoring was accomplished through the use of a camera encased in a spare railroad signal cabinet aimed at the crossing at a 45 degree angle from the road. The Video monitoring system was manufactured and installed by G.E. Harris Harmon DJR Services, LLC of Glenelg, Maryland.

Initially, the camera was activated by the locomotives' engineer radio, but this arrangement turned out to be problematic. NCDOT Rail Division engineers determined that there were numerous false activations occurring when they compared the train logs with the EVA system data logs. The video logs showed recorded information when trains were not present. Considering the EVA system's sensitivity (capable of being activated by any metal object, even a shovel if circumstances were right) engineers revised the camera system to activate when the EVA signals activated, to overlap with activation by the engineers. When that adjustment was made, engineers were able to determine that a majority of the false activations were engendered by hunters on all-terrain vehicles (ATVs) and maintenance of way equipment.

Analysis of the signal-activated video log allowed for a much more accurate assessment of EVA System's reliability. The data could then be correlated with any available logs of train activity and with the internal monitoring capabilities of the EVA equipment.

Once the reliability of the EVA system's ability to identify the presence of a train was confirmed, the next step was to gauge the action of motorists (human factors) to the innovative EVA signal display. The study procedure, by the Institute for Transportation Research and Education at North Carolina State University (NCSU), involved a combination of data gathering approaches to assess short and long term driver response. NCSU was also to evaluate the functionality of the circuitry.

## Results

From its initial deployment, the EVA system was plagued with a number of difficulties, some of which were systemic and some weather-related. The original start date for the project was projected to be May 2001 but had to be delayed until August of the same year due to lack of a power drop. Eventually, the EVA 1000 circuitry was turned on. After a four week period of evaluation, the above ground equipment (flashers and infrared train detection) were installed. The lights were bagged at this juncture and remained bagged until mid-March 2002, due to reliability issues.

In the first dry run, on October 1, 2001, there was a consistent tail ringing issue on one approach. The signals continued activating and deactivating as the train was pulling away from the railroad crossing. Officials also noted that the system would not reset for five (5) minutes and operated on backup utilizing only two of the six probes for that period. In addition, the system would lose a short consist at track speed due to spacing between the backup sensors being too long to maintain the existence of a short train. NCDOT Rail Division officials canceled an event unveiling the system in early October because of the problems attending to the installed system.

EVA personnel later returned to the site in late October to address the problems and to install a new logic sensor. EVA technicians also increased the delay time for the system to time out, which corrected the lost train problem and held the signals active for a short, slow moving train. Still, when the system was on backup, the tail ringing continued for the increased time. At this same time, the underground vault, which had become flooded through the electrical conduit, was removed and the EVA system was installed in an above ground cabinet provided by NCDOT Rail Division. It was also at this time that the camera equipment was revised to activate when the flashers activate, as well as when keyed up by the locomotives engineer radio.

Over the next couple of months, the system worked satisfactorily only intermittently and officials were constantly puzzled by the amount of false activations and discrepancies in recorded train speed. A goodly amount of the false activations were determined to be four-wheelers operating in the area of the crossing or maintenance of way activities, but not all were attributable to these sources. Significant differences in train speed were logged in February and March of 2003. For example, at one point on February 22, 2003 the system recorded a 39.3 mph train speed on the approach and 12.3 on the island. The same thing happened on February 28, when the system logged a 22.2 mph train speed on the approach and 9.6 on the island. And again on March 2, a similar discrepancy occurred when the system logged a 19 mph train speed on the approach and 12.2 mph on the island.

But on the positive side, the system didn't seem to have a problem detecting a train. Prior to this time, NCDOT Rail Division engineers noted that all of the false activations observed were on the side of excessive warning time or activation in the absence of train.

By June of 2002, state officials were becoming increasingly concerned and in a bi-annual report to the FHWA (Exhibit 1), the NCDOT Rail Division reported that their evaluation of the EVA Signal System had disclosed a number of faults that, in their view, could be a causal factor in a grade crossing collision.

A central concern was the back-up detection. The EVA System was designed with a primary detection system that utilizes a speed trap to calculate warning time and then a backup detection system that acts like an island circuit (if a train passes a backup probe, it activates the signals). If the primary system has recently been activated (within 5 minutes) then the system relies on detecting train movement from two backup probes located at 150 feet and 1540 feet on each approach. It was determined that a short consist (three locomotives) could be lost in the detection system between the two backup probes. The short consist activated the signals when it passed the backup probe at 1540 feet. The logic system would not see the locomotives pass the primary activation probes, as these are deactivated while in backup mode. The system would simply determine that the event was not train-induced based on an internal timer for further activity. The delay timer would time out deactivating the signals. The system next recognizes a train movement when the lead locomotive passes the backup probe located at 150 feet, which would provide approximately three (3) seconds of warning time before the locomotive entered the crossing at track speed. This should only be possible for short consists, but NCDOT Rail division personnel observed on video some instances where this occurred for longer freight trains. In reviewing the EVA data log, there was no prior activation recorded that would have put the system into backup mode in the case noted. In addition, it was observed through video that some trains were provided with three (3) seconds of warning time without any prior activation. After observing the video and reviewing the log data, NCDOT personnel determined that on occasion, the system activates in backup mode when it should be functioning in the primary mode.

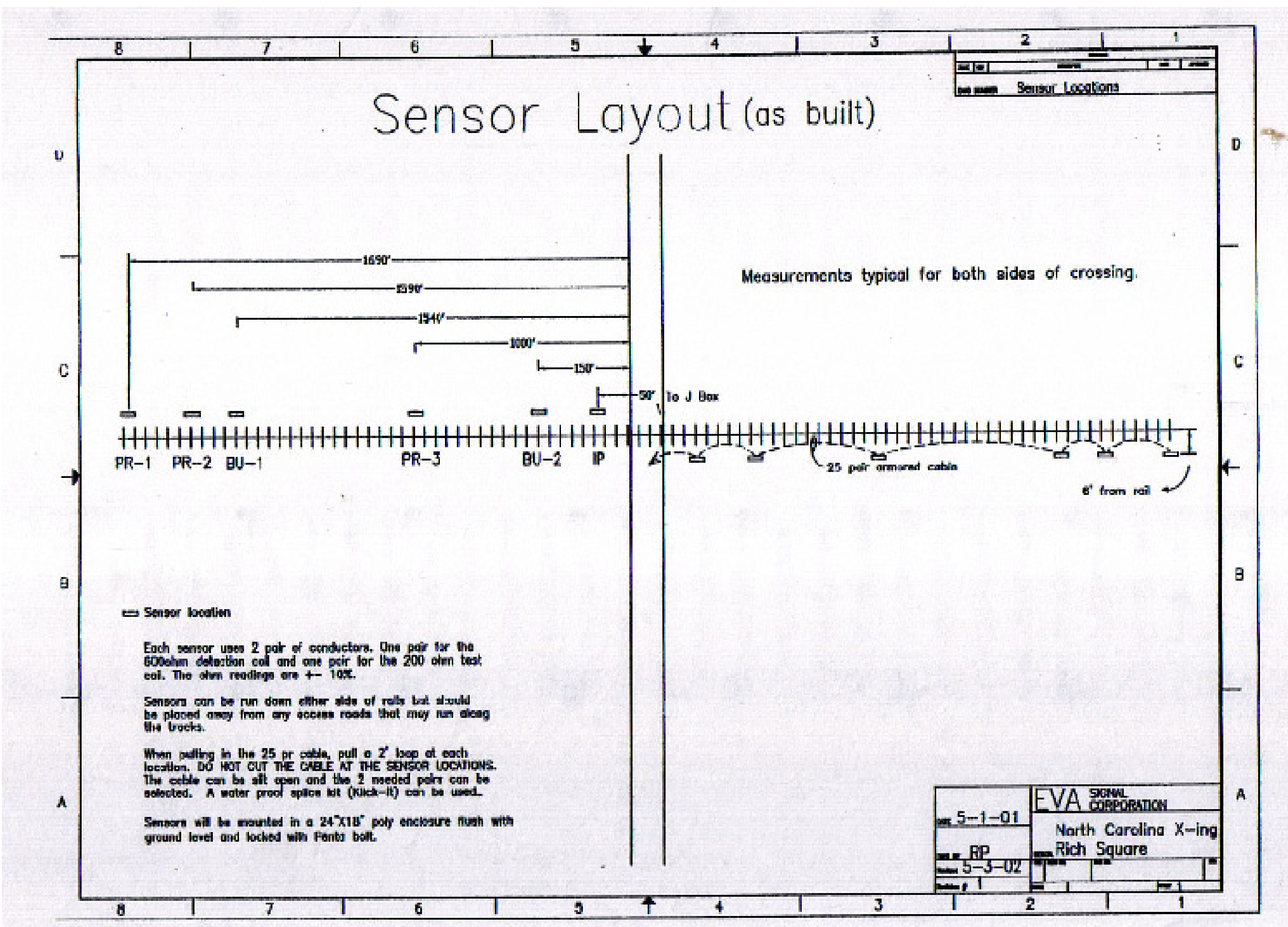


**Figure 6.1 – Sensor layout at Rich Square, NC**

Other problems observed with the system included:

- Tail ringing when the system was in back-up mode.
- Water entering the underground vault through the electrical conduit.
- Incorrect calculation of train speeds on one of the speed traps which consistently provided conflicting train speed information. Sometimes the train speed was more than doubled with the second speed calculation.
- Malfunction of the Train Directional Advisor which eventually caused it to cease operation.
- Malfunction of one of the animated crossbuck displays causing the display to become stuck in one illumination phase.
- Bulbs burning out on the animated crossbucks.

An additional phase of the test project called for a driver behavior study, however, by the time the project had progressed to the point where such a study could be undertaken, the signals had been bagged for more than nine (9) months and NCDOT Rail Division officials determined that a driver behavior study assessing drivers' response to the EVA Signal System would be faulty given the fact that residents who utilized the crossing would consider the signals "old news".

At this point in the process, NCDOT decided to make some changes to the project. Rail Division engineers would remove the strobe flashers and replace them with standard LED flashers, relocate the animated crossbucks above the flashers in accordance with MUTCD and instruct EVA to replace the existing detection system with the new EVA 3000 detection system for evaluation. NCDOT Rail Division would then allow for two months of evaluation before the decision would have to be made to replace the entire system with standard equipment or to remove the bags from the standard flashers and animated crossbucks.

For their part, EVA Corporation officials responded to all of the functionality issues identified by NCVARR and NCDOT Rail Division, but were not in agreement that the problems were solely the result of reliability issues. They pointed out that they had designed the system for the Lovers Lane Road application, only to have the specifications change quickly after installation. They were told by NCDOT Rail Division personnel that there would be 2 to 3 trains a day at the crossing, but the railroad subsequently decided to change crews at that location. Had they known about the change, EVA engineers claimed that they would have had to install their EVA 3000 system (which was under development when the EVA 1000 was installed) with presence detection. The EVA 3000 was eventually installed in July of 2003 to address the island detection issue. However, NCDOT Rail Division officials were never able to fully evaluate the EVA 3000 because the system dropped into a fail-safe mode shortly after installation and they were not able to free it. EVA officials initially argued that the malfunction was likely weather-related according to a letter dated August 22, 2003 (Exhibit 2) and offered to replace the existing logic center at additional cost to the NCDOT Rail Division if it was determined to be damaged by lightening or other weather conditions.

According to EVA executives, they were hampered by a lack of communication with officials of the railroad. The times they were able to communicate were largely the result of a relay through NCDOT Rail Division personnel. (Note: It was about this time that NCVARR underwent a change in general managers.)

In a letter dated September 5, 2003, (Exhibit 3) EVA executives offered to address the problems. The company offered to install new "active" sensors to enhance the island functionality. These sensors were not available when the project began but emerged later on as new technology. Company technicians advised that the change would address the railroad's crew change activities near the crossing. EVA officials also agreed to install a new logic center capable of handling the advanced sensors and completely test the entire system. They made an additional offer to train railroad personnel on maintaining the system.

By September 2003, the State of North Carolina determined they no longer wished to continue experimenting with the EVA Signal System. Both the railroad and the State had expended considerable money and manpower maintaining and supporting the system. NCDOT Rail Division officials felt that the EVA system had ample time in the testing to address all of the functional issues. Railroad officials were also frustrated; according to them, they repeatedly went out of their way while making a significant investment only to have, in their words "the crossing down most of the time."

As provided for in the initial agreement, the Railroad was permitted to decline leaving the EVA system in place at the conclusion of the project. In a September 29, 2003 letter to EVA's president, NCDOT Rail Division's crossing project engineer informed the company that it was felt nothing further could be learned about the EVA Signal System and directed the company to remove it from the crossing by the end of October 2003. The system was finally removed in December of 2003 by the Railroad.

NCDOT Rail Division officials determined that, in their professional engineering judgment, the EVA 1000 and EVA 3000 were not suitable for the Lovers Lane Road location. EVA executives took the position that it was merely a case of weather-related misfortunes and operational changes. Because EVA engineers were not on site 100 percent of the time it is difficult to determine if the recommended practices and maintenance schedules contained in the EVA System manuals were followed. A high level of system maintenance and record-keeping would have been essential since the EVA system was an experimental and non-conventional means of traffic control.

The system was stored on the Railraod's yard for approximately a year awaiting a decision between the Railroad and EVA Signal Corporation the best method for returning the equipment to EVA Signal Corporation. Eventually, the system was returned by the NCVARR in August of 2004. EVA executives and engineers performed diagnostic testing at that time. They disclosed their findings in a report to NCDOT Rail Division officials on August 20, 2004 (Exhibit 4).

The specific problems discovered were the following:

1. Sensor cards 1A, 2A, 3A, 2B, 1B were damaged.
2. +12 volt power trace was burnt.
3. Sensors 1B through 6B do not go into test due to V206 IC was bad on Main CPU's A& .B.
4. XR+ trace was burnt and open.

The company pointed out that after concluding discussions with the maintainer when the system failed, the railroad was sent a new Peripheral Interface board which was installed. But after seeing the actual damage, the entire logic center needed to be replaced due to the burnt trace on the motherboard. The company went on to say that it is hard and costly to protect electronic devices from direct or close lightning strikes. Since the installation near Rich Square, NC, EVA has incorporated a much higher degree of protection against transient lightning through the use of voltage-limiting terminal blocks manufactured by a company in Germany. This block uses a suppression diode rated at 305 amps at 59 volts that is capable of carrying the excess current to ground. Company officials acknowledged that it is impossible to determine if this particular form of lightning suppression would have protected the system at Rich Square, but they expressed confidence that it would be a great help in cases where transient voltage spikes occur from nearby lightning.

In concluding their report, company officials acknowledged that due to the uncertainty of a lightning strike and inexperience of the railroad's maintainer with EVA equipment, they should have requested that the entire EVA logic center be returned to company offices in Omaha, NE for repair and testing instead of relying on others to do the company's diagnostic work. If that had happened, the damaged components would have been discovered and repaired or replaced very quickly and shipped to the railroad within two (2) to three (3) days.

## Conclusion

While the EVA System functioned to everybody's satisfaction on some occasions, it became more and more problematic. The system activated in the "fail-safe" mode and railroad maintenance personnel and NCDOT Rail Division engineers were unable to free it. This fact, along with the extended length of the project and the escalating costs prompted state officials to discontinue the test project. Eventually NCDOT Rail Division officials found that they were not able to invest additional time and resources in the project and requested that EVA Corporation remove it.

EVA System engineers were able to conduct an examination of their own when the system was returned to them in August of 2004. In a letter from EVA executives and engineers to NCDOT Rail Division officials, EVA concluded that a lightening strike had damaged the system to such an extent that it was irreparable without being returned to EVA.

NCDOT Rail Division engineers and planners will continue to monitor development of new and innovative technologies related to railway highway at-grade crossing safety. Discussions continue regarding the design parameters and requirements that grade crossing systems must meet to function in a manner that fulfills the required safety application, is safe for the public, and cost beneficial. As train speeds and capacity increase and technology advances, railroad train control and crossing signal systems will continue to become more and more complex. The NCDOT Rail Division will continue to consider new technologies for research and development as the ongoing mission of improving safety for motorists, train crews and passengers continues.