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# **EVALUATION OF VIDEO DETECTION SYSTEMS VOLUME 3 - EFFECTS OF WINDY CONDITIONS IN THE PERFORMANCE OF VIDEO DETECTION SYSTEMS**

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16. Abstract  The performance of three Video Detection Systems (VDS), namely Autoscope, Iteris, and Peek, was evaluated at stop bar and advance locations, at an instrumented signalized intersection located in Rantoul, Illinois, utilizing a side-by-side installation and large data sets covering a variety of conditions. This report contains the analysis and findings of the VDS performance under windy conditions during cloudy noon, sunny morning, and nighttime. There are three other reports that describe the effects of adverse weather, illumination, and adjusting the configuration of the VDS zones. The performance of the VDS in windy conditions was assessed based on the frequency of false, missed, stuck-on, and dropped calls (errors in detection); and was compared to calm weather scenarios (without wind). Results indicate minor wind effects during cloudy conditions at the stop bar zones, and less than 10% increases in the false calls at advance zones. In the sunny morning scenario (where long shadows were observed) false calls increased significantly at both stop bar (22-39%) and advance zones (20-70%), missed calls increased at advance zones for one VDS, while they decreased for the other two VDS, and stuck-on calls increased by less than 2% due to the shadow of the crossing street pole. At nighttime, false calls increased at stop bar zones (5-53%), and at advance zones (2-27%), and there were small fluctuations in the percentage of missed calls.					
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## **DISCLAIMER**

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## EXECUTIVE SUMMARY

The performance of three Video Detection Systems (VDS) was evaluated at a signalized intersection at both stop bar and advance locations, using a side-by-side installation and large data sets. The brand names of the VDS are: Autoscope, Iteris, and Peek. This report contains the analysis and results of the VDS performance under windy conditions for cloudy noon and sunny morning scenarios, as well as nighttime. This report is part of a series that describe the effects of adverse weather, illumination, and adjusting the configuration of the VDS zones. The performance of the VDS in windy conditions was assessed based on the frequency of false, missed, stuck-on, and dropped calls (errors in detection); and was compared to calm weather scenarios (without wind). Results indicate minor wind effects during cloudy conditions at the stop bar zones, and less than 10% increases in the false calls at advance zones. In the sunny morning scenario (where long shadows were observed) false calls increased significantly at both stop bar (22-39%) and advance zones (20-70%), missed calls increased at advance zones for one VDS, while they decreased for the other two VDS, and stuck-on calls increased by less than 2% due to the shadow of the crossing street pole. At nighttime, false calls increased at stop bar zones (5-53%), and at advance zones (2-27%), and there were small fluctuations in the percentage of missed calls.

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## CHAPTER 1 INTRODUCTION

The use of video detection systems (VDS) at intersections has increased significantly in the last few years. However, despite their increasing popularity, very limited information on their performance in a wide variety of conditions is available.

Previous research has assessed VDS performance under various conditions, such as day time or even night time. One of the earliest evaluations was presented by MacCarley (1998) on the Vantage Video Traffic Detection System (VTDS). Performance was evaluated under twelve conditions, including combinations of weather, time of day, traffic volume and electromagnetic interference. His results showed good performance under ideal lighting and light traffic conditions, but were based on 15-minute data sets. Later in 2001, Minnesota DOT and SRF Consulting Group (MnDOT and SRF 2001) also evaluated the performance of VDS at intersections. In this case Peek Video Trak 900, Autoscope 2004, EVA 2000 and TrafficCam systems were installed at different mounting locations and heights. Similar to the MacCarley study, factors such as shadows (both stationary and moving) and wind were found to affect VDS performance. Grenard, Bullock and Tarko (2001) also evaluated Econolite Autoscope and Peek VideoTrak-905 for their performance at a signalized intersection. Results from overcast, night rain, and partly sunny conditions from three days were presented. It was concluded that night-time detection was a concern and VDS should not be used for dilemma zone protection.

More recently, a study by Rhodes et al. (2006, 2007) that followed the 2001 study by Grenard, Bullock and Tarko indicated significantly more false and missed detections using VDSs than inductive loop detectors. The study installed three systems next to each other: Autoscope (version 8.10), Peek UniTrak (version 2), and Iteris Vantage (Camera CAM-RZ3). Results from two full days of data were analyzed, finding that all the three VDSs had moderate to high degree of missed and false calls and none was superior to the others. An additional publication by Rhodes et al. (2007) evaluated the stochastic variation of activation/deactivation times between day and night condition using data from one day, finding earlier detections at night due to headlight reflection in the pavement.

Thus, the variety of weather and illumination conditions, as well as data collection periods in previous studies seems rather limited. Under such setups, in consequence, it is very difficult to control or to account for specific factors that affect VDS performance, such as sustained periods of wind, sunny, or cloudy conditions.

In this light, the results presented in this paper aim to overcome some of the limitations of previous studies on the performance of VDSs, including: 1) large data sets from multiple days and very specific conditions, 2) multistage analysis procedure that includes automation in the computation of the measures of performance and final visual inspection of every error using video recorded images, and 3) side-by-side installation of the VDS cameras to perform an evaluation using the exact same field data for all three systems.

More specifically, this paper focuses on the VDS performance under windy conditions when the weather is sunny (shadows may be present), cloudy, and during nighttime. Data was carefully chosen to avoid confounding effects of additional factors not analyzed in this paper. For example, data sets from cloudy days were obtained from calm noon hours with no significant wind, no rain, and no cloudy to sunny changes. Also, separate data sets of the cloudy windy condition were collected in different dates under steady windy hours (no cloudy-to-sunny changes) and at the same time of day than data sets for cloudy data without wind. This makes the analysis more precise and allows for the quantification of the true effect of wind on the performance of VDSs.

The subsequent section briefly describes the data collection site and the data collection procedure, followed by the methodology and the analysis of the results. Finally, a summary of the major findings and the conclusions is presented.

## CHAPTER 2 TEST SETUP AND DATA COLLECTION

Video detection systems from three major manufacturers (Image Sensing Systems, Peek Traffic, and Iteris) were installed at the intersection of Century Blvd and Veteran's Pkwy in Rantoul, Illinois. A camera from each system was mounted next to each other on the luminaire arm of the southeast corner of the intersection at a height of approximate 40 ft above the ground, facing the eastbound approach. No vertical extensions were used in this setup. None of these cameras was connected to the actual traffic controller managing the traffic lights, therefore they had no impact on the operation of the intersection and VDSs do not obtain feedback from the signal controller. The layout of the eastbound approach consists of two left-turn lanes and one shared right-through lane (See Figure 2.1). This approach was equipped with six inductive loops 6ft by 6ft in size. Three loops were installed before the stop bar, one on each lane, and the other three were installed at advance locations on all three lanes, about 250ft upstream from the stop bar.

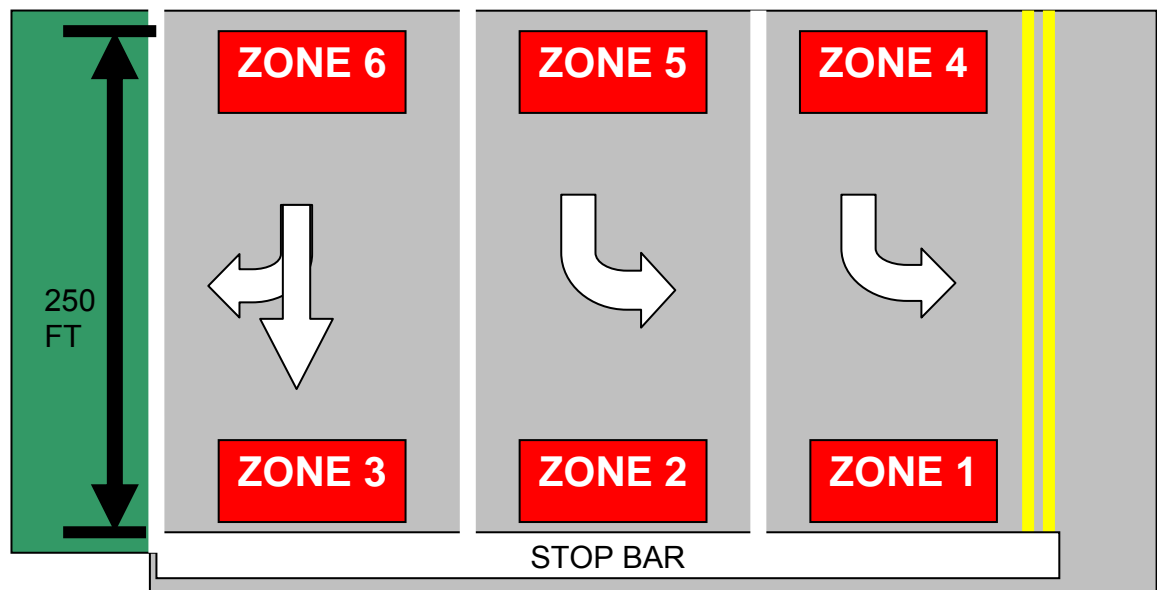


Figure 2.1. Intersection layout.

Video detection systems were configured by the manufacturer or the distributor, using the same arrangement of detection zones the loops had, i.e. with three advance and three stop bar locations. A representative from one of the manufacturers/distributors was present at the evaluation site during the setup. The following product versions were installed: Autoscope (SoloPro with v 8.13), Peek (Unitrak with v 2.2), and Iteris (Edge 2 with v 1.08). In addition, manufacturers/distributors were given two opportunities to improve their configuration after they received preliminary results from daytime and nighttime sent by the research team. The authors believe that modifications after initial installation is normal practice and appropriate. Based on information given by Illinois Department of Transportation staffs, it is not unusual to do modifications to the initial VDS configurations, and the authors are aware of situations that required changes more than once to fine tune the video detection system. Thus, the authors believe that the manufacturers/distributors were given fair amount of opportunity to improve the performance of their system, and that



the final configurations were the result of the best efforts from manufacturer/distributor teams in all three VDSs.

Two types of data were collected: time stamps and video images. Time stamps were the times at which each of the VDS zones and inductive loops were activated or deactivated, and were recorded using a programmable input/output communications processor.

The video data consisted of a quad image showing, in three of the quadrants, images taken by the three VDS cameras after the video had been processed by the company's video card, and in the fourth quadrant, a real-time graphical depiction of the detection states in each VDS zone and loop in the last two minutes. A sample image from the videos is shown in Figure 2.2.

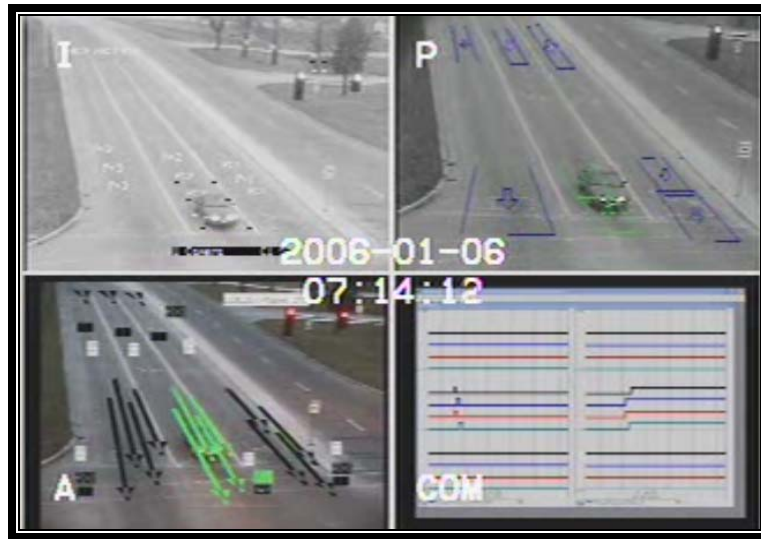


Figure 2.2. Sample quad image.

## CHAPTER 3 DATA ANALYSIS

Four measures of performance (MOEs) were defined to quantify the detection errors from the VDSs and to evaluate their performance: False calls, missed calls, dropped calls, and stuck-on calls. These MOEs were estimated for each detection zone following a two step procedure.

The first step used a computer code developed to read the time stamps from both VDSs and loops and establishing if there was a discrepancy between the two, thus using the loop calls as a reference to locate potential errors in the VDS detections. The second step consisted in visually verifying every potential error by watching the recorded video images at the exact time they occurred.

Since it was important to evaluate the VDSs when they were performing their best, manufacturers/distributors were given the freedom to choose the field of view and zoom level that would yield best performance, given that detection was required on each lane at advance and stop bar locations. The authors believe the freedom to choose their best camera setup provides a fair condition for all three VDSs, and helps avoiding possible bias towards a system that otherwise could have advantages over the others. Thus, activation and deactivation times from VDSs and loops are not expected to match exactly, and it was necessary to define time windows around loop calls or VDS calls in the computer code where the detections are considered acceptable and are not classified as errors.

The concepts used to define the measures of performance, as well as the logic used in the computer code, are briefly discussed as follows:

- Missed calls. These occur when the VDS fails to detect vehicles in the detection zone. These errors have adverse safety effects due to potential red light runners in cases where the corresponding phase is not called by the controller. In terms of time stamps, for every loop call if there is no corresponding VDS call in a window that starts “X” seconds before the start of loop call and ends “Y” seconds after the end of the loop call, it is considered a potential missed call.
- False Calls. These are defined as calls placed by the VDS when there was no vehicle in the detection zone, having a potential negative effect in the operational efficiency of the intersection. In the algorithm, for every call by a VDS, if there is no corresponding call from the loop detector in a window that starts “X” seconds before the beginning of the VDS call and ends “Y” seconds after the VDS call is dropped, it is considered a potential false call.
- Dropped calls. These occur when a call by the VDS is dropped even while the vehicle is still present in the detection zone. If VDSs prematurely drop the call placed to the controller, this may prevent the corresponding phase from being called, generating potential safety issues due to red light runners. In terms of time stamps, if the VDS call is terminated more than “X” seconds before the end of loop call, it is considered as a potential dropped call.
- Stuck-on calls. These are defined as those calls which are held by the VDS (after detecting the vehicle correctly) after the departure of the vehicle from the detection zone. Stuck-on calls affect operational efficiency of the signalized intersection. In the algorithm, if a VDS call continues to be active more than “X” seconds after the end of the loop call, it is counted as a stuck-on call.

Values assigned for the acceptable windows (X, Y) varied depending on the location and size of their detection zones. Different thresholds were used to avoid unfair classification of calls as errors (false, missed, stuck-on, or dropped calls) when they actually were not. From Figure 2.2, it is clearly seen that some zones are longer and closer to the

stop bar in the back and shorter in the front compared to other. These differences translate in vehicle detections starting at slightly different time and in calls not having the exact same duration as those from the other two systems. The selected time windows (X and Y values) were obtained to work for day and night conditions based on calibration and validation efforts that used day and night data. Calibration was performed by matching the errors from the computer code with the errors from manual verification of the videos; finally, for validation, results from the calibrated computer code matched those from a manual verification using data sets different from the ones in the calibration process. Final X and Y values after validation are showed in Table 3-1.

Table 3.1. X and Y Values for Estimating Potential Errors

Location	MOE					
	Missed Calls		False Calls		Dropped Call	Stuck-on Call
	X	Y	X	Y	X	X
<b>Stop Bar</b>	2(3*)	1(0*)	1(1*)	2(3*)	5	10
<b>Advance</b>	1(0*)	2(4*)	3(5*)	1(0*)	5	10

\* Peek Values; \*\* All values in seconds

It is noted that no errors were observed in the loop detection. Had any loop error occurred, it would have been identified since it would have created a discrepancy with the VDSs. Also, the manual verification process that took place would have prevented any loop error from having effects in the evaluation of the VDS performance.

## CHAPTER 4 RESULTS AND ANALYSIS

The results for the following three conditions were evaluated to determine effects of wind in the performance of the VDSs, and are presented in this section:

- Wind in Cloudy Noon Conditions
- Wind in Sunny Morning Conditions
- Wind in Nighttime

The results from each of these conditions are compared against a base condition to obtain the net change in performance. The base condition was selected as the scenario with most favorable weather conditions. For the wind effects during the daytime the base condition is the VDSs performance in a cloudy day around noon; and for the nighttime the base is the calm night condition. In both of the base conditions, there were no wind or any other adverse weather related factors.

The performances presented in this Chapter are analyzed when the data sets from different days but same condition were aggregated into one single data set to represent each condition. The performance for each day is also presented in Appendix I of this report, for the reader to observe how much variation was measured from one day to another.

Statistical comparisons were made between the evaluated condition and the base condition using Z tests for proportions. A confidence level of 95% is used to interpret the test result. Also, Z values are included for all comparisons so the interpretation of the test can easily be adjusted based on a different confidence level.

It is noted that very few dropped calls were found in the base data sets and the windy conditions presented in this report. Dropped calls were observed only at stop bar zones, with three occurrences in nighttime one in daytime, and all of them in the base condition. No dropped calls were observed in the windy conditions. The following sections describe and analyze the VDS performance in terms of the other three types of errors defined in this study: false, missed, and stuck-on calls.

### 4.1 WIND IN CLOUDY NOON CONDITIONS

#### 4.1.1 Stop Bar Zones

##### 4.1.1.1 False Calls

The windy condition increased false calls in Iteris, from 5.7% to 8.1% for all stop bar zones combined. However, for Autoscope and Peek, the false calls remained close to the performance in cloudy noon conditions at 3.9% and 6.9%, respectively.

At the individual zone level, it is noted that the increase in false calls for Iteris comes from Zone 1, which changed from 15.1% to 21.4% and it was caused by turning vehicles generating false calls that went on and off repeated times (mostly due to camera movement). The decrease observed in Zone 1 for Autoscope was not due to the wind itself, but to the combination of turning vehicles, which favored the lower occurrence of false calls for this particular system.

Table 4.1. False Calls in Windy Noon and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind	1634	3.9%	-0.57	Not Significant	1938	6.9%	0.11	Not Significant	1808	8.1%	-2.83	Increased
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Wind	492	5.5%	2.38	Decreased	627	19.3%	0.52	Not Significant	618	21.4%	-2.77	Increased
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Wind	607	3.1%	-2.83	Increased	692	1.2%	-0.28	Not Significant	642	2.0%	0.40	Not Significant
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Wind	535	3.4%	-2.68	Increased	619	0.6%	-1.34	Not Significant	548	0.4%	-0.57	Not Significant
	Base	515	1.0%			615	0.2%			544	0.2%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

Zones 2 and 3 were not affected by wind in Iteris and Peek, but it showed small increases in false calls for Autoscope, with 3.1% in Zone 2 and 3.4% in Zone 3. These were due to camera vibration that suddenly moved portions of the detection zone over the white stripes of the traveled lanes or the painted crosswalk, creating a change in contrast and the resulting false calls.

#### 4.1.1.2 Missed Calls

No significant changes were observed in missed calls in any zone or VDS compared to the base condition. The only system that had missed calls in the windy condition was Peek, with one missed vehicle in Zone 2 (a motorcycle) and four more missed in Zone 3 (two of them motorcycles).

Table 4.2. Missed Calls in Windy Noon and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind	2049	0.0%	0.00	Not Significant	2049	0.2%	-1.64	Not Significant	2049	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Wind	568	0.0%	0.00	Not Significant	568	0.0%	0.00	Not Significant	568	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Wind	805	0.0%	0.00	Not Significant	805	0.1%	-1.00	Not Significant	805	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Wind	676	0.0%	0.00	Not Significant	676	0.6%	-1.34	Not Significant	676	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops

#### 4.1.1.3 Stuck-on Calls

Stuck-on calls did not have any significant change in the windy condition, remaining zero for Iteris and Peek, and representing only 0.4% if the calls in Autoscope (4 stuck-on calls in Zone 1 and two in Zone 2). The four stuck-on calls in Zone 1 lasted 11 seconds to 12 seconds each, and the two stuck-on calls in Zone 2 lasted 30 seconds and 37 seconds.

Table 4.3. Stuck-on Calls in Windy Noon and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind	1634	0.4%	-1.38	Not Significant	1938	0.0%	0.00	Not Significant	1808	0.0%	0.00	Not Significant
	Base	1584	0.1%		Significant	1928	0.0%		Significant	1730	0.0%		
Zone 1	Wind	492	0.8%	-1.33	Not Significant	627	0.0%	0.00	Not Significant	618	0.0%	0.00	Not Significant
	Base	484	0.2%		Significant	615	0.0%		Significant	549	0.0%		
Zone 2	Wind	607	0.3%	-1.42	Not Significant	692	0.0%	0.00	Not Significant	642	0.0%	0.00	Not Significant
	Base	585	0.0%		Significant	698	0.0%		Significant	637	0.0%		
Zone 3	Wind	535	0.0%	1.00	Not Significant	619	0.0%	0.00	Not Significant	548	0.0%	0.00	Not Significant
	Base	515	0.2%		Significant	615	0.0%		Significant	544	0.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system

### 1.1.1 Advance Zones

#### 4.1.2.1 False Calls

Table 4.4. False Calls in Windy Noon and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind	2000	3.1%	-3.04	Increased	1970	9.5%	-4.06	Increased	2339	15.2%	-11.57	Increased
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Wind	472	4.2%	0.45	Not Significant	567	16.0%	0.76	Not Significant	593	14.3%	-1.18	Not Significant
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Wind	891	4.6%	-4.82	Increased	759	8.8%	-5.49	Increased	859	4.7%	-1.42	Not Significant
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Wind	637	0.2%	0.57	Not Significant	644	4.7%	-5.32	Increased	887	26.0%	-16.50	Increased
	Base	642	0.3%			634	0.2%			645	0.9%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

False calls increased significantly for all systems in the windy condition. Combining all advance zones Autoscope had 3.1% false calls, Peek had 9.5% and Iteris had 15.2%. However, not all systems were affected in the same zones. Autoscope only had increases in Zone 5, Peek in zones 5 and 6, and Iteris only in Zone 6. The highest increase was observed for Iteris, coming from Zone 6.

#### 4.1.2.2 Missed Calls

Missed calls in the windy condition changed for Peek and Iteris, with no change for Autoscope. An increase of 1.7% was observed for all Peek zones combined, resulting from 34 vehicles missed in Zone 5, 11 vehicles missed in Zone 4, and 4 more in Zone 6. As a comparison, a total of 14 vehicles were missed in the base condition for all advance zones in Peek.

For Iteris the situation was the opposite, with lower number of vehicles missed in the wind (total 15), compared to 36 vehicles missed in the base condition. Observation of video

images from the intersection did not provide insights about possible reasons for such decrease in Iteris, or increase in Peek.

Table 4.5. Missed Calls in Windy Noon and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind	2161	1.2%	-0.92	Not Significant	2161	2.3%	-4.48	Increased	2161	0.7%	2.93	Decreased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Wind	521	1.0%	0.86	Not Significant	521	2.1%	-3.35	Increased	521	0.2%	1.91	Not Significant
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Wind	949	1.4%	-1.42	Not Significant	949	3.6%	-3.76	Increased	949	1.4%	2.26	Decreased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Wind	691	1.2%	-0.81	Not Significant	691	0.6%	0.02	Not Significant	691	0.1%	0.59	Not Significant
	Base	681	0.7%			681	0.6%			681	0.3%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops

### Stuck-on Calls

Very small changes were observed in the wind condition, where no stuck-on calls were observed for Iteris and Peek, but a few on Autoscope (0.4%). This 0.4% represented 7 stuck-on calls, three of them from Zone 5 ( $\leq 23$  secs each), three from Zone 6 ( $\leq 34$  secs each), and one from Zone 4 (68 seconds). The causes for the stuck-on calls were not clear from the manual verification of the videos.

Table 4.6. Stuck-on Calls in Windy Noon and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind	2000	0.4%	-2.13	Increased	1970	0.0%	0.00	Not Significant	2339	0.0%	0.00	Not Significant
	Base	2011	0.0%			2033	0.0%			2065	0.0%		
Zone 4	Wind	472	0.2%	-1.00	Not Significant	567	0.0%	0.00	Not Significant	593	0.0%	0.00	Not Significant
	Base	474	0.0%			581	0.0%			575	0.0%		
Zone 5	Wind	891	0.3%	-1.73	Not Significant	759	0.0%	0.00	Not Significant	859	0.0%	0.00	Not Significant
	Base	895	0.0%			818	0.0%			845	0.0%		
Zone 6	Wind	637	0.5%	-1.01	Not Significant	644	0.0%	0.00	Not Significant	887	0.0%	0.00	Not Significant
	Base	642	0.2%			634	0.0%			645	0.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system

## 4.2 WIND IN SUNNY MORNING CONDITIONS

### 4.2.1 Stop Bar Zones

#### 4.2.1.1 False Calls

False calls for all stop bar zones in the three VDSs increased in sunny mornings with wind compared to those in the base condition. For all zones combined, Autoscope increased from 3.5% to 25.3%, Peek increased from 7% to 43.3%, and Iteris increased from 5.7% to 44.7%.

For Zone 1, the average percentage of false calls in calm sunny mornings for all VDSs varied from 20% to 25%, whereas in windy conditions these averages ranged from 34% to 50%. Most of the false calls in the base condition occurred due to the image of the vehicles (especially tall vehicles) falling over the VDS zone. This affected mostly Zone 1, when vehicles making sharp left turns from the center lane occupied a portion of Zone 1, placing at least one false call. Similar situations occurred in windy conditions, but given that the camera image vibrated due to the wind, some of the false calls went off and on back again repeated times. This had a multiplying effect on the false calls that further increased the errors. So, for the same vehicle in the adjacent lane, several false calls could be placed depending on the wind and the amplitude of the camera movement.

Table 4.7. False Calls in Windy Sunny Morning and Base Conditions at Stop Bar Zones

		False Calls											
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind + Shadows	1656	25.3%	-18.68	Increased	2547	43.3%	-31.85	Increased	2620	44.7%	-34.78	Increased
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Wind + Shadows	604	35.3%	-10.92	Increased	664	34.0%	-5.51	Increased	1134	57.4%	-19.94	Increased
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Wind + Shadows	628	27.5%	-14.63	Increased	612	18.3%	-10.75	Increased	1073	47.6%	-27.61	Increased
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Wind + Shadows	424	7.8%	-4.96	Increased	1271	60.1%	-43.33	Increased	413	2.2%	-2.69	Increased
	Base	515	1.0%			615	0.2%			544	0.2%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

In Zone 2, there were between 0.9% and 2.4% false calls in the base condition and these increased to 18.3% to 47.6% in the windy condition. The increase in false calls during windy conditions is due to repeated calls from the same vehicle as the camera image moves because of the wind, similar to Zone 1. However, note that for all three systems, the percentage of false calls in Zone 2 is lower than in Zone 1. This is expected since for Zone 2 vehicles on the adjacent lane either go through or turn right, thus there are no false calls due to turning vehicles, as in Zone 1.

Zone 3 was also affected by wind but in lesser proportion than other zones. False calls in this zone changed from being very rare in the base condition ( $\leq 1\%$ ) to errors between 2.2% and 60.1% in the sunny windy morning condition. Most of these false calls were caused by camera vibration that made the edge of the zone (especially for Peek) partially fall over the edge of the curb, generating a change in contrast that was detected as a vehicle.

#### 4.2.1.2 Missed Calls

Windy condition did not have any effect on the missed calls of Autoscope and Iteris, but showed an increase in Peek (0.7%) for all zones combined. Changes in Peek were caused by more vehicles missed in Zone 3, where missed calls increased from 0.1% (1 missed vehicle) to about 2.4% (11 vehicles missed). From manual verification of the video tapes the exact cause for missing these vehicles was not clear.



Table 4.8. Missed Calls in Windy Sunny Morning and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind + Shadows	1500	0.0%	0.00	Not Significant	1500	0.7%	-3.04	Increased	1500	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Wind + Shadows	461	0.0%	0.00	Not Significant	461	0.0%	0.00	Not Significant	461	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Wind + Shadows	579	0.0%	0.00	Not Significant	579	0.0%	0.00	Not Significant	579	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Wind + Shadows	460	0.0%	0.00	Not Significant	460	2.4%	-3.08	Increased	460	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops

#### 4.2.1.3 Stuck-on Calls

Each VDS was affected differently in sunny windy condition in terms of stuck-on calls. For Autoscope, a significant increase was observed for all stop bar zones combined, from 0.1% to 1.6%, with most of these stuck-on calls were generated in Zone 2 (19 out of 27). For Peek, stuck-on calls also increased for all stop bar zones combined, from 0% to 0.5%, coming mainly from zones 1 (8 stuck-on calls) and 2 (5 stuck-on calls). The reason behind these stuck-on calls was in large part the shadow coming from the pole of the crossing street, which fell across the three traveled lanes and had the potential to affect all three VDS zones (as illustrated in Figure 4.1).

On the other hand, no significant changes were observed in Iteris, showing only little changes due to the shadow from the pole.

Table 4.9. Stuck-on Calls in Windy Sunny Morning and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind + Shadows	1656	1.6%	-4.64	Increased	2547	0.5%	-3.75	Increased	2620	0.1%	-1.73	Not Significant
	Base	1584	0.1%			1928	0.0%			1730	0.0%		
Zone 1	Wind + Shadows	604	0.5%	-0.82	Not Significant	664	1.2%	-2.84	Increased	1134	0.0%	0.00	Not Significant
	Base	484	0.2%			615	0.0%			549	0.0%		
Zone 2	Wind + Shadows	628	3.0%	-4.42	Increased	612	0.8%	-2.24	Increased	1073	0.3%	-1.73	Not Significant
	Base	585	0.0%			698	0.0%			637	0.0%		
Zone 3	Wind + Shadows	424	1.2%	-1.76	Not Significant	1271	0.1%	-1.00	Not Significant	413	0.0%	0.00	Not Significant
	Base	515	0.2%			615	0.0%			544	0.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system



Figure 4.1. Sample image of stuck-on calls caused by shadow of mast arm from crossing street.

## 4.2.2 Advance Zones

### 4.2.2.1 False Calls

False Calls increased significantly for all systems, with a particularly higher increase for Iteris. Combining all advance zones, average false calls for Autoscope increased from 1.6% to 25.6%, for Peek increased from 6.1% to 25.9%, and for Iteris from 5% to 74.6%. Most false calls for Autoscope and Peek were generated in zones 4 and 5, while for Iteris these came from Zone 6.

The presence of both shadows and wind clearly increased the false calls when vehicle shadows fell over the zones and the zone went on and off repeated times. This situation was observed in zones 4 and 5 due to shadows from vehicles on the center and the right-true lane, respectively, and caused most of the false calls. In Iteris in Zone 6, most of the false calls were generated when the zone was moved due to the wind and its edge reached the short shadow that the curb projected over the pavement. This rather specific case generated literally hundreds of false calls over the 10 hour period analyzed.

Table 4.10. False Calls in Windy Sunny Morning and Base Conditions at Advance Zones

		False Calls											
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind + Shadows	1929	25.6%	-23.19	Increased	1790	25.9%	-17.03	Increased	5813	74.6%	-93.30	Increased
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Wind + Shadows	733	42.8%	-18.27	Increased	601	35.4%	-7.04	Increased	1018	58.6%	-22.69	Increased
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Wind + Shadows	790	22.4%	-14.18	Increased	792	29.9%	-16.02	Increased	902	35.8%	-18.98	Increased
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Wind + Shadows	406	0.7%	-0.89	Not Significant	397	3.5%	-3.58	Increased	3893	87.7%	-133.83	Increased
	Base	642	0.3%			634	0.2%			645	0.9%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

#### 4.2.2.2 Missed Calls

Results from sunny windy conditions showed mixed trends in terms of missed calls. For all advance zones combined, Autoscope and Iteris had significant decreases in missed calls, but Peek had an increase on them. Even though these changes may seem relatively small (2.4% for Peek, -1.4% in Iteris, and -0.9% in Autoscope), they translate to a considerable number of vehicles. For Autoscope, the reduction in missed calls represented a change of 20 missed vehicles in the base condition compared to no missed vehicles in the sunny windy condition. Also, for Iteris these changes represented missing only 5 vehicles in sunny windy condition compared to 36 vehicles in the base scenario. For Peek it increased from missing 14 vehicles in all advance zones together, to missing 47 vehicles. Manual verification of the videos did not show evidence of possible causes for the increase in missed calls for Peek.

Table 4.11. Missed Calls in Windy Sunny Morning and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind + Shadows	1592	0.0%	4.49	Decreased	1592	3.0%	-5.05	Increased	1592	0.3%	4.36	Decreased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Wind + Shadows	447	0.0%	2.85	Decreased	447	5.6%	-5.14	Increased	447	0.0%	2.46	Decreased
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Wind + Shadows	715	0.0%	2.65	Decreased	715	2.5%	-2.25	Increased	715	0.7%	3.49	Decreased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Wind + Shadows	430	0.0%	2.24	Decreased	430	0.9%	-0.63	Not Significant	430	0.0%	1.42	Not Significant
	Base	681	0.7%			681	0.6%			681	0.3%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops

#### 4.2.2.3 Stuck-on Calls

No stuck-on calls were observed during the base or the sunny windy conditions, indicating no effects in terms of this error.

Table 4.12. Stuck-on Calls in Windy Sunny Morning and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind + Shadows	1929	0.0%	1.00	Not Significant	1790	0.0%	0.00	Not Significant	5813	0.0%	0.00	Not Significant
	Base	2011	0.0%			2033	0.0%			2065	0.0%		
Zone 4	Wind + Shadows	733	0.0%	0.00	Not Significant	601	0.0%	0.00	Not Significant	1018	0.0%	0.00	Not Significant
	Base	474	0.0%			581	0.0%			575	0.0%		
Zone 5	Wind + Shadows	790	0.0%	0.00	Not Significant	792	0.0%	0.00	Not Significant	902	0.0%	0.00	Not Significant
	Base	895	0.0%			818	0.0%			845	0.0%		
Zone 6	Wind + Shadows	406	0.0%	1.00	Not Significant	397	0.0%	0.00	Not Significant	3893	0.0%	0.00	Not Significant
	Base	642	0.2%			634	0.0%			645	0.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system

## 4.3 WIND IN NIGHTTIME

### 4.3.1 Stop Bar Zones

#### 4.3.1.1 False Calls

False calls during night time increased significantly in windy conditions for all three systems. For all stop bar zones combined, false calls in Autoscope increased from 29.5% to 34.6%, in Peek from 8.5% to 11.5%, and in Iteris from 6.2% to 59.2%.

Table 4.13. False Calls in Windy Night and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind at Night	1584	34.6%	-3.18	Increased	1246	11.5%	-2.58	Increased	2563	59.2%	-45.62	Increased
	Base	1801	29.5%			1616	8.5%			1411	6.2%		
Zone 1	Wind at Night	392	32.9%	-8.37	Increased	358	4.2%	2.02	Decreased	1346	78.8%	-34.77	Increased
	Base	366	9.3%			502	7.4%			383	11.0%		
Zone 2	Wind at Night	540	33.7%	0.35	Not Significant	603	20.2%	-3.12	Increased	668	48.4%	-19.68	Increased
	Base	707	34.7%			720	13.8%			513	5.5%		
Zone 3	Wind at Night	652	36.3%	-0.67	Not Significant	285	2.1%	-1.73	Increased	549	24.6%	-10.64	Increased
	Base	728	34.6%			394	0.5%			515	3.3%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

In Zone 1 false calls greatly increased for Iteris, from 11% to 78.8%, and for Autoscope, from 9.3% to 32.9%. For Peek, a decrease occurred showing its lower sensitivity to the effects of wind in nighttime. It should be noted that for Iteris, and to lesser degree for Autoscope, Zone 1 repeatedly hit the edge of the raised median when the camera image oscillated, creating such increase in the false calls.

For zones 2 and 3, Iteris also had the greater increases (42.9% and 21.3%) compared Peek (6.4% and 1.6%) and Autoscope. Iteris was affected the most by the wind, generating false calls when camera vibrated and small portions of the zone moved over the painted lane markings.

#### 4.3.1.2 Missed Calls

No significant changes in missed calls were observed for Autoscope and Iteris. However, an increase was observed for Peek in Zone 3 (26.6%), which already had a very high missing rate in the night condition (19.1%). The 26.6% represented 126 vehicles missed during night time, out of which about 90% went straight through the intersection and 10% were right turners. The reasons Peek missed the through vehicles were not clear from the videos, but some right turners were missed when the vehicles aligned in the direction of the turning movement, pointing their headlights away from the camera field of view.

Table 4.14. Missed Calls in Windy Night and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind at Night	1186	0.0%	0.00	Not Significant	1186	10.7%	-3.07	Increased	1186	0.0%	0.00	Not Significant
	Base	1538	0.0%			1538	7.3%			1538	0.0%		
Zone 1	Wind at Night	294	0.0%	0.00	Not Significant	294	0.0%	0.00	Not Significant	294	0.0%	0.00	Not Significant
	Base	391	0.0%			391	0.0%			391	0.0%		
Zone 2	Wind at Night	419	0.0%	0.00	Not Significant	419	0.2%	-1.00	Not Significant	419	0.0%	0.00	Not Significant
	Base	561	0.0%			561	0.0%			561	0.0%		
Zone 3	Wind at Night	473	0.0%	0.00	Not Significant	473	26.6%	-2.89	Increased	473	0.0%	0.00	Not Significant
	Base	586	0.0%			586	19.1%			586	0.0%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops

#### 4.3.1.3 Stuck-on Calls

No significant changes in stuck-on calls were observed in the windy condition for Autoscope and Peek, but for Iteris there was a 2.5% decrease in stuck-on calls (35 stuck-on calls). The decrease indicates a positive effect of wind on stuck-on calls, possibly because the camera movement helped to end the stuck calls.

Table 4.15. Stuck-on Calls in Windy Night and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Wind at Night	1584	0.0%	1.73	Not Significant	1246	0.0%	0.00	Not Significant	2563	0.0%	5.99	Decreased
	Base	1801	0.2%			1616	0.0%			1411	2.5%		
Zone 1	Wind at Night	392	0.0%	0.00	Not Significant	358	0.0%	0.00	Not Significant	1346	0.0%	0.00	Not Significant
	Base	366	0.0%			502	0.0%			383	0.0%		
Zone 2	Wind at Night	540	0.0%	1.42	Not Significant	603	0.0%	0.00	Not Significant	668	0.0%	5.64	Decreased
	Base	707	0.3%			720	0.0%			513	5.8%		
Zone 3	Wind at Night	652	0.0%	1.00	Not Significant	285	0.0%	0.00	Not Significant	549	0.0%	2.24	Decreased
	Base	728	0.1%			394	0.0%			515	1.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system

#### 4.3.2 Advance Zones

##### 4.3.2.1 False Calls

A significant increase in the false calls was observed for all systems. When looking at all advance zones combined, false calls in Autoscope increased by 7.2%, in Peek increased by 2.3%, and in Iteris by 28.3%. Iteris showed the greatest increases in false calls due to wind, mostly due to the zone hitting the edge of static objects such as the curb, the raised median, and the white stripes dividing the traveled lanes.

Table 4.16. False Calls in Windy Night and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind at Night	1704	33.0%	-4.85	Increased	1090	5.6%	-2.75	Increased	1851	33.6%	-23.08	Increased
	Base	2066	25.8%			1432	3.3%			1708	5.3%		
Zone 4	Wind at Night	259	1.9%	-1.02	Not Significant	279	6.8%	2.46	Decrease	345	28.1%	-3.93	Increased
	Base	332	0.9%			370	12.4%			424	16.3%		
Zone 5	Wind at Night	611	25.7%	-3.39	Increased	360	5.6%	-4.60	Increased	602	12.3%	-6.58	Increased
	Base	764	18.1%			519	0.0%			751	2.7%		
Zone 6	Wind at Night	834	48.0%	-3.27	Not Significant	451	4.9%	-4.55	Increased	904	49.9%	-29.39	Increased
	Base	970	40.3%			543	0.2%			533	0.4%		

\* The percentage of false calls is computed based on the total number of calls placed by the VD system

#### 4.3.2.2 Missed Calls

Missed calls were increased in windy night condition for Autoscope and Peek, with no significant change for Iteris in any of the advance zones. Increases in Autoscope (from 0.1% to 0.7%) represented a change from 2 vehicles missed with no wind, to a total of 9 vehicles missed with wind, two of which occurred in Zone 5 and the other seven in Zone 6. Out of these vehicles, the two vehicles missed in Zone 5 and three others from Zone 6 were caused by too much glare on the camera image due to headlight of approaching vehicles (see Figure 4.2), while the rest four vehicles were traveled directly over the zone without an obvious reason for being missed.

Table 4.17. Missed Calls in Windy Night and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind at Night	1272	0.7%	-2.33	Increased	1272	4.6%	-3.92	Increased	1272	0.5%	-1.65	Not Significant
	Base	1623	0.1%			1623	1.9%			1623	0.1%		
Zone 4	Wind at Night	302	0.0%	0.00	Not Significant	302	0.3%	0.47	Not Significant	302	0.7%	-1.42	Not Significant
	Base	348	0.0%			348	0.6%			348	0.0%		
Zone 5	Wind at Night	497	0.4%	-0.80	Not Significant	497	9.1%	-4.26	Increased	497	0.8%	-1.54	Not Significant
	Base	686	0.1%			686	2.9%			686	0.1%		
Zone 6	Wind at Night	473	1.5%	-2.25	Increased	473	2.5%	-1.14	Not Significant	473	0.0%	1.00	Not Significant
	Base	589	0.2%			589	1.5%			589	0.2%		

\* The percentage of missed calls is computed based on the total number of calls placed by the loops



Figure 4.2. Sample image of missed call due to reflection of headlights.

For Peek, 4.6% of the total vehicles in all three advance zones combined were missed (58 vehicles). Most of these vehicles were missed by Zone 5 (45 vehicles) and traveled over the detection zone without placing a call. Only one vehicle was missed in Zone 4, and the rest 12 vehicles were missed by Zone 6. No particular pattern (vehicle type or color) could be identified as a cause to missing calls in Peek.

#### 4.3.2.3 Stuck-on Calls

No significant changes were observed on the advance zones, with no stuck-on calls in Peek and Iteris and only one in Autoscope in Zone 6 (lasting 13 sec). In the base condition, two stuck-on calls were also observed in Autoscope in Zone 6, lasting 13 sec and 29 sec.

Table 4.18. Stuck-on Calls in Windy Night and Base Conditions at Advance Zones

		Stuck-on Calls											
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Wind at Night	1704	0.1%	0.42	Not Significant	1090	0.0%	0.00	Not Significant	1851	0.0%	0.00	Not Significant
	Base	2066	0.1%			1432	0.0%			1708	0.0%		
Zone 4	Wind at Night	259	0.0%	0.00	Not Significant	279	0.0%	0.00	Not Significant	345	0.0%	0.00	Not Significant
	Base	332	0.0%			370	0.0%			424	0.0%		
Zone 5	Wind at Night	611	0.0%	0.00	Not Significant	360	0.0%	0.00	Not Significant	602	0.0%	0.00	Not Significant
	Base	764	0.0%			519	0.0%			751	0.0%		
Zone 6	Wind at Night	834	0.1%	0.46	Not Significant	451	0.0%	0.00	Not Significant	904	0.0%	0.00	Not Significant
	Base	970	0.2%			543	0.0%			533	0.0%		

\* The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system

#### 4.4 SUMMARY VDS PERFORMANCE IN WINDY CONDITIONS

A summary of the VDS performance in the 3 conditions presented in this report (wind in cloudy, sunny and nighttime conditions) is included in this section. Results are shown in both graphical and table form, indicating for the three VDSs the general performance at the stop bar zones and advance zones separated. The reader will observe the general picture of the VDS performance on each condition from the graphical representation of the errors, where the maximum and minimum values are shown to illustrate the range of errors in the three systems. This glance to the error range could be used by VDS users to observe in general terms potential strengths and critical errors on each zone and illumination condition.

##### 4.4.1 False Calls

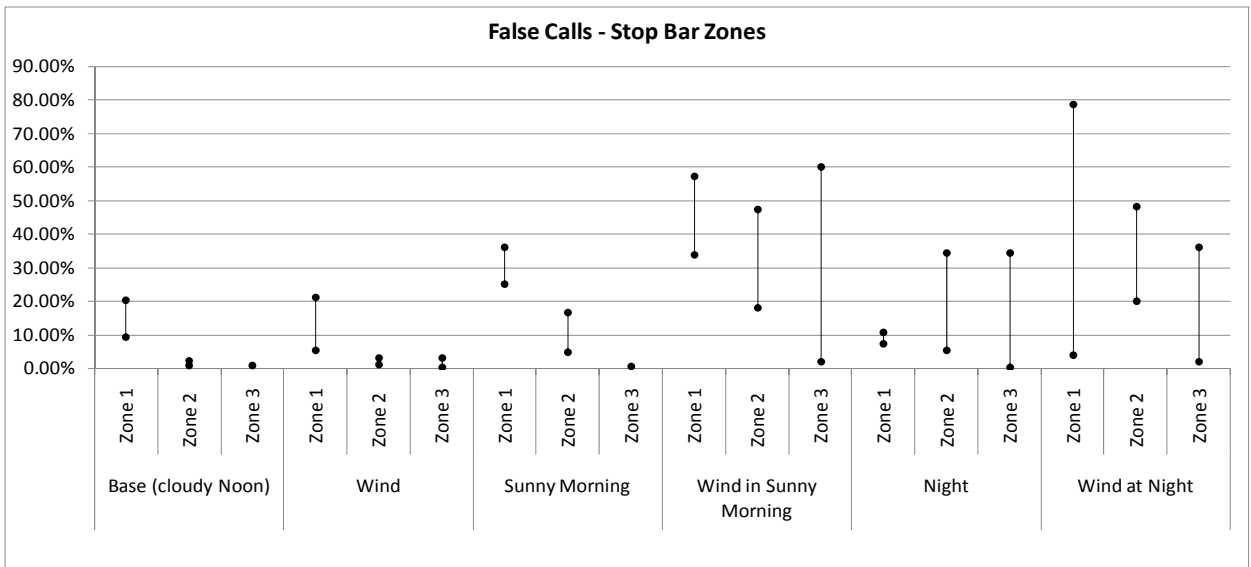


Figure 4.3. Summary false calls at stop bar zones.

Table 4.19. Summary False Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
False Calls	Base (cloudy Noon)	Zone 1	9.50%	20.49%	15.12%
		Zone 2	0.85%	1.00%	2.35%
		Zone 3	0.97%	0.16%	0.18%
	Wind	Zone 1	5.49%	19.30%	21.36%
		Zone 2	3.13%	1.16%	2.02%
		Zone 3	3.36%	0.65%	0.36%
	Sunny Morning	Zone 1	25.18%	30.59%	36.18%
		Zone 2	4.98%	6.78%	16.67%
		Zone 3	0.63%	0.27%	0.00%
	Wind in Sunny Morning	Zone 1	35.26%	34.04%	57.41%
		Zone 2	27.55%	18.30%	47.62%
		Zone 3	7.78%	60.11%	2.18%
	Night	Zone 1	9.29%	7.37%	10.97%
		Zone 2	34.65%	13.75%	5.46%
		Zone 3	34.62%	0.51%	3.30%
	Wind at Night	Zone 1	32.91%	4.19%	78.75%
		Zone 2	33.70%	20.23%	48.35%
		Zone 3	36.35%	2.11%	24.59%



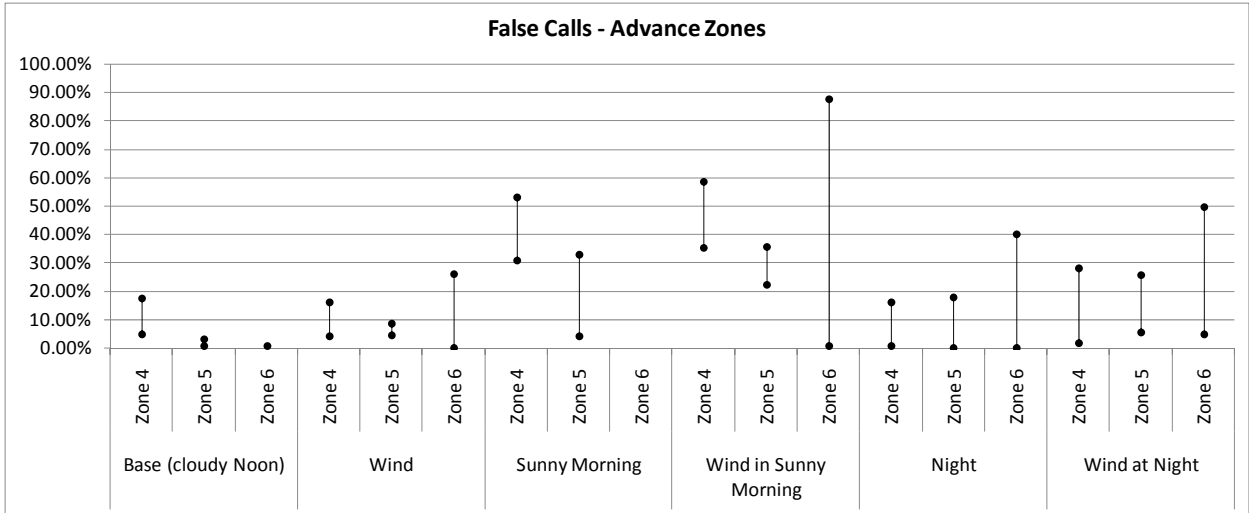


Figure 4.4. Summary false calls at advance zones.

Table 4.20. Summary False Calls at Advance Zone

Error Type	Condition	Zone	Autoscope	Peek	Iteris
False Calls	Base (cloudy Noon)	Zone 4	4.85%	17.73%	12.00%
		Zone 5	0.89%	2.44%	3.31%
		Zone 6	0.31%	0.16%	0.93%
	Wind	Zone 4	4.24%	16.05%	14.33%
		Zone 5	4.60%	8.83%	4.66%
		Zone 6	0.16%	4.66%	26.04%
	Sunny Morning	Zone 4	47.57%	31.07%	53.15%
		Zone 5	32.82%	4.26%	32.88%
		Zone 6	0.00%	0.00%	0.00%
	Wind in Sunny Morning	Zone 4	42.84%	35.44%	58.64%
		Zone 5	22.41%	29.92%	35.81%
		Zone 6	0.74%	3.53%	87.70%
	Night	Zone 4	0.90%	12.43%	16.27%
		Zone 5	18.06%	0.00%	2.66%
		Zone 6	40.31%	0.18%	0.38%
	Wind at Night	Zone 4	1.93%	6.81%	28.12%
		Zone 5	25.70%	5.56%	12.29%
		Zone 6	47.96%	4.88%	49.89%

#### 4.4.2 Missed Calls

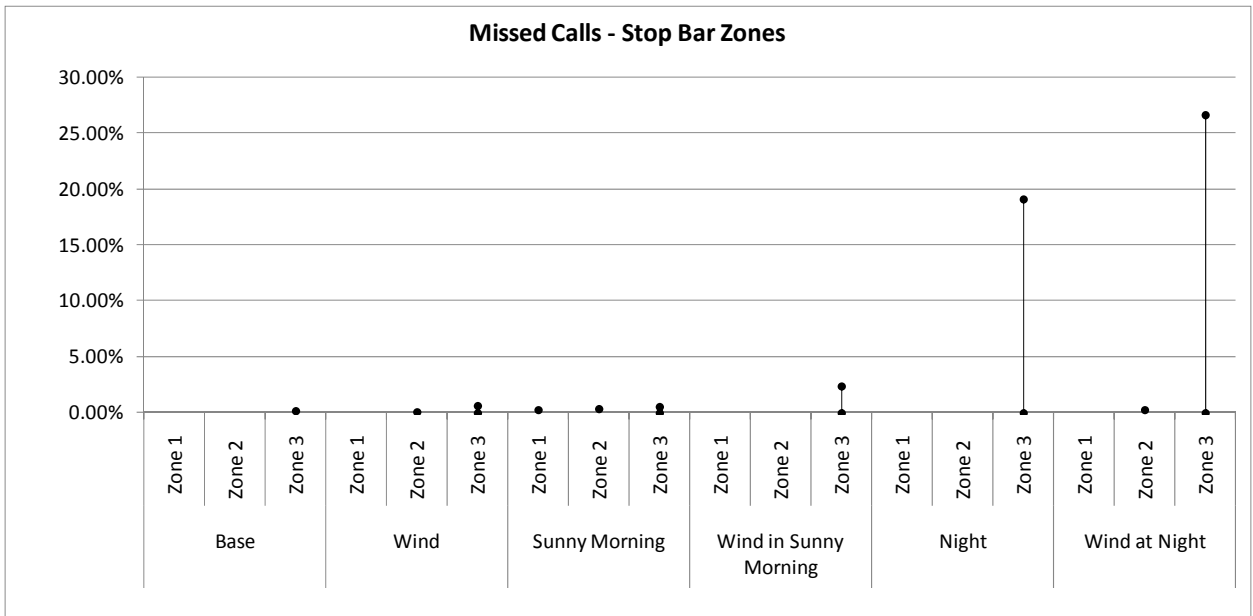


Figure 4.5. Summary missed calls at stop bar zones.

Table 4.21. Summary Missed Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Missed Calls	Base	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	0.15%	0.00%
	Wind	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.12%	0.00%
		Zone 3	0.00%	0.59%	0.00%
	Sunny Morning	Zone 1	0.00%	0.24%	0.00%
		Zone 2	0.00%	0.40%	0.00%
		Zone 3	0.00%	0.51%	0.00%
	Wind in Sunny Morning	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	2.39%	0.00%
	Night	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	19.11%	0.00%
	Wind at Night	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.24%	0.00%
		Zone 3	0.00%	26.64%	0.00%

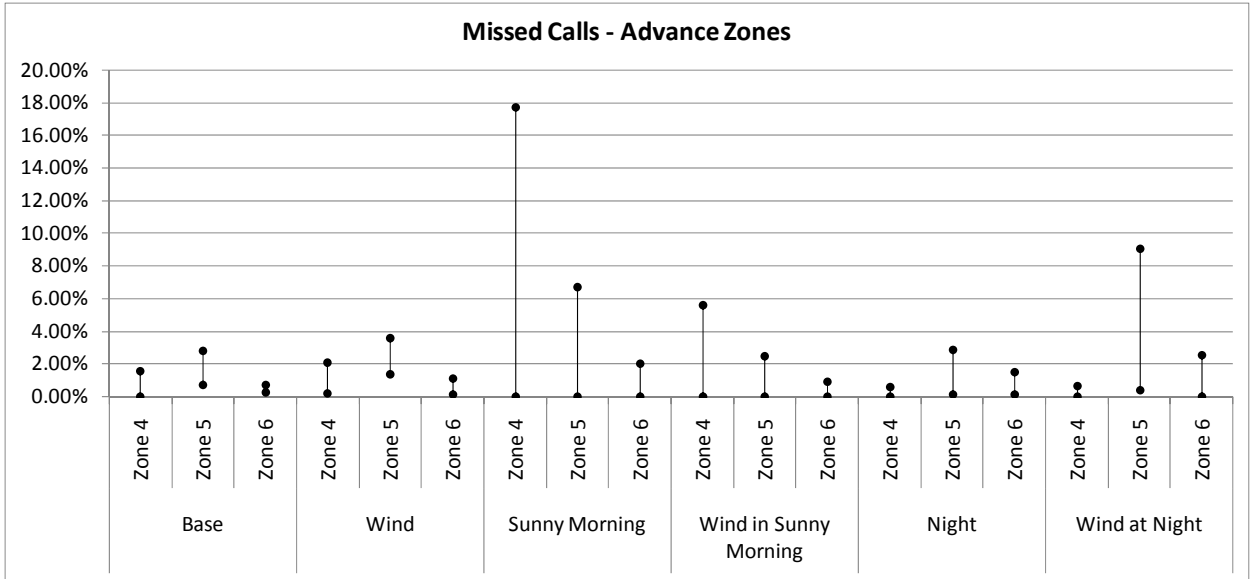


Figure 4.6. Summary missed calls at advance zones.

Table 4.22. Summary Missed Calls at Advance Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Missed Calls	Base	Zone 4	1.56%	0.00%	1.17%
		Zone 5	0.71%	1.02%	2.84%
		Zone 6	0.73%	0.59%	0.29%
	Wind	Zone 4	0.96%	2.11%	0.19%
		Zone 5	1.37%	3.58%	1.37%
		Zone 6	1.16%	0.58%	0.14%
	Sunny Morning	Zone 4	0.00%	17.74%	1.29%
		Zone 5	0.00%	6.74%	2.30%
		Zone 6	0.00%	2.02%	0.00%
	Wind in Sunny Morning	Zone 4	0.00%	5.59%	0.00%
		Zone 5	0.00%	2.52%	0.70%
		Zone 6	0.00%	0.93%	0.00%
	Night	Zone 4	0.00%	0.57%	0.00%
		Zone 5	0.15%	2.92%	0.15%
		Zone 6	0.17%	1.53%	0.17%
	Wind at Night	Zone 4	0.00%	0.33%	0.66%
		Zone 5	0.40%	9.05%	0.80%
		Zone 6	1.48%	2.54%	0.00%

### 4.4.3 Stuck-on Calls

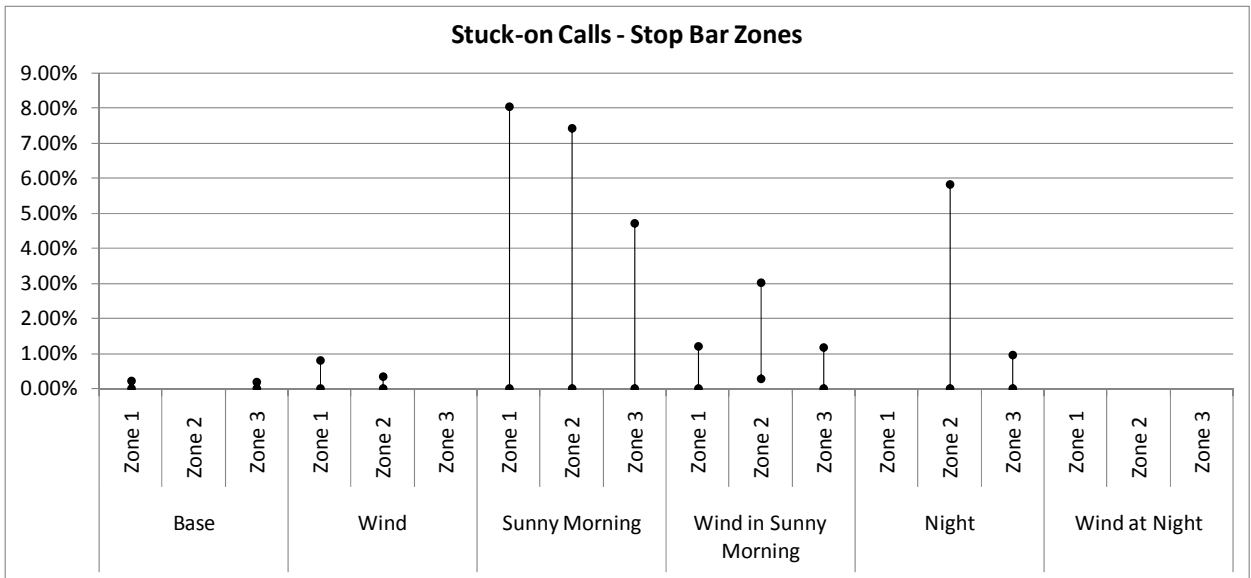


Figure 4.7. Summary stuck-on calls at stop bar zones.

Table 4.23. Summary Stuck-on Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Stuck-on Calls	Base	Zone 1	0.21%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.19%	0.00%	0.00%
	Wind	Zone 1	0.81%	0.00%	0.00%
		Zone 2	0.33%	0.00%	0.00%
		Zone 3	0.00%	0.00%	0.00%
	Sunny Morning	Zone 1	8.08%	1.47%	0.00%
		Zone 2	7.46%	1.03%	0.00%
		Zone 3	4.75%	0.00%	0.29%
	Wind in Sunny Morning	Zone 1	0.50%	1.20%	0.00%
		Zone 2	3.03%	0.82%	0.28%
		Zone 3	1.18%	0.08%	0.00%
	Night	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.28%	0.00%	5.85%
		Zone 3	0.14%	0.00%	0.97%
	Wind at Night	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	0.00%	0.00%

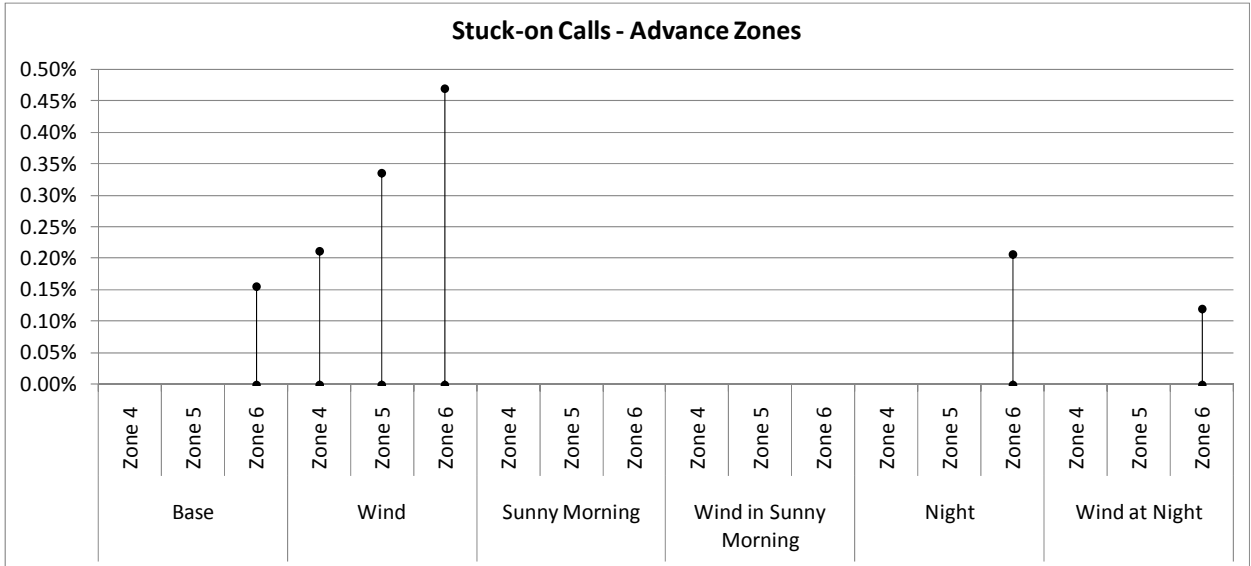


Figure 4.8. Summary stuck-on calls at advance zones.

Table 4.24. Summary Stuck-on Calls at Advance Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Stuck-on Calls	Base	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.16%	0.00%	0.00%
	Wind	Zone 4	0.21%	0.00%	0.00%
		Zone 5	0.34%	0.00%	0.00%
		Zone 6	0.47%	0.00%	0.00%
	Sunny Morning	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.00%	0.00%	0.00%
	Wind in Sunny Morning	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.00%	0.00%	0.00%
	Night	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.21%	0.00%	0.00%
	Wind at Night	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.12%	0.00%	0.00%

## **CHAPTER 5 CONCLUSIONS**

### **5.1 WIND IN CLOUDY CONDITIONS**

The effects of wind in cloudy noon conditions on video detection systems performance at the stop bar zones were very limited (with <3% increase in false calls, and <0.5% increase in missed and stuck-on calls). Some of these changes resulted in statistically significant differences, but practically should not have major implications in the performance of the VDS. However, that was not the case for the advance zones, where the false calls increased between 1.5% and 9.8% for the average of the three advance zones. Small changes were observed during windy conditions for the missed calls (0.3% - 1.7% on average), with increases for Peek and Autoscope, and decreases for Iteris; and the stuck-on calls remained very low (less than 1%) for all zones and VDSs.

### **5.2 WIND IN SUNNY CONDITIONS**

At the stop bar zones, wind had significant effects on the false calls and minor effects on stuck-on calls. The average false calls were clearly increased in windy conditions and reached between 25.3% and 44.7%, compared to the base condition that had 3.5% to 7% false calls. Shadows from vehicles on the adjacent lanes combined with image movement due to wind were the main cause of the false calls. Stuck-on calls increased by small amount ( $\leq 1.5\%$ ) for two of the systems (Autoscope and Iteris), specifically due to the shadow of the mast arm and the traffic signal pole from the crossing street. This highlights the potential for stuck-on calls when slow moving shadows are present, potentially affecting VDS performance. On the other hand, missed calls remained very low at the stop bar zones, with no missed vehicles for Autoscope and Iteris, and under 1% missed for Peek.

At the advance zones, a significant increase in false calls was found in windy conditions for all systems, reaching 25.6% to 74.6% compared to 1.6% to 6.1% in the base condition. As expected, the most affected zone was Zone 4, since shadows from vehicles on the adjacent lanes fell on this zone. In addition, when image moved due to the wind, the edge of Zone 6 in Iteris overlapped with the curb and generated a great number of calls. This suggests that potential image movement should be accounted for when placing and drawing the detection zones. Missed calls increased in windy conditions for Peek (from 14 vehicles to 47 vehicles total), while they decreased for Autoscope (from 20 to no vehicles missed) and Iteris (from 36 to 5 vehicles missed). Note that these changes although are a low percentage of the total volume (<2%), they translate to many vehicles that should not be missed. No changes in stuck-on calls were observed in windy conditions and remained zero for all systems at the advance zones.

### **5.3 WIND IN NIGHTTIME**

At the stop bar zones, the false calls increased in windy conditions for all three VDS and reached 11.5% to 59.2% compared to 6.2% to 29.5% in the base case. Some of these false calls were generated when image oscillated and portions of the zones overlapped with the median or the painted lane markings. No general effects of wind were observed in missed calls, with no missed vehicles in Autoscope and Iteris; however, about 10.7% vehicles were missed by Peek, mostly coming from Zone 3 (26.6% in windy, and 19.1% in

base conditions). Also, stuck-on calls did not generally change except for a decrease in Iteris (from 2.5% to 0%), which could be associated with image movement in windy conditions helping dropping potential stuck-on calls.

At the advance zones, significant increases in false calls were observed, mostly for Iteris (from 5.3% in the base case to 33.6% during might windy conditions), followed by Autoscope (from 25.8% to 33%) and Peek (from 3.3% to 5.6%). Many false calls were generated when the detection zones overlapped with the curb, raised median, or painted lane markings. Missed calls increased by less than 3% in Peek, with minor changes in Autoscope and Iteris. Stuck-on calls were very rare in windy conditions ( $\leq 0.4\%$ ) and did not change significantly.

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## **APPENDIX A. DAILY VARIATION OF VIDEO DETECTION PERFORMANCE**

As explained in Chapter 4, performance of VDS under Cloudy Noon, Sunny Morning, and Nighttime conditions was compared with the performance obtained during similar illumination conditions, but including wind. The duration and number of data sets from each condition could vary from one to the other, but within each condition, the lighting and wind scenario to be evaluated remained very similar throughout all the selected data. Thus, the VDS performance was analyzed when all data sets from a given condition were aggregated into one single data set. In this Appendix, the VDS performance is presented on a day-by-day basis, so it is possible to observe the daily variation of the performance measures for each of three the systems. To do this, tables with the actual percentage of the four types of error from each day, and in each detection zone are provided. Also, a graphical representation indicating the variation range (maximum and minimum) and the average percentage for all types of errors in all detection zones are included for an easier interpretation of the data.

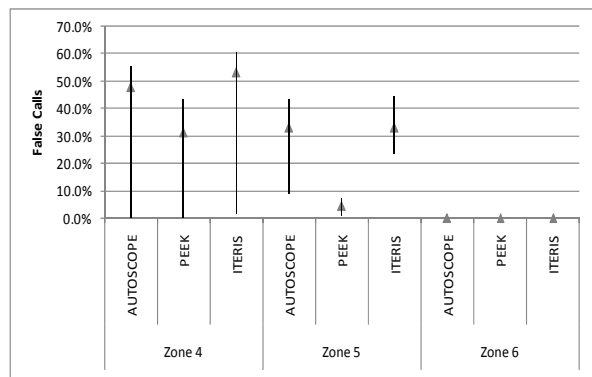
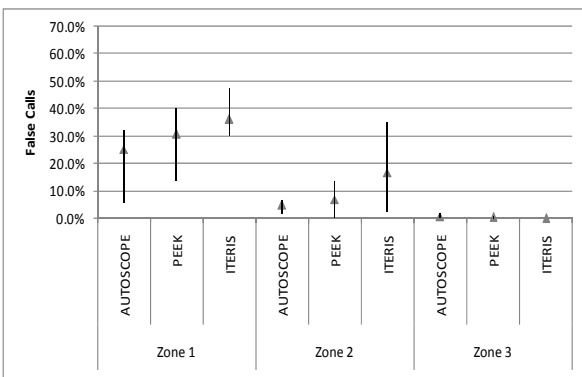
## Sunny Morning Condition

### False Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	24.1%	13.9%	32.6%	ZONE 4	DAY 1	42.8%	20.3%	46.4%
	DAY 2	30.9%	33.3%	35.2%		DAY 2	55.4%	24.3%	49.6%
	DAY 3	25.0%	34.5%	30.0%		DAY 3	50.8%	43.1%	55.6%
	DAY 4	32.2%	40.2%	36.6%		DAY 4	53.8%	40.0%	60.8%
	DAY 5	6.0%	28.8%	47.1%		DAY 5	0.0%	0.0%	1.9%
ZONE 2	DAY 1	4.4%	1.0%	2.2%	ZONE 5	DAY 1	25.0%	1.0%	26.6%
	DAY 2	6.9%	2.1%	5.6%		DAY 2	31.3%	2.2%	23.5%
	DAY 3	4.8%	12.0%	24.4%		DAY 3	40.2%	6.6%	44.6%
	DAY 4	5.8%	13.4%	12.7%		DAY 4	43.2%	7.3%	35.5%
	DAY 5	1.8%	0.0%	35.0%		DAY 5	9.0%	3.6%	26.6%
ZONE 3	DAY 1	1.9%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	1.1%	0.9%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%

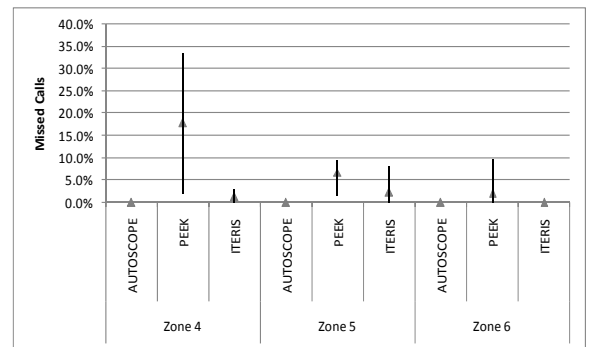
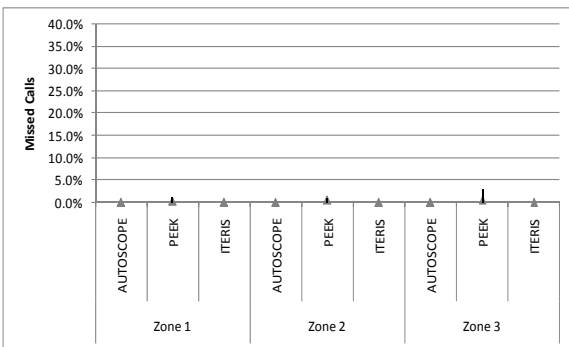


### Missed Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	1.8%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	3.4%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	33.3%	3.0%
	DAY 4	0.0%	1.3%	0.0%		DAY 4	0.0%	27.8%	2.8%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	24.5%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	1.6%	1.6%
	DAY 2	0.0%	1.0%	0.0%		DAY 2	0.0%	7.4%	8.3%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	9.5%	0.6%
	DAY 4	0.0%	0.9%	0.0%		DAY 4	0.0%	8.1%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	5.5%	2.7%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	1.2%	0.0%		DAY 2	0.0%	1.2%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	2.5%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	1.0%	0.0%
	DAY 5	0.0%	3.1%	0.0%		DAY 5	0.0%	9.7%	0.0%

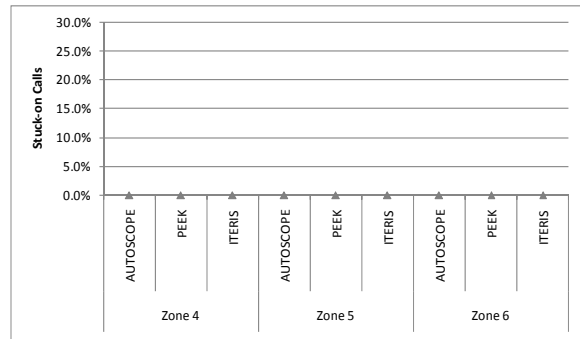
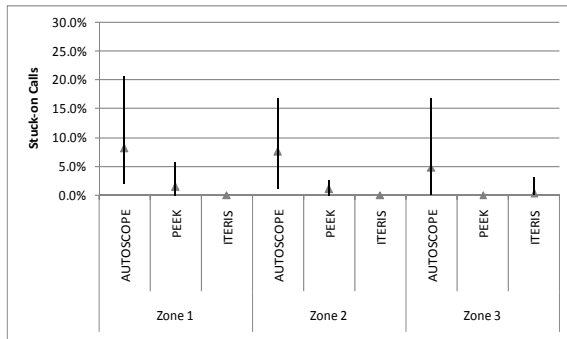


# Stuck-on Calls

## Stop Bar Zones

## Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	1.8%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	3.7%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	20.5%	5.6%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	10.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	4.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	1.1%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	2.3%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	16.7%	2.6%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	14.0%	1.7%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	1.8%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	1.3%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	3.4%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	8.6%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	16.7%	0.0%	3.0%		DAY 5	0.0%	0.0%	0.0%



## Sunny Windy Morning Condition

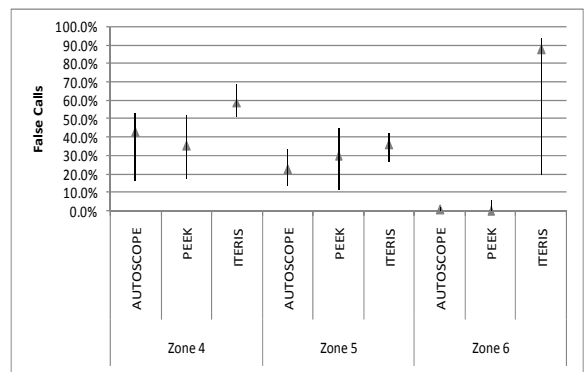
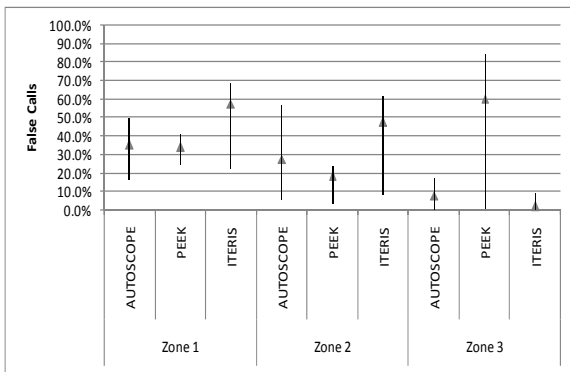
### False Calls

#### Stop Bar Zones

Zone	Day	Stop Bar Zones		
		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	37.5%	39.0%	69.0%
	DAY 2	29.8%	24.3%	22.8%
	DAY 3	34.9%	41.1%	59.4%
	DAY 4	16.5%	32.7%	67.6%
	DAY 5	49.7%	32.5%	33.3%
ZONE 2	DAY 1	15.7%	22.1%	61.4%
	DAY 2	5.7%	23.9%	8.4%
	DAY 3	6.9%	3.8%	29.5%
	DAY 4	21.9%	17.1%	56.2%
	DAY 5	56.3%	21.4%	53.1%
ZONE 3	DAY 1	0.0%	0.9%	0.0%
	DAY 2	0.0%	8.5%	0.0%
	DAY 3	1.3%	2.8%	0.0%
	DAY 4	17.0%	84.4%	9.0%
	DAY 5	16.3%	50.0%	0.0%

#### Advance Zones

Zone	Day	Advance Zones		
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	53.3%	44.3%	68.9%
	DAY 2	41.6%	17.0%	57.7%
	DAY 3	52.0%	52.0%	60.9%
	DAY 4	16.3%	26.3%	51.8%
	DAY 5	33.9%	25.3%	50.9%
ZONE 5	DAY 1	33.3%	31.3%	42.0%
	DAY 2	17.9%	11.3%	29.5%
	DAY 3	27.2%	30.4%	38.3%
	DAY 4	13.9%	17.1%	42.0%
	DAY 5	15.5%	44.9%	26.5%
ZONE 6	DAY 1	1.5%	3.2%	93.7%
	DAY 2	0.0%	2.6%	43.4%
	DAY 3	0.0%	2.6%	93.2%
	DAY 4	2.0%	3.2%	81.6%
	DAY 5	0.0%	5.8%	19.4%



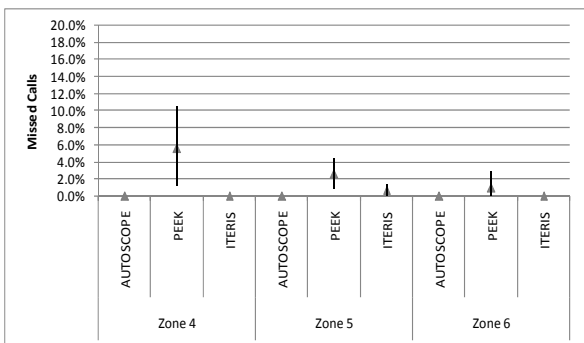
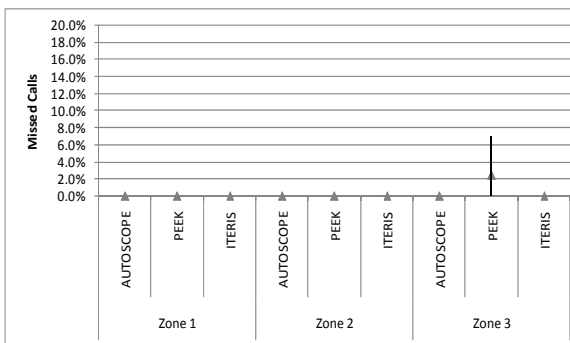
### Missed Calls

#### Stop Bar Zones

Zone	Day	Stop Bar Zones		
		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	1.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	1.2%	0.0%
	DAY 4	0.0%	3.0%	0.0%
	DAY 5	0.0%	6.9%	0.0%

#### Advance Zones

Zone	Day	Advance Zones		
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	7.6%	0.0%
	DAY 3	0.0%	5.6%	0.0%
	DAY 4	0.0%	1.3%	0.0%
	DAY 5	0.0%	1.2%	0.0%
ZONE 5	DAY 1	0.0%	4.4%	0.7%
	DAY 2	0.0%	1.7%	0.6%
	DAY 3	0.0%	3.5%	1.4%
	DAY 4	0.0%	0.8%	0.0%
	DAY 5	0.0%	2.1%	0.7%
ZONE 6	DAY 1	0.0%	2.9%	0.0%
	DAY 2	0.0%	1.1%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	1.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%

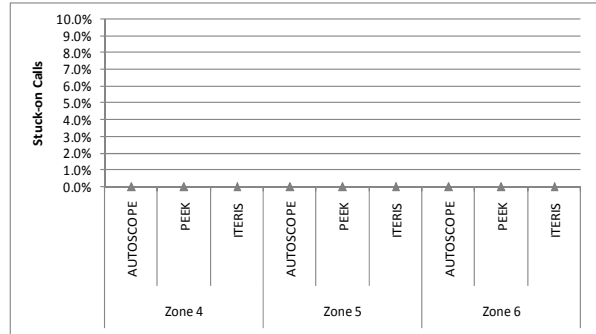
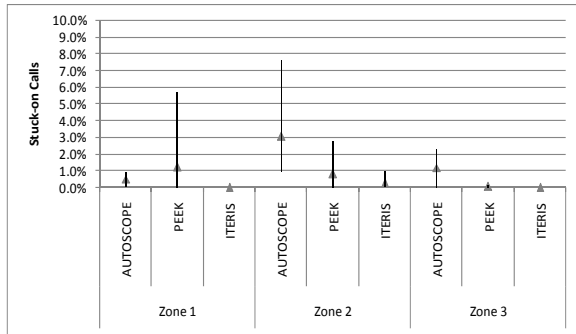


# Stuck-on Calls

## Stop Bar Zones

## Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.9%	5.7%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.7%	0.7%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.8%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	4.9%	0.8%	0.9%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	7.6%	2.8%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	2.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	1.9%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
ZONE 3	DAY 5	0.9%	0.0%	0.0%	ZONE 6	DAY 5	0.0%	0.0%	0.0%
	DAY 1	0.0%	0.0%	0.0%		DAY 1	0.0%	0.0%	0.0%
	DAY 2	1.3%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	1.9%	0.1%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	2.3%	0.0%	0.0%	DAY 5	0.0%	0.0%	0.0%	



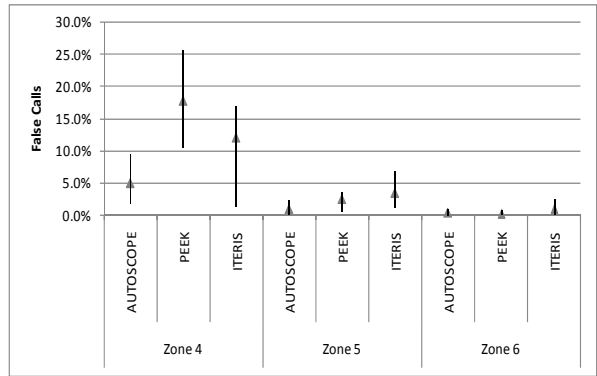
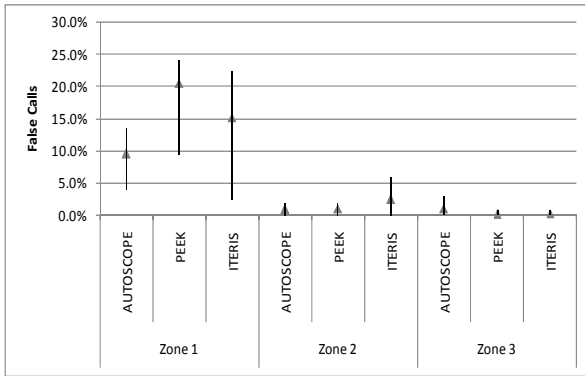
## Cloudy Noon Condition

### False Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
<b>ZONE 1</b>	DAY 1	13.5%	23.9%	21.4%	<b>ZONE 4</b>	DAY 1	4.7%	25.5%	16.9%
	DAY 2	6.4%	23.7%	13.1%		DAY 2	5.9%	14.4%	11.2%
	DAY 3	3.9%	9.4%	2.5%		DAY 3	1.7%	10.4%	1.4%
	DAY 4	9.5%	17.7%	11.4%		DAY 4	1.8%	16.2%	9.9%
	DAY 5	12.4%	23.6%	22.2%		DAY 5	9.3%	18.5%	16.0%
<b>ZONE 2</b>	DAY 1	0.8%	0.6%	2.9%	<b>ZONE 5</b>	DAY 1	2.3%	3.6%	1.5%
	DAY 2	1.8%	1.6%	5.8%		DAY 2	1.3%	2.7%	6.9%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	1.4%	2.7%
	DAY 4	0.8%	2.0%	0.8%		DAY 4	0.0%	3.6%	4.8%
	DAY 5	0.8%	0.7%	2.3%		DAY 5	0.6%	0.6%	1.1%
<b>ZONE 3</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 6</b>	DAY 1	0.0%	0.0%	0.7%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.8%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.7%	0.8%	0.7%
	DAY 4	2.8%	0.8%	0.0%		DAY 4	0.0%	0.0%	2.4%
	DAY 5	1.6%	0.0%	0.8%		DAY 5	0.0%	0.0%	0.6%

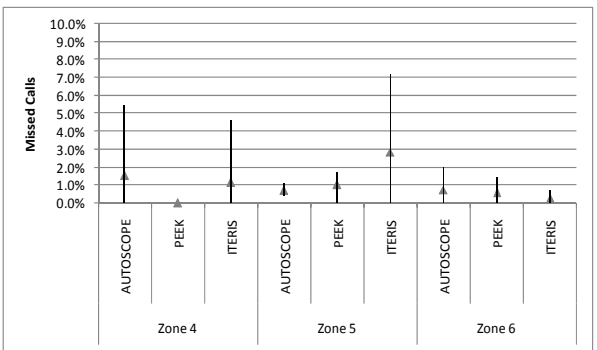
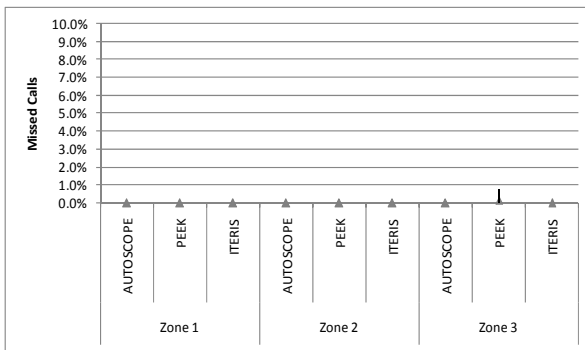


### Missed Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
<b>ZONE 1</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 4</b>	DAY 1	0.9%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.9%	0.0%	4.6%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	5.4%	0.0%	1.4%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	2.0%	0.0%	0.0%
<b>ZONE 2</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 5</b>	DAY 1	0.4%	0.4%	1.3%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	1.1%	0.0%	3.4%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.6%	1.7%	2.9%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.5%	1.5%	7.2%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	1.0%	1.5%	0.0%
<b>ZONE 3</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 6</b>	DAY 1	2.0%	0.0%	0.0%
	DAY 2	0.0%	0.8%	0.0%		DAY 2	1.5%	0.8%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	1.4%	0.7%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.7%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.6%	0.0%

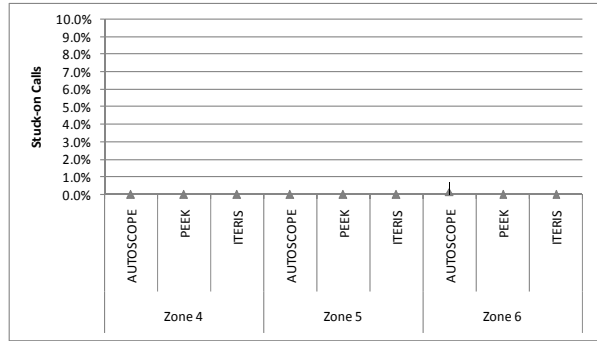
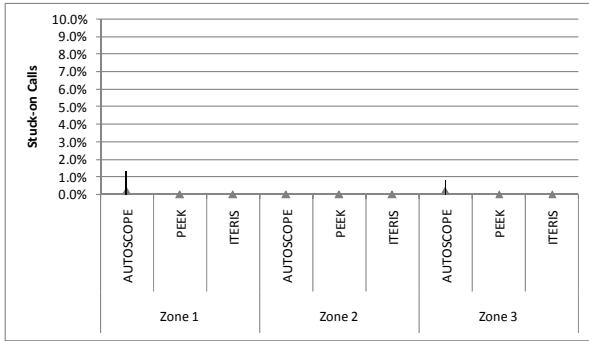


# Stuck-on Calls

## Stop Bar Zones

## Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	1.3%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.7%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.8%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%



## Cloudy Windy Noon Condition

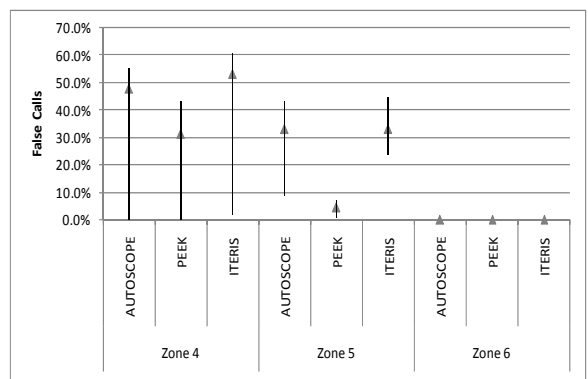
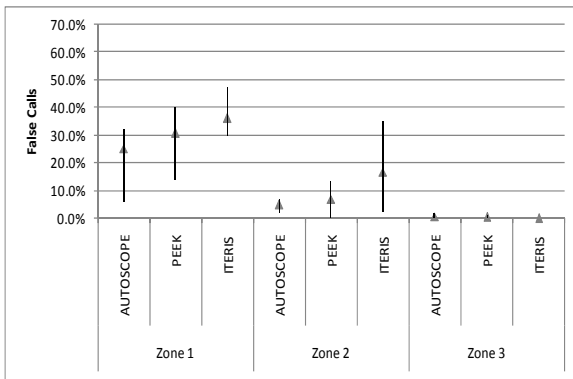
### False Calls

#### Stop Bar Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 1		
ZONE 1	DAY 1	10.8%	29.7%	21.8%
	DAY 2	1.1%	16.9%	5.9%
	DAY 3	1.9%	14.8%	13.2%
	DAY 4	11.7%	16.9%	36.3%
	DAY 5	0.0%	16.8%	21.3%
Zone 2				
ZONE 2	DAY 1	1.8%	3.0%	3.3%
	DAY 2	0.0%	0.8%	0.9%
	DAY 3	8.1%	0.6%	1.4%
	DAY 4	4.0%	1.3%	4.3%
	DAY 5	0.0%	0.0%	0.0%
Zone 3				
ZONE 3	DAY 1	2.7%	1.5%	0.0%
	DAY 2	0.0%	1.0%	0.0%
	DAY 3	9.4%	0.8%	1.7%
	DAY 4	2.7%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%

#### Advance Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 4		
ZONE 4	DAY 1	6.9%	19.0%	18.4%
	DAY 2	1.9%	15.5%	4.6%
	DAY 3	4.4%	10.0%	3.5%
	DAY 4	6.2%	21.4%	23.4%
	DAY 5	1.2%	13.1%	19.4%
Zone 5				
ZONE 5	DAY 1	5.6%	10.3%	7.1%
	DAY 2	1.4%	11.5%	3.5%
	DAY 3	9.8%	6.2%	2.1%
	DAY 4	3.0%	9.3%	5.0%
	DAY 5	1.3%	7.2%	5.7%
Zone 6				
ZONE 6	DAY 1	0.0%	5.9%	0.0%
	DAY 2	0.0%	4.8%	5.4%
	DAY 3	0.7%	2.9%	0.7%
	DAY 4	0.0%	4.5%	4.3%
	DAY 5	0.0%	5.5%	65.0%



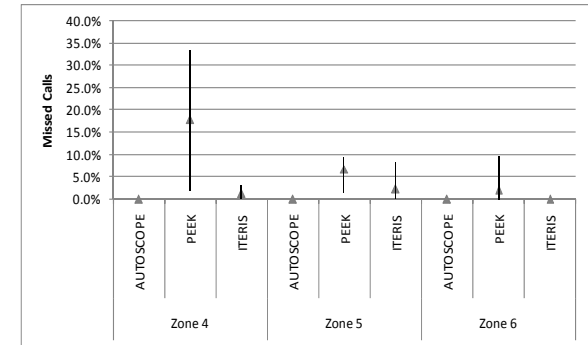
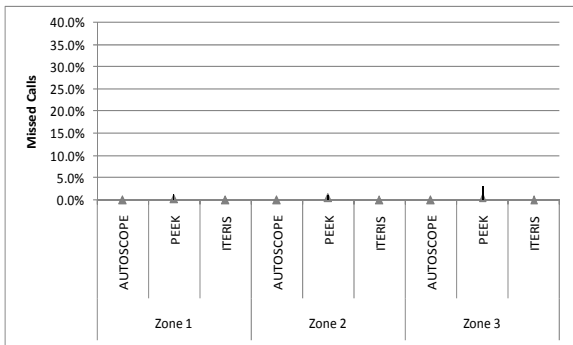
### Missed Calls

#### Stop Bar Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 1		
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
Zone 2				
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.7%	0.0%
Zone 3				
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	2.5%	0.0%
	DAY 5	0.0%	0.0%	0.0%

#### Advance Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 4		
ZONE 4	DAY 1	1.9%	0.9%	0.0%
	DAY 2	0.0%	1.0%	0.0%
	DAY 3	1.7%	0.0%	0.9%
	DAY 4	0.9%	1.8%	0.0%
	DAY 5	0.0%	8.4%	0.0%
Zone 5				
ZONE 5	DAY 1	1.6%	1.1%	1.1%
	DAY 2	0.0%	0.6%	4.8%
	DAY 3	2.8%	0.0%	0.5%
	DAY 4	1.4%	5.1%	0.9%
	DAY 5	0.6%	12.3%	0.0%
Zone 6				
ZONE 6	DAY 1	1.4%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.9%
	DAY 3	2.0%	1.3%	0.0%
	DAY 4	1.2%	0.0%	0.0%
	DAY 5	0.8%	1.7%	0.0%



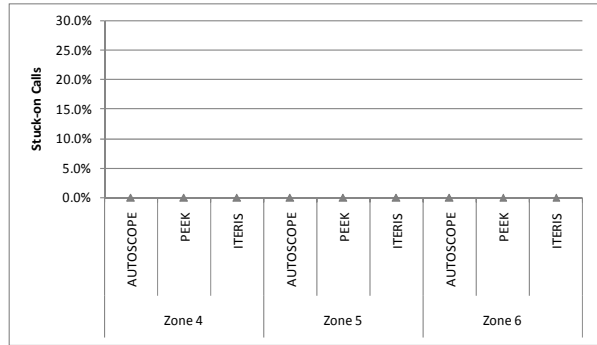
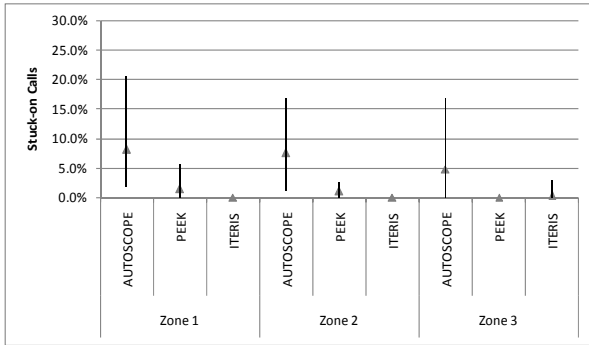
### Stuck-on Calls



### Stop Bar Zones

### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
<b>ZONE 1</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 4</b>	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	1.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	2.7%	0.0%	0.0%		DAY 4	1.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
<b>ZONE 2</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 5</b>	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	1.6%	0.0%	0.0%		DAY 4	1.5%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
<b>ZONE 3</b>	DAY 1	0.0%	0.0%	0.0%	<b>ZONE 6</b>	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	2.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%



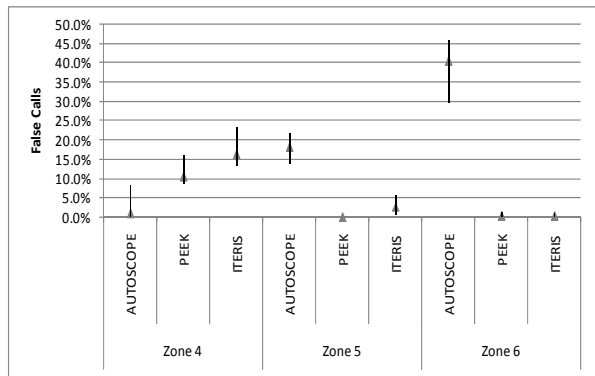
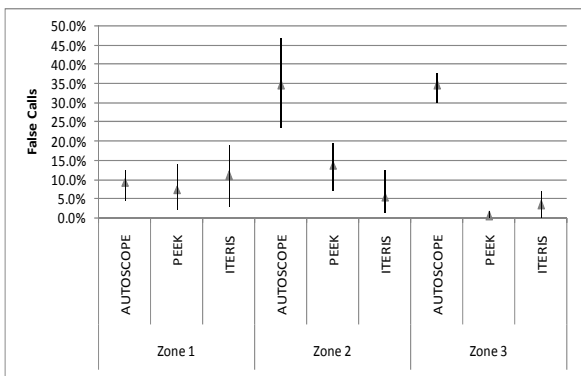
## Night Condition

### False Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	4.5%	14.1%	15.7%	ZONE 4	DAY 1	0.0%	13.6%	23.2%
	DAY 2	4.3%	2.1%	2.9%		DAY 2	0.0%	8.9%	17.2%
	DAY 3	11.9%	10.0%	11.9%		DAY 3	8.3%	14.3%	17.7%
	DAY 4	12.5%	12.5%	18.7%		DAY 4	1.8%	8.6%	15.5%
	DAY 5	10.9%	4.0%	8.5%		DAY 5	1.7%	15.8%	13.4%
ZONE 2	DAY 1	23.5%	8.7%	1.2%	ZONE 5	DAY 1	14.3%	0.0%	0.8%
	DAY 2	35.3%	19.4%	4.1%		DAY 2	21.6%	0.0%	5.8%
	DAY 3	31.1%	12.7%	3.3%		DAY 3	17.9%	0.0%	1.7%
	DAY 4	28.6%	7.0%	3.5%		DAY 4	13.6%	0.0%	2.5%
	DAY 5	46.7%	18.4%	12.5%		DAY 5	20.7%	0.0%	2.1%
ZONE 3	DAY 1	33.0%	0.0%	0.0%	ZONE 6	DAY 1	43.1%	1.3%	0.0%
	DAY 2	29.9%	0.0%	1.9%		DAY 2	46.0%	0.0%	0.9%
	DAY 3	34.4%	1.4%	3.4%		DAY 3	43.0%	0.0%	1.0%
	DAY 4	37.4%	0.0%	2.6%		DAY 4	42.7%	0.0%	0.0%
	DAY 5	36.8%	1.1%	7.1%		DAY 5	29.5%	0.0%	0.0%

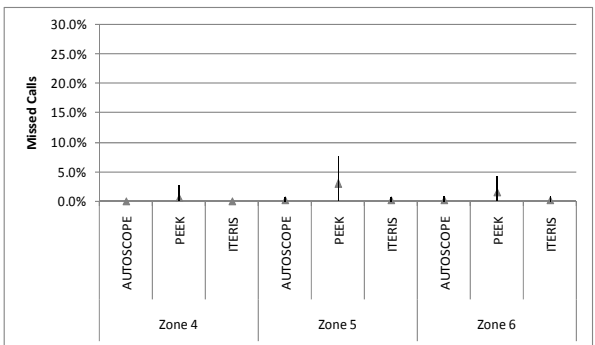
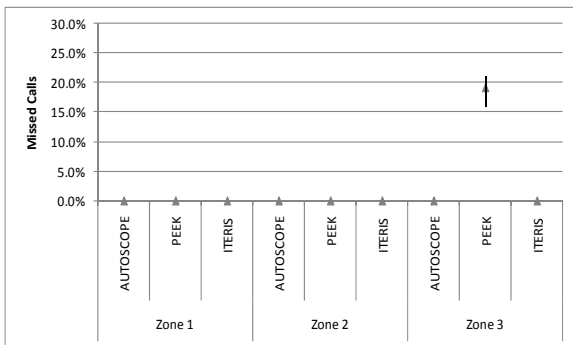


### Missed Calls

#### Stop Bar Zones

#### Advance Zones

		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	2.5%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	1.3%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	7.5%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	6.7%	0.7%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.9%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.7%	1.4%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	15.9%	0.0%	ZONE 6	DAY 1	0.0%	2.3%	0.0%
	DAY 2	0.0%	20.7%	0.0%		DAY 2	0.0%	4.1%	0.8%
	DAY 3	0.0%	16.7%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	21.1%	0.0%		DAY 4	0.8%	0.0%	0.0%
	DAY 5	0.0%	19.5%	0.0%		DAY 5	0.0%	1.4%	0.0%

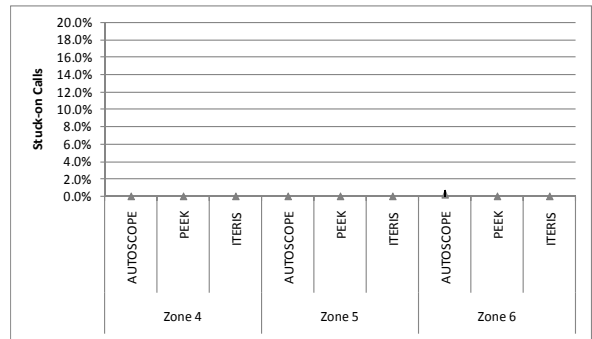
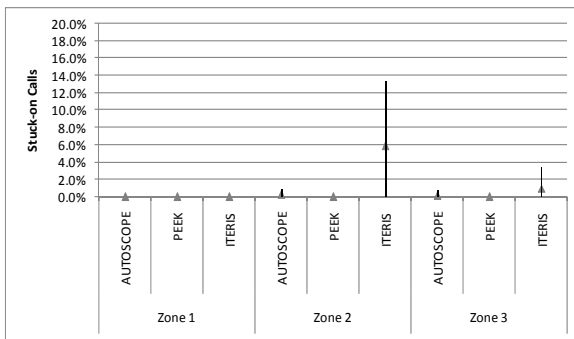


# Stuck-on Calls

## Stop Bar Zones

## Advance Zones

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	1.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.8%	0.0%	6.6%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	6.1%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	13.3%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.7%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.5%	0.0%	0.0%
	DAY 3	0.8%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	3.4%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.8%		DAY 5	0.0%	0.0%	0.0%



## Night Windy Condition

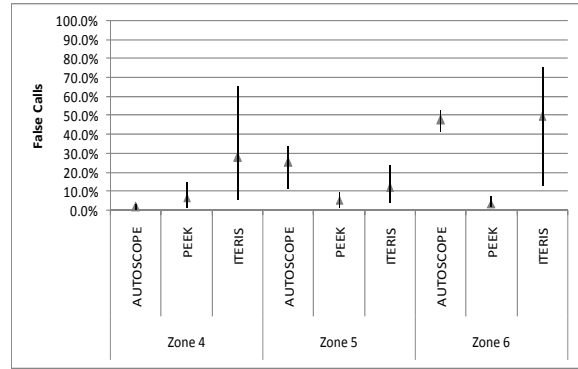
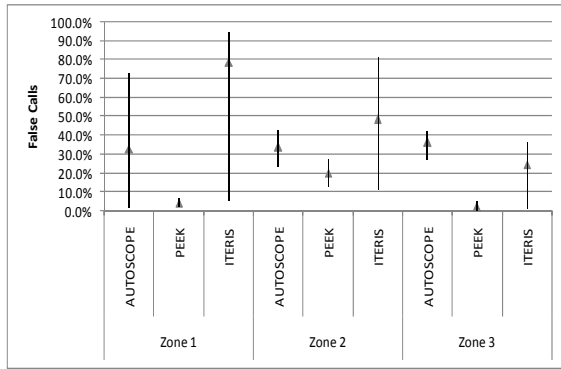
### False Calls

#### Stop Bar Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 1		
ZONE 1	DAY 1	8.3%	4.9%	18.6%
	DAY 2	5.4%	3.8%	5.2%
	DAY 3	1.7%	5.8%	10.6%
	DAY 4	72.5%	6.6%	94.3%
	DAY 5	12.5%	1.9%	59.9%
Zone 2				
ZONE 2	DAY 1	23.9%	12.6%	11.1%
	DAY 2	34.0%	16.0%	28.6%
	DAY 3	36.9%	27.6%	37.4%
	DAY 4	26.9%	19.5%	41.7%
	DAY 5	42.8%	22.3%	80.8%
Zone 3				
ZONE 3	DAY 1	27.0%	5.4%	1.2%
	DAY 2	37.5%	0.0%	7.5%
	DAY 3	35.7%	1.6%	31.1%
	DAY 4	37.8%	1.4%	36.2%
	DAY 5	42.1%	2.1%	31.6%

#### Advance Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 4		
ZONE 4	DAY 1	3.3%	8.8%	10.5%
	DAY 2	1.8%	5.3%	18.9%
	DAY 3	0.0%	1.6%	65.9%
	DAY 4	2.6%	14.9%	29.0%
	DAY 5	2.7%	6.3%	5.8%
Zone 5				
ZONE 5	DAY 1	11.5%	5.4%	3.8%
	DAY 2	25.8%	2.9%	4.6%
	DAY 3	33.9%	1.5%	23.7%
	DAY 4	21.1%	9.9%	16.0%
	DAY 5	31.2%	7.7%	10.9%
Zone 6				
ZONE 6	DAY 1	41.4%	5.3%	12.7%
	DAY 2	53.3%	2.7%	18.0%
	DAY 3	48.9%	2.0%	75.1%
	DAY 4	44.2%	6.8%	41.9%
	DAY 5	51.7%	7.5%	33.8%



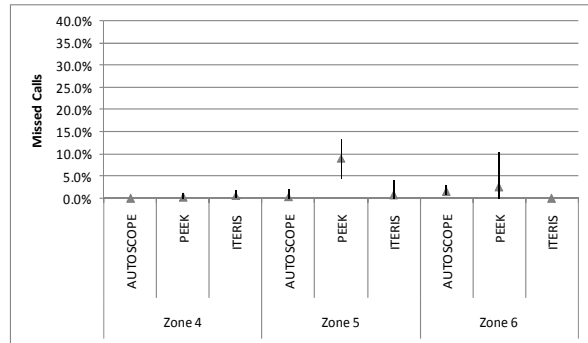
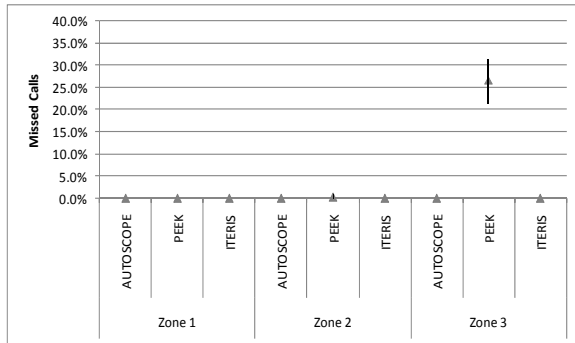
### Missed Calls

#### Stop Bar Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 1		
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
Zone 2				
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	1.1%	0.0%
	DAY 5	0.0%	0.0%	0.0%
Zone 3				
ZONE 3	DAY 1	0.0%	28.3%	0.0%
	DAY 2	0.0%	30.4%	0.0%
	DAY 3	0.0%	23.4%	0.0%
	DAY 4	0.0%	21.4%	0.0%
	DAY 5	0.0%	31.5%	0.0%

#### Advance Zones

Zone	Day	AUTOSCOPE	PEEK	ITERIS
		Zone 4		
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	1.8%
	DAY 3	0.0%	0.0%	1.1%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	1.3%	0.0%
Zone 5				
ZONE 5	DAY 1	2.1%	6.3%	0.0%
	DAY 2	0.0%	9.5%	4.2%
	DAY 3	0.0%	4.4%	0.0%
	DAY 4	0.0%	13.4%	0.0%
	DAY 5	0.0%	10.9%	0.0%
Zone 6				
ZONE 6	DAY 1	1.1%	0.0%	0.0%
	DAY 2	1.3%	0.0%	0.0%
	DAY 3	1.0%	0.0%	0.0%
	DAY 4	2.9%	1.9%	0.0%
	DAY 5	1.0%	10.4%	0.0%



# Stuck-on Calls

## Stop Bar Zones

## Advance Zones

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.6%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%

