

Virginia State Route 7 Video Detection System Performance Assessment



Prepared for:
Honorable Congressman Frank Wolf

Prepared by:
U.S. Department of Transportation
Federal Highway Administration

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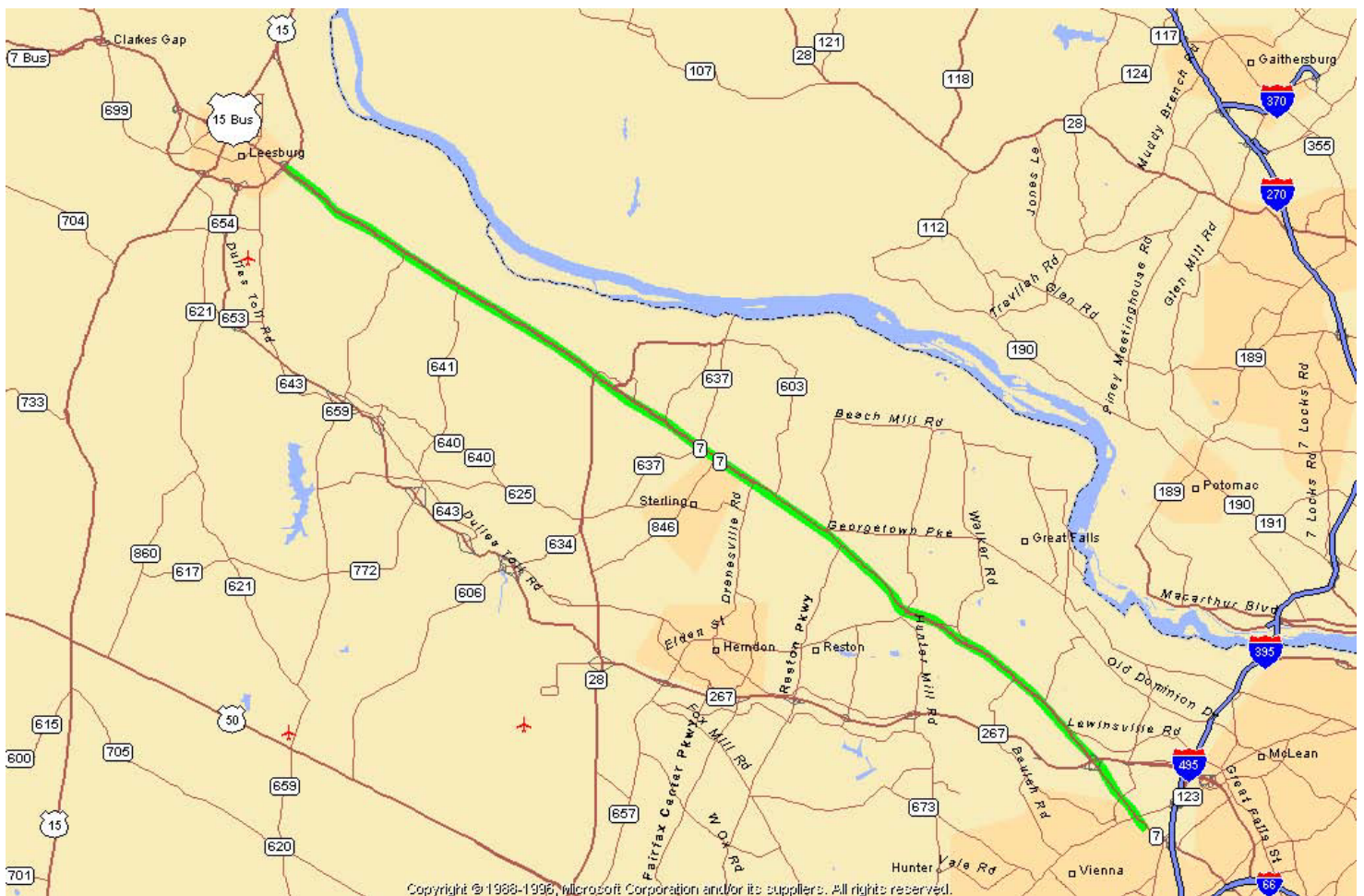
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1. INTRODUCTION

The Honorable Congressman Frank Wolf, in his letter dated November 7, 2005 to the Federal Highway Administration (FHWA), requested an analysis of traffic operational issues along Route 7 in the Northern Virginia area, particularly those associated with video based traffic detectors. The Virginia Department of Transportation (VDOT) had installed video based traffic detectors along Route 7 and the performance of the detectors was found to be unacceptable.

VDOT engineered and contracted to have video imaging detector system (VIDS) devices installed along Route 7. The system, however, experienced significant detection errors and VDOT decided to discontinue its use. The principal concerns were missed vehicle detections for the left turn movements off Route 7 and significant over counts as well as missed detections for the side street movements. VDOT has reverted back to the inductive loop detectors that were in place prior to the installation of VIDS.

Figure 1: STUDY SITE ALONG ROUTE 7



2. BACKGROUND

The study area is approximately 21 miles long (Figure 1). The land use along Route 7 is strip shopping malls east of the Dulles Toll Road, which changes to residential, then back to strip shopping malls in the Sterling area. The area becomes more rural as it progresses west towards Leesburg. Posted speed limits range from 35 MPH on the congested east side to 55 MPH in the western section. It is a divided facility for the entire length with a four-lane cross-section on the eastern side and a six-lane cross-section towards the west. This route features left turn bays as well as channelized right turn lanes. With few exceptions, the left turn bays off Route 7 are two lane movements. The total number of traffic signals between Tyson’s Corner and the Town of Leesburg is 36. Further, these signals are grouped in four sub systems, as shown in Table 1.

Table 1: ROUTE 7 TRAFFIC SIGNAL GROUPING

Tyson’s Corner Network	7D Network
Route 7, Leesburg Pike @	Route 7, Leesburg Pike @
<i>Old Gallows Rd</i>	<i>Lewinsville Rd</i>
<i>Tyson’s Blvd</i>	<i>Towlston Rd</i>
<i>International Dr</i>	<i>Beulah/Forestville Dr</i>
<i>Chain Bridge Rd East</i>	<i>Colvin Run Rd/Carpers Farm Way</i>
<i>Chain Bridge Rd West</i>	<i>Baron Cameron Ave/Springvale Rd</i>
<i>Marshalls/Service Rd</i>	<i>Utterback Store Rd</i>
<i>Westpark Dr/Gosnell Rd</i>	<i>Reston Pkwy</i>
<i>Spring Hill Rd</i>	<i>Georgetown Pike</i>
<i>Tyco Rd</i>	<i>Rolling Holly Rd</i>
<i>Dulles Toll Road East</i>	
<i>Dulles Toll Road West</i>	
7E Network	7F Network
Route 7, Harry Byrd Hwy @	Route 7, Harry Byrd Hwy @
<i>Dranesville Rd</i>	<i>George Wash. Blvd</i>
<i>Lakeland Dr</i>	<i>Loudoun Co. Pkwy</i>
<i>Augusta Dr</i>	<i>Lexington Dr</i>
<i>Sterling Blvd</i>	<i>Ashburn Village Blvd</i>
<i>Potomac View Rd</i>	<i>Ashburn Rd</i>
<i>NVCC Campus Rd</i>	<i>Belmont Ridge Rd</i>
<i>Loudoun Tech Dr</i>	<i>Cochran Mill Rd</i>
<i>Countryside Blvd</i>	<i>River Creek Parkway</i>

System Description

The traffic signals on Route 7 are managed by a centralized computerized signal system located at VDOT’s Smart Traffic Center in Arlington. The system uses the MIST traffic control software developed by PB Farradyne Corporation. Because traffic signals under coordinated operation have to have a common signal cycle length for a particular time period, traffic engineers look for commonality in traffic demand in order to group the signals in a logical sub system. VDOT engineers have grouped the traffic signals within the study area in the four subsystems shown in Table 1. The subsystems have 5 signal

timing plans each, which are operated on a time-of-day basis. This means that each subsystem operates on a common traffic signal cycle length for a given time period such as AM peak hours. The signal subsection grouping can be different for a given time period, however, VDOT maintains the same signal grouping for all times of the day. Although Route 7 in the study area has four subsystems, one centralized computer system supervises all traffic signals.

Starting at 10:00 PM and ending at 5:00 AM, the traffic signals are allowed to operate in a “free” mode, meaning there are no subsystems or signal coordination. This is an appropriate operational strategy, because with diminished traffic demands there is little need for signal coordination. This type of late night “free” operation reduces side street delay.

The communication between the traffic signals and the central system computer is via leased, twisted pair copper media, multiplexed at 9600 bits per second.

Local Signal Description

The 36 traffic signals within the study limits have a mixture of span wire and mast arm type of signal support. The span wire type of signal support uses four corner steel strain poles to hang span wire across all of the approaches of the intersection. The mast arm type of installation also uses steel poles to support the cantilevered arms for the placement of signal heads. The older traffic signals use the span wire arrangement and the newer signals are of mast arm design.

For the study area, the traffic signal controllers are identical, Type 170 controllers, running Bi-Tran local control software. All traffic signals have full-actuated signal software and operation, however, these signals operate in semi-actuated mode during coordinated operation. Under semi actuated operation Route 7 detectors are disabled and the signal stays green for Route 7 until side street or left turn demand off Route 7 is registered via traffic detectors. As pointed out earlier, after 10:00 PM all signals are permitted to operate individually in a full-actuated operation.

The cycle lengths for the four sub systems are as follows:

Tyson’s Corner Network:	AM Peak - 180 Seconds, PM Peak - 190 Seconds
7D Network:	AM Peak - 210 Seconds, PM Peak - 200 Seconds
7E Network:	AM Peak - 180 Seconds, PM Peak - 180 Seconds
7F Network:	AM Peak - 210 Seconds, PM Peak - 190 Seconds

Detector Subsystem

Vehicle detectors are principally used to register traffic demand. Vehicle detector systems have evolved over the years. In 1928, Mr. Charles Adler invented the first vehicle detector¹. It was installed in the city of Baltimore, Maryland. This type of detector consisted of a passive roadside transducer, which registered vehicle demand when the horn of the car was activated. Pressure sensitive types of detectors followed these. This

type of detector consisted of an electrical contact encased in a rubber mat that was enclosed in a frame and installed in the roadbed. The vehicle weight would close the contact, thus completing an electric circuit and registering vehicle demand.

Today, the majority of the detectors use the inductive loop technology. The detector element consists of a pavement saw cut, insertion of one or more turns of electrical wires in the pavement, and a saw cut sealing compound. Electronics associated with loop detectors are usually installed in the controller cabinet. The passage of the metal part of the vehicle causes change in the loop inductance, which the electronics translate into vehicle demand.

Besides registering demand for traffic signal and freeway applications, roadway detectors also measure speed, occupancy, vehicle classification and volumes. Traffic engineers use this data not only for transportation planning purposes, but also for developing signal timing and congestion mitigation strategies.

There are advantages and disadvantages associated with all detector technologies. For inductive loop detectors the advantages are the simplicity and low cost of installation and maintenance coupled with high degree of data accuracy. However, since the loop resides in the pavement, once the pavement fails or is milled, the detector is lost. The other disadvantage is that a lane closure is required to install the detector and the modern day congestion is not conducive to in-road operations without causing additional congestion and delay.

Since the invention of the loop detector, other types of detector technologies, such as sonar, laser, microwave, radar and video based systems have also evolved. Since the focus of this study is a video based system, a pertinent discussion follows.

Video Imaging Detection System (VIDS)

In late 1970s, FHWA's research program funded VIDS research at the University of Minnesota. This research led to the first development of prototype VIDS and later to commercialization by ISS, Inc. and also by Econolite under the "Autoscope" product name. Since then, VIDS based detectors have been developed by many U.S. and foreign companies. Iteris, Inc., an Anaheim, California company, manufactured the VIDS detectors installed on Route 7.

The VIDS system consists of a specialized closed circuit TV camera and pixel processing electronics with appropriate software. The camera is aimed at the particular vehicle traffic movement(s) that needs to be detected. The electronics are usually installed in the controller cabinet and process the visual data for use in the operation of the signal. One camera is able to detect more than one lane for a particular traffic movement.

The VIDS installation is fairly consistent throughout the study area. With few exceptions at strain pole signalized intersections, the cameras are mounted on the mast arms at the far side location with a seven-foot riser (Figure 2).

Figure 2: TYPICAL VIDS CAMERA INSTALLATION



Theory of operation for VIDS: Electronic pictures are made up of small dot-type picture elements called pixels. VIDS software recognizes changes in pixels from one video frame to the next. When the VIDS is first installed, it must be programmed to mimic loop detectors, identifying which areas of the screen represent the detection zones. Once the VIDS is operational, all fixed pixels that make up the background, including roadside fixtures are deleted, with the exception of detection zones. This is done to simplify the image recognition process as well as to reduce the amount of data processing.

Because of this theory of operation, VIDS are principally utilized to detect vehicles on arterial streets. Although it is possible to capture raw video footage for surveillance purposes, such functionality is limited for a number of reasons. Under a VIDS application once detector positions are established, the camera cannot be moved because the detector positioning will be lost. Then the VIDS detection must be reconfigured. For traditional traffic surveillance systems, video cameras utilize pan, tilt and zoom functions. There is no signal-processing unit in a VIDS detection system to perform these functions.

As with other technologies, VIDS have advantages and disadvantages.

Advantages:

- Since VIDS is based on light, its operation is unaffected by electrical transients generated by power surges or lightning. However, with camera being the highest point at a traffic signal, direct lightning hits are possible.
- With change in intersection geometry, VIDS can be easily repositioned, reprogrammed and reused.
- VIDS effectively competes with other technologies from an installation and maintenance costs basis.
- VIDS is installed outside the pavement, therefore, is not affected by pavement changes and deterioration.
- One VIDS setup can provide multiple detection zones, making this technology cost effective.

Disadvantages:

- Technical studies on the performance of VIDS by Rhodes, et. al.,² found that statistically, VIDS-based detectors produce a higher number of false detections, as well as a higher number of missed detections, than inductive loop detectors. For example, “occlusion” is a major issue resulting in either over or under counting of vehicles, and thus poor data accuracy. Occlusion means that the camera cannot “see” through blocking objects. Thus small vehicles shadowed by trucks are not recognized properly. Additionally, turning vehicles can also block the camera’s view and register false demand because of intersection geometry.
- Low camera angles can cause the vehicle to be missed due to low angle sun glare that overwhelms the iris control of the sensitivity of the camera at sunrise and sunset, particularly in the east or west orientation.
- Detection zones experience changes at nighttime. This is due to vehicle headlights lighting a different part of the pavement detection zone at nighttime.
- Vehicle counting and classification under saturated conditions is suspect since VIDS classifies automobiles with small headways as a large truck-type of vehicle.
- Another study by Baculinao³ found that VIDS effectively increases the vehicle lengths due to camera mounting height. Therefore, the vehicle passage setting in the traffic signal controller requires higher values of green time than those associated with inductive loop detectors.

3. STUDY METHODOLOGY, VIDS DESIGN AND INSTALLATION

The study methodology consisted of three parts: a general meeting and discussion with the VDOT’s management and technical staff; data collection both from VDOT and the field; and an analysis of the data in the FHWA’s Traffic Research Lab (TReL). The following intersections were analyzed in the field.:

- Route 7 at Off ramp from southbound Dulles Toll Road West and Jarrett Valley Road, VDOT intersection number 7150
- Route 7 at Baron Cameron Avenue, VDOT intersection number 7175

- Route 7 at Dranesville Road, VDOT intersection number 7200
- Route 7 at NVCC Campus Drive, VDOT intersection number 7220
- Route 7 at Country Side Boulevard, VDOT intersection number 7230
- Route 7 at Belmont Ridge Drive, VDOT Intersection number 7255

These signalized intersections were selected for field study in consultation with the VDOT technical staff. The selection criteria was such that these sample signals represent the 22 signalized intersections with VIDS out of a total of 36 signalized intersections.

The review team consisted of technical staff from VDOT and from FHWA's Office of Operations R&D, Office of Transportation Management, the Resource Center, and the Virginia Division office. Two days were spent in the field documenting the camera locations, detector configurations at the controller cabinet level and documentation of any unusual geometric and traffic patterns. Over 300 electronic pictures and video clips were also shot for later lab analysis.

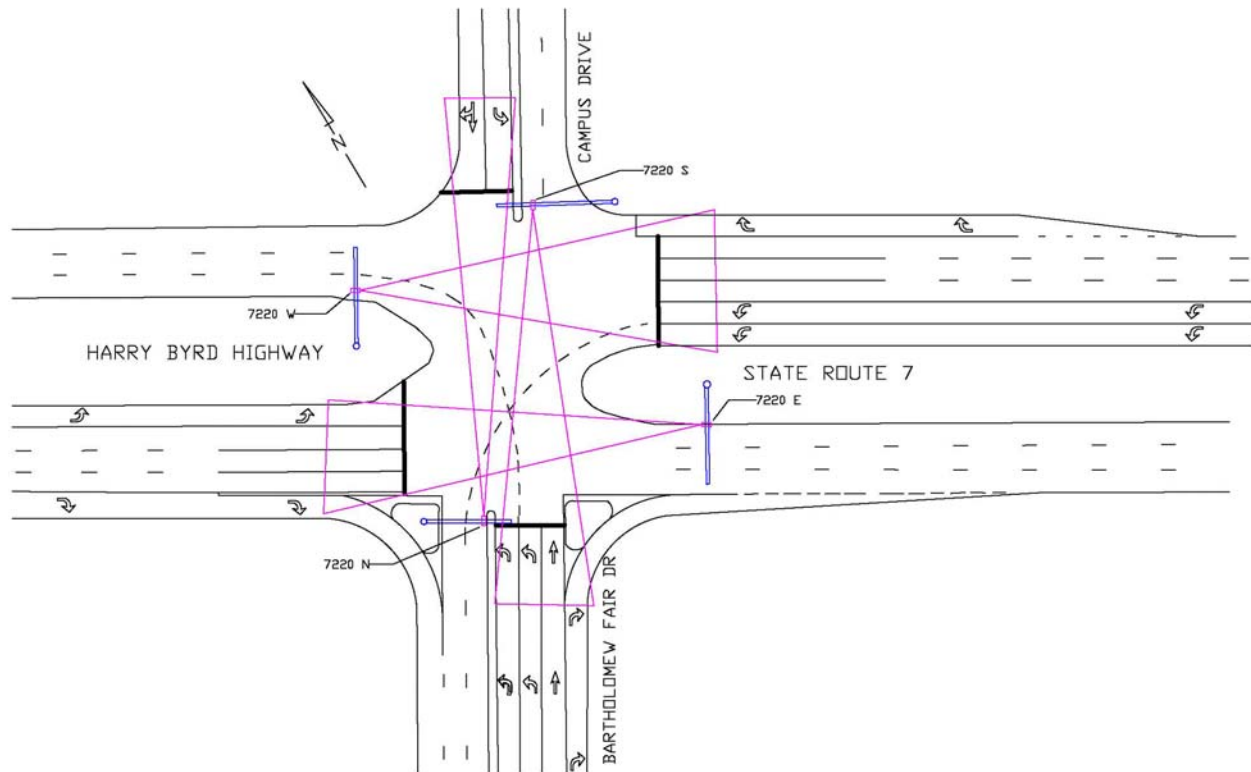
VIDS Design and Installation

The VDOT technical staff, in concert with personnel from the equipment distributor and the installation contractor, performed the VIDS design. The design work consisted principally of field investigation and the identification of VIDS camera locations. The camera locations show lots of commonality, e.g., Route 7 cameras as well as side street cameras are all located on the far side of the approach as shown in Figure 3. The pink triangles show the current camera's view and angle. The number of VIDS and related intersections are indicated in Appendix A.

Analysis of the VIDS design showed several deficiencies. These findings are based on field evaluation of the VIDS system, lab analysis of captured video streams and discussion with the VDOT staff. Typically, a standard, all-purpose video camera should be used to record the view at the proposed VIDS location as part of the installation process. This analysis was not performed on a case-by-case basis for Route 7. Second, the VIDS camera locations show consistency regardless of the intersection geometry. Each camera is located on the far side of the approach. Again, camera location should have been analyzed on an intersection-by-intersection basis.

It is recommended that future VIDS application design be performed on a more detailed basis including the documentation of proposed camera positioning, anticipated view in static and video capture. This type of analysis can serve to point out issues such as occlusion, low sun light intrusion and others at the design stage.

Figure 3: EXISTING VIDS CONFIGURATION



4. ISSUES, RAMIFICATIONS & RECOMMENDATIONS

VDOT has worked with both the manufacturer and the local distributor to overcome the shortcomings of the installed VIDS system. Several software revisions were implemented without resolution of the cited issues. Ultimately, the VIDS installed for detection of side street and left turn movements off Route 7 were disabled.

An analysis of the data showed commonality in detection errors. The major issues, their ramification and a recommended course of action are addressed as follows. A literature search also produced a publication, “*Guidelines for Using Video Detection at Intersections and Interchanges*”⁴ which was used to develop the recommended actions, as well.

It should be noted that not all recommendations apply to each of the 22 affected traffic signals. The recommendations are based on a review of a sample of intersections, technical knowledge and engineering judgment. Each intersection within the study area features unique geometry and traffic operations. Therefore, a detailed intersection-by intersection analysis within these broad recommendations will be required. It is further recommended that these recommendations be field validated at one or two identified intersections before a full-scale effort to implement these recommendations is started.

Using the following technical recommendations, VDOT should select one or more of the affected intersections for analysis. Working with the manufacturer and the local distributor of the VIDS, VDOT should develop a corrective plan for issues associated with the VIDS detectors. An evaluation of the corrective actions should be performed to determine their applicability to other locations. Nevertheless, a similar analysis will be required for each malfunctioning VIDS.

1. VIDS consistently over counts traffic volumes.

Although, the original objective for the VIDS system was to provide signal detection, use of the system for volume, occupancy and other system performance measurements is appropriate. However, VDOT personnel working with the system manufacturer were not able to obtain the specified accuracy of 95%. Use of the over counted data will disrupt the operation of the signal in real-time, as well as skew the data needed for planning purposes. Dissatisfied, the VDOT staff has turned off the system VIDS and returned to using the inductive loops for system detection. The remaining VIDS in operation are being used solely for stop bar detection.

Recommendation: The 95% accuracy metric comes from the loop detector technology and it may not be achievable via VIDS. Therefore, it is recommended that the VIDS not be used for system performance data collection. However, as a minimum, it is recommended that VDOT permit the manufacturer to assess if additional software/hardware modifications are possible to improve the data accuracy.

2. VIDS consistently does not register side street and left turn demand.

It should be noted that VDOT has been using a loop detector system throughout the Route 7 signal systems, prior to the VIDS installation. Due to miscounts VDOT has discontinued the use of VIDS for the side street and left turn movements throughout the Route 7 signal system.

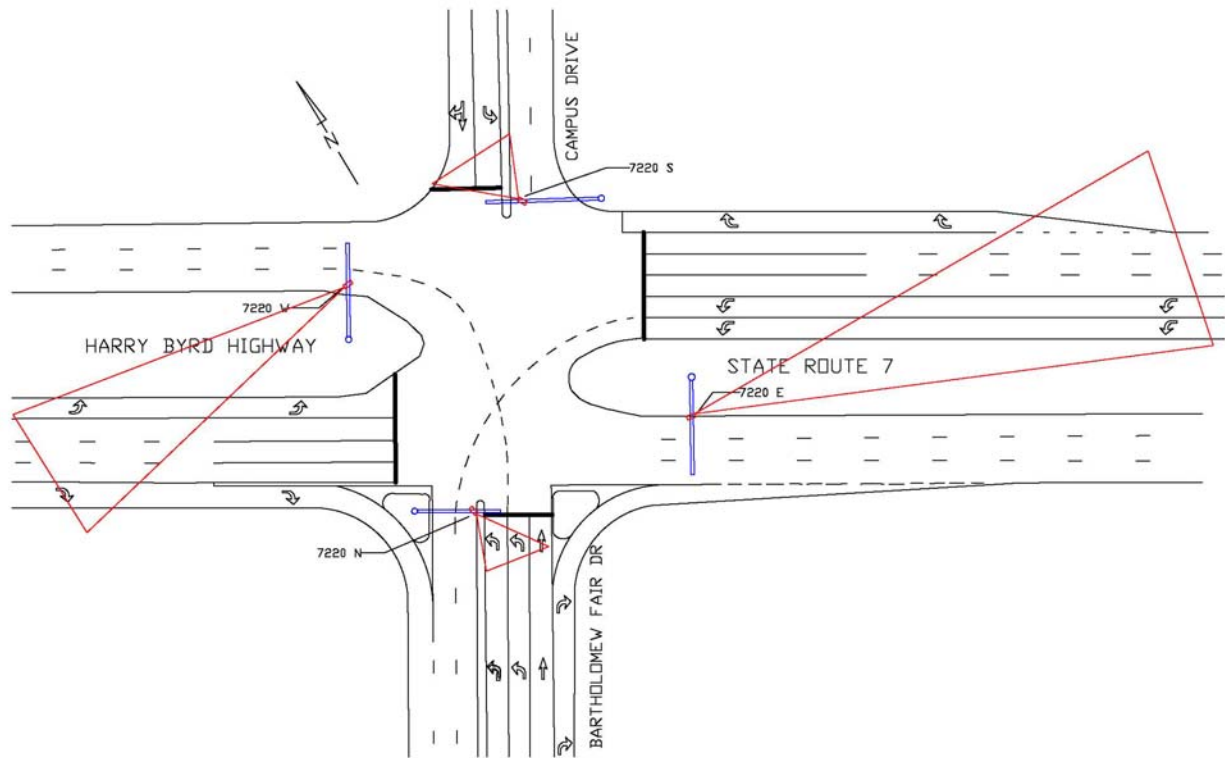
Recommendation: VDOT has switched to the existing loop detectors and should continue their use until there is a resolution of the cited issues. As with recommendation number 1, it is recommended VDOT work with the manufacturer on possible solutions.

3. Occlusion issues occur frequently at the side street VIDS camera locations.

False and missed calls due to occlusion cause the performance of the signal timing to degrade. This is a common problem for most of the signals along Route 7 because the cameras are located on the far side of the intersection.

Recommendation: Rotate the side street cameras 180 degrees horizontally and vertically with the camera pointing to the near side stop line (almost vertically looking down), (Figure 4). Reassign the cameras to the appropriate side street signal phase through software assignment in the signal controller. This realignment should mitigate the missed calls and occlusion on the side streets.

Figure 4: POSSIBLE SOLUTION - CAMERAS ROTATED 180 DEGREES



4. Sunrise and sunset low angle glare causes data errors for the mainline cameras on Route 7.

All 22 signalized intersections have far side VIDS camera for both east and westbound directions of the Route 7. Currently, the cameras are aimed and programmed to pick up traffic data at the Route 7 stop lines. The glare from the low angle of the sun during sunrise and sunset causes significant data errors.

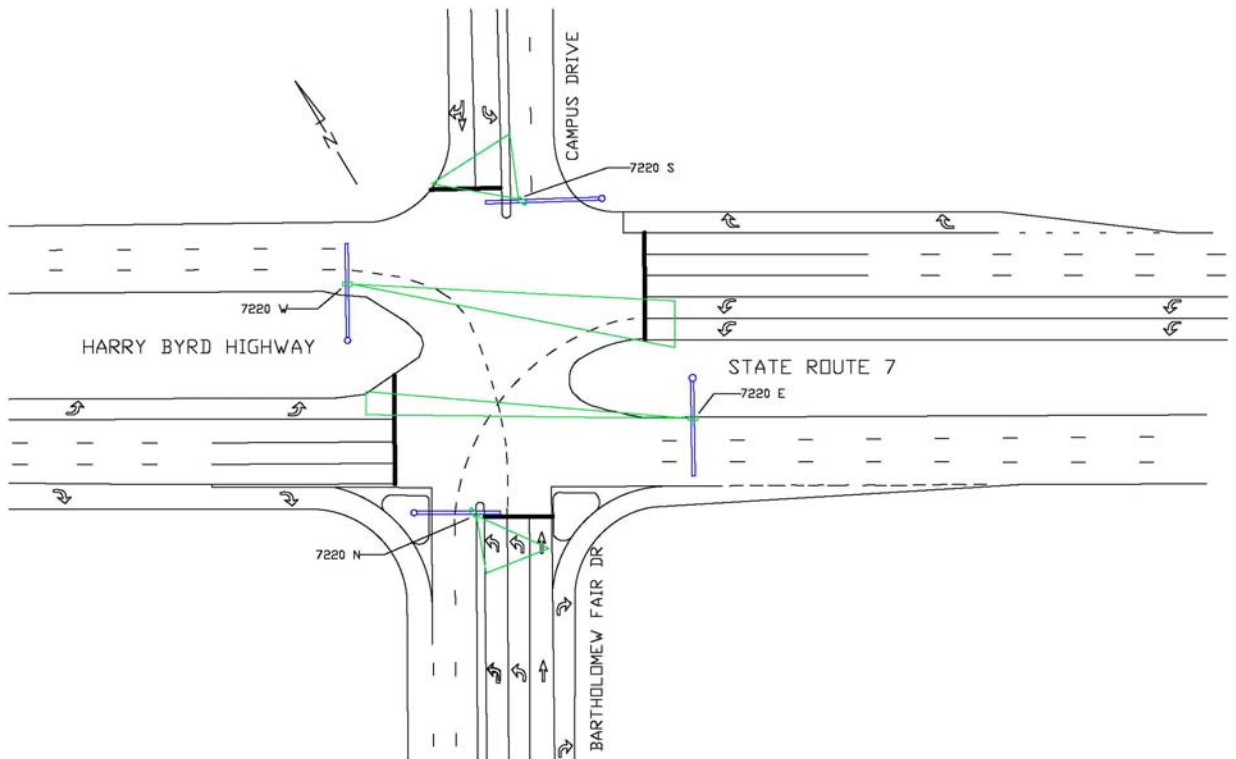
Recommendation: These issues will have to be addressed on an intersection-by-intersection basis, if these VIDS are to be used for any function. However, rotating the cameras 180 degrees horizontally and making using them for near side detection would provide some relief from the sun glare issues (Figure 4). This recommendation cannot be universally applied everywhere due to the variations in the vertical and horizontal alignments of Route 7.

5. Because of the VIDS camera location and programming for Route 7 approaches, these detectors cannot be utilized either as a system detector or as an intersection detector for traffic signal operation.

For system detection the cameras must be pointed at free flow conditions and for intersection operation the cameras must be pointed at the dilemma zones. Therefore, with cameras being aimed at the stop line, they cannot perform either function.

Recommendation: This issue must also be addressed on an intersection-by-intersection basis. A potential use of these cameras can be for the detection of left turn phases only off Route 7. Under this scheme, the cameras will be redirected to the left turn lane stop lines, (Figure 5). However, the deployment of this recommendation will limit the use of Route 7 cameras to the left turn movement detection only.

Figure 5: ROUTE 7 VIDS LEFT TURN BAY ONLY



6. For very wide intersections it is unclear if more than one camera is required for VIDS.

The literature search produced no technical guidance on this subject. Further, recent discussions with Iteris, the VIDS distributor, also produced no substantive guidelines. However, some agencies use more than one camera per approach because of the restrictive intersection geometry or mounting options. Rarely, this is done because of the width of the intersection. The primary advantage to deploying more than one camera per approach is the mitigating effect it has on adjacent lane occlusion by separating the left turn from the through lanes. However, the side street approaches at the Route 7

intersections are split phased, where one direction of a street is shown green before the other direction. With split phasing, multiple cameras would likely have little benefit.

Recommendation: Contact the local VIDS distributor to see if additional cameras might improve the operation.

FUTURE CONSIDERATIONS

Many public agencies, including VDOT, are concerned that the in pavement detectors such as inductive loop detectors are susceptible to pavement failures, resurfacing and milling operations. Given the frequency of such occurrences, it is difficult to maintain a desirable number of detectors for adequate traffic signal operation. Therefore, there is a desire to migrate to other types of technologies such as VIDS. Many jurisdictions including the States of Maryland and New Mexico have decided to use nothing but VIDS. Preliminary observations in the Maryland suburbs of Washington D.C. show the same experience as VDOT. Although, the detector manufacturer in Maryland is different than in Virginia, the issues are the same due to the principles of VIDS technology.

The use of VIDS in traffic signal applications should be limited to signal detection at least for the time being. For applications that require more accurate data, such as the development of signal plans and highway planning applications, inductive loop detectors have proven highly satisfactory. Careful installation as well as installing the loops in the sub base of the pavement also lengthens the service life of the loop detectors. Further, other technologies that are outside the pavement such as radar, microwave and laser should also be evaluated.

VDOT generally concurs with this report's recommendations. Further, both the manufacturer and VDOT are willing to experiment with the recommended VIDS camera repositioning in the field in order to assess any improvements by such experimentation.

FHWA can assist VDOT in the field experimentation, including performance analysis and assessment. It is envisioned that two or three 'typical' intersections be identified for further investigation. Iteris staff have also shown willingness to participate in this process. Based on the outcome of this field trial, additional countermeasures can be developed to increase the accuracy of the balance of the VIDS deployments.

List of References

1. Traffic Devices: Historical Aspects Thereof. ITE Publication No. HB-001, 1971
2. Rhodes, A., Bullock, D., Sturdevant, J., and Clark, Z., Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections. Proceedings from the 84th TRB Annual Meeting, January 9-13, 2005, Washington, D.C.
3. Baculinao, N.M., "Video Detection Technology: Are they ready to replace loops?" 1998 Compendium of Technical Papers. District 6 Meeting-San Diego, California, Institute of Transportation Engineers, Washington, D.C.
4. Bonneson, J., Abbas, M., "Guidelines for Using Video Detection at Intersections and Interchanges", Texas Transportation Institute, Project 0-4285-S, January 2003.

Appendix A

No.	Intersection	Intersection #	Intersection Type				# Camera	Camera Type	Install Date	Activation Date	
			M=Mast S=Span	EB	WB	SB					NB
1	Rt. 7 & Tyson's Blvd	7110	S	1	1	1	1	4	ITERIS	4/6/2005	4/7/2005
2	Rt. 7 & International Dr.	7115	M	1	1			2	ITERIS	1/26/2005	4/7/2005
3	Rt. 7 & West park Dr.	7135	S	1	1	1	1	4	ITERIS	4/5/2005	4/6/2005
4	Rt. 7 & Spring Hill Rd.	7140	M	1	1	1	1	4	ITERIS	1/26/2005	4/6/2005
5	Rt. 7 & Toll Rd. East	7148	M	1	1	1	1	4	ITERIS	12/13/2004	4/1/2005
6	Rt. 7 & Toll Rd. West	7150	M	1	1		1	3	ITERIS	1/26/2005	4/1/2005
7	Rt. 7 & Lewinsville Rd.	7155	M	1	1	1	1	4	ITERIS	11/30/2004	4/4/2005
8	Rt. 7 & Baron Cameron	7175	S	1	1	1	2	5	ITERIS	4/1/2005	4/4/2005
9	Rt. 7 & Reston Pky	7179	M	1	1	1	1	4	ITERIS	11/30/2004	4/7/2005
10	Rt. 7 & Rolling Holly Dr.	7190	M	1	1			2	ITERIS	11/30/2004	3/31/2005
11	Rt. 7 & Drainsville Rd	7200	S	1	1	1	1	4	ITERIS	1/31/2005	3/31/2005
12	Rt. 7 & Lakeland Dr.	7205	M	1	1	1	1	4	ITERIS	12/29/2004	3/23/2005
13	Rt. 7 & Augusta Dr.	7207	M	1	1			2	ITERIS	1/27/2005	3/23/2005
14	Rt. 7 & Sterling Blvd	7210	S	1	1	1	1	4	ITERIS	1/31/2005	3/23/2005
15	Rt. 7 & Potomac View	7215	M	1	1	1	1	4	ITERIS	12/17/2004	3/25/2005
16	Rt. 7 & NOVA Community College Ent.	7220	M	1	1	1	1	4	ITERIS	12/17/2004	3/29/2005
17	Rt. 7 & Country Side	7230	M	1	1	1	1	4	ITERIS	12/17/2004	4/7/2005
18	Rt. 7 & Ashburn Village Blvd.	7246	M	1	1	1	1	4	ITERIS	12/17/2004	3/30/2005
19	Rt. 7 & Belmont Ridge Dr.	7255	M		1	1		2	ITERIS	2/1/2005	3/29/2005
20	Rt. 7 & Lents Mill Rd/Cochran Mill	7260	M	1	1		1	3	ITERIS	3/29/2005	3/30/2005
21	Rt. 7 & Cardinal Dr.	7265	M	1	1	1		3	ITERIS	4/4/2005	4/5/2005
22	Rt. 7 & Lexington Dr.	7247	M	1	1			2	ITERIS	1/27/2005	3/29/2005
Total Install								76			