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To: SmartMicro

From: Dr. Lily Elefteriadou

Cc: Tim McGuire, Smartmicro
Dominic Victoria, Smartmicro
Melvyn Haxby, Smartmicro

Date: 09/30/2019

Re: AGR0000013702 (AWD05842)**:** Testing and Evaluation of Traffic Detection Devices **– Final Deliverable: Tech Memo**

The purpose of this memorandum is to document the results from the testing and evaluation of the smartmicro sensor (SMS) - UMRR-0C Type 42 3D/UHD. The following section summarizes the study location, data sources, evaluation criteria, and vehicle presence detection accuracy.

Study Location:

The SMS was installed at the intersection of W Newberry RD & Oaks Mall St in Gainesville, FL (**Figure 1**). Westbound (WB) approach was selected for analysis which comprised of a left turn bay, two through lanes, and a shared through/right turn lane.

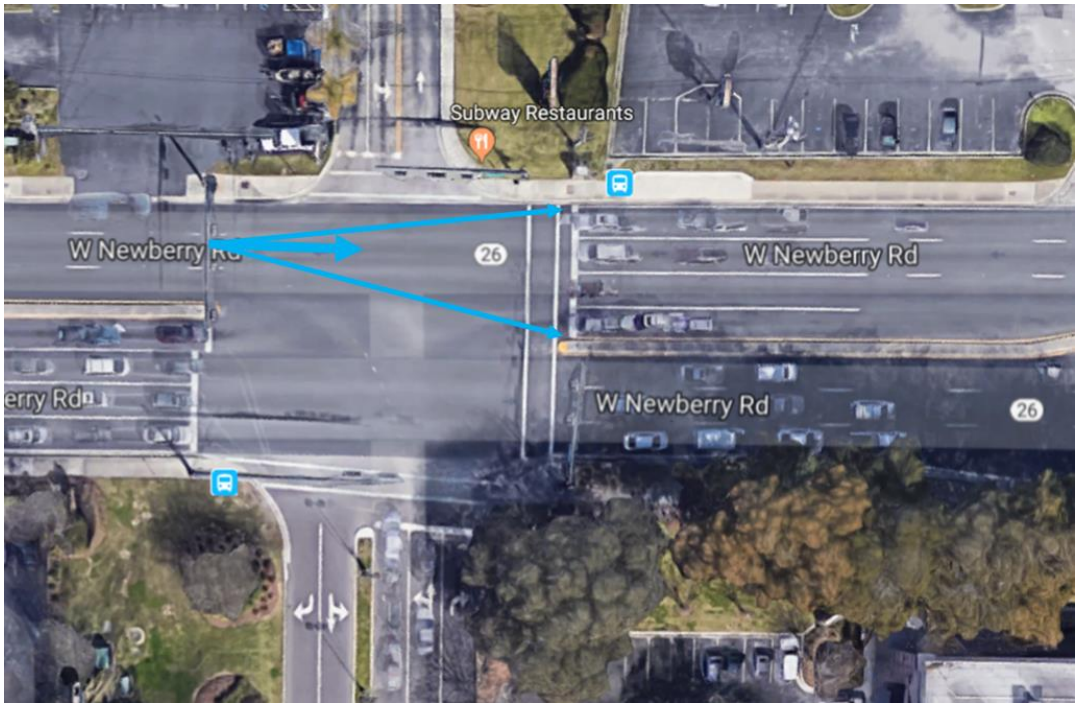

Figure 1 The intersection of W Newberry Rd and Oaks Mall ST

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Data sources

Two data sources were used in this study:

1. Smartmicro sensor (SMS) data
2. Iteris video detection data (ground truth)

Smartmicro sensor (SMS) data (TMConfigurator):

Smartmicro has a Graphical User Interface (TMC) that shows each detected vehicle in the detection range. The virtual detection zones should be defined by users in the software. The detection zones turn red whenever a vehicle presence in the zone. This software has the capability of showing the real-time flow of traffic.

Iteris video data (ground truth):

Iteris is a video data source that records the traffic passing through the field of view. The timestamp on Iteris video was behind the real time by 1 hour, 5 minutes, and 22 seconds (1:05:22). For instance, the correct timestamp of the footage in **Figure 2** should be 11:58:22 (10:53:00+01:05:22). Finding the time difference was done through two different approaches. First, finding special events like bus presence at the bus stop or bicyclist at the sidewalk and matching that with DR2 files[1]. Second, analyzing an off-peak video to find the time difference. However, by recording the real-time Iteris video and Smartmicro TMConfigurator side by side the time difference problem was resolved.

Figure 2 Iteris video footage

[1] Smartmicro output

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Methodology and Results

The study focused on analyzing the accuracy of vehicle presence detection using the radar equipment. To evaluate the presence detection accuracy, two hours of video data were collected that included Iteris and smartmicro TMC real-time side by side. The two hours of video were collected on Jul-19-2019 from 8:57 a.m. to 9:57 a.m. and from 1:13 p.m. to 2:13 p.m. **Figure 3** shows a screenshot of side by side video (on another date). As shown in **Figure 3**, the detection zone turns red whenever a vehicle is detected in the zone.

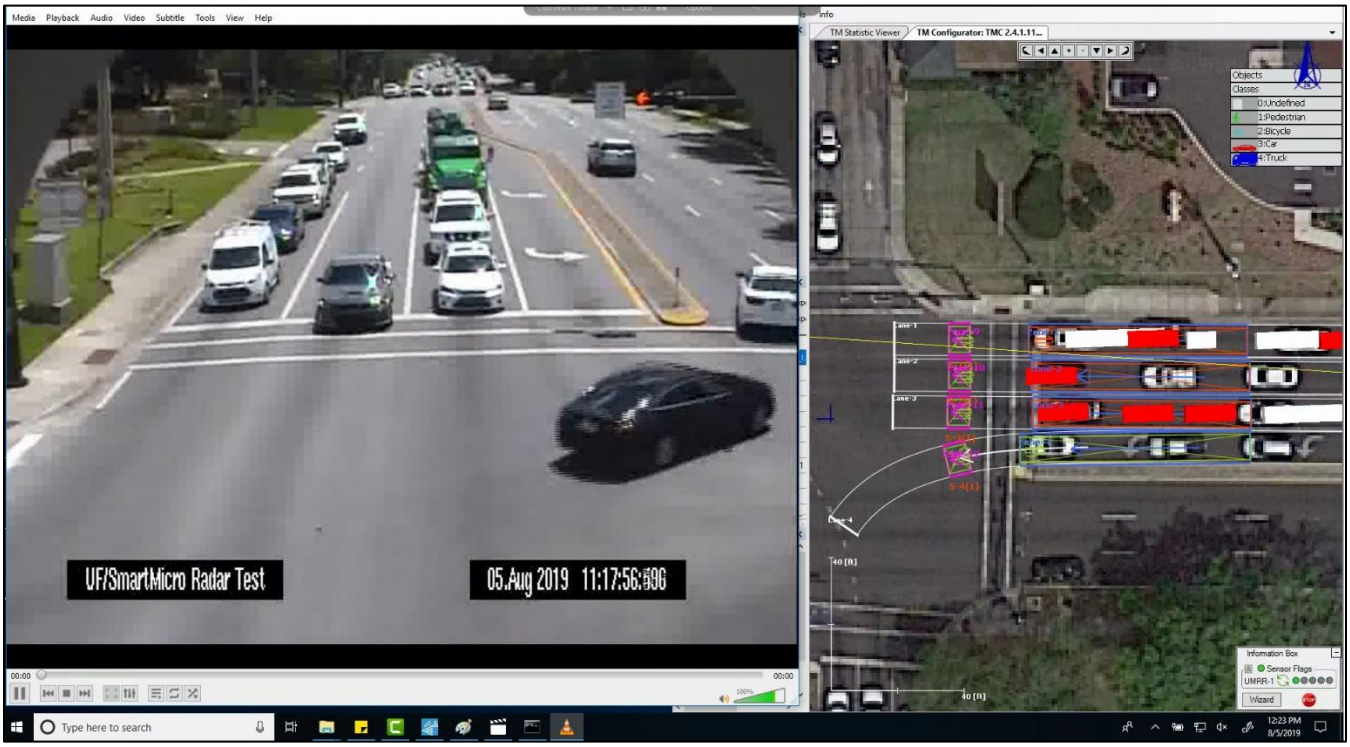

Figure 3 Screenshot of recorded video for measuring detection accuracy

At each moment four different conditions may occur for the detection zones as shown in **Table 1**:

Table 1. Possible detection conditions

		Radar	
		Detected	Not Detected
Video	Car is in detection zone	1	2
	No Car in detection zone	3	4

The conditions 1 and 4 are true positive and true negative respectively. Conditions 2 and 3 are false negative and false positive. Although both 2 and 3 are undesired, the worse condition for traffic operations would be condition-2 in which the radar failed to detect the vehicle which is on the detection zone. **Figure 4** shows a screenshot of condition 3, where there is no car in lane #2 but radar has detected a vehicle presence.

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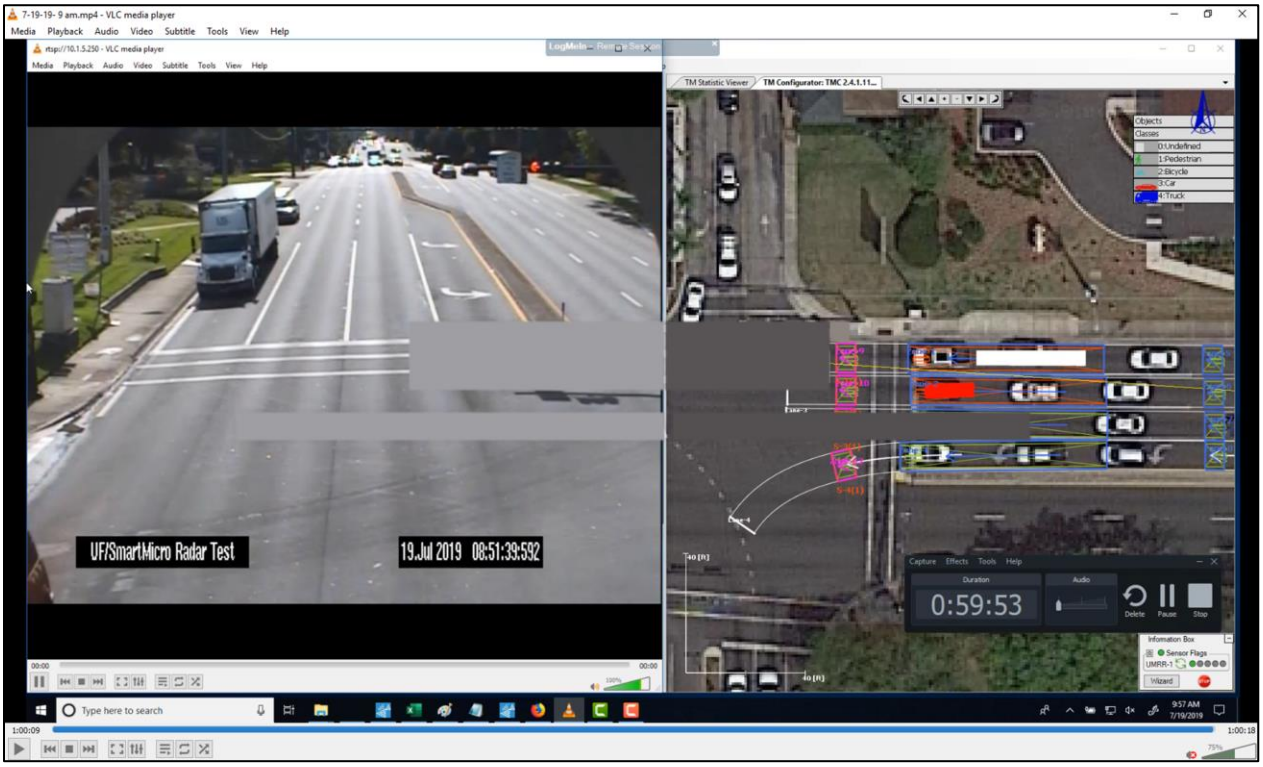

Figure 4 Wrong detection on lane #2 (False positive, condition 3)

As shown in **Figure 5**, there is a fraction of a second time lag between Iteris video and smartmicro TMC. This issue makes the data collection challenging especially in high volume moving traffic condition.

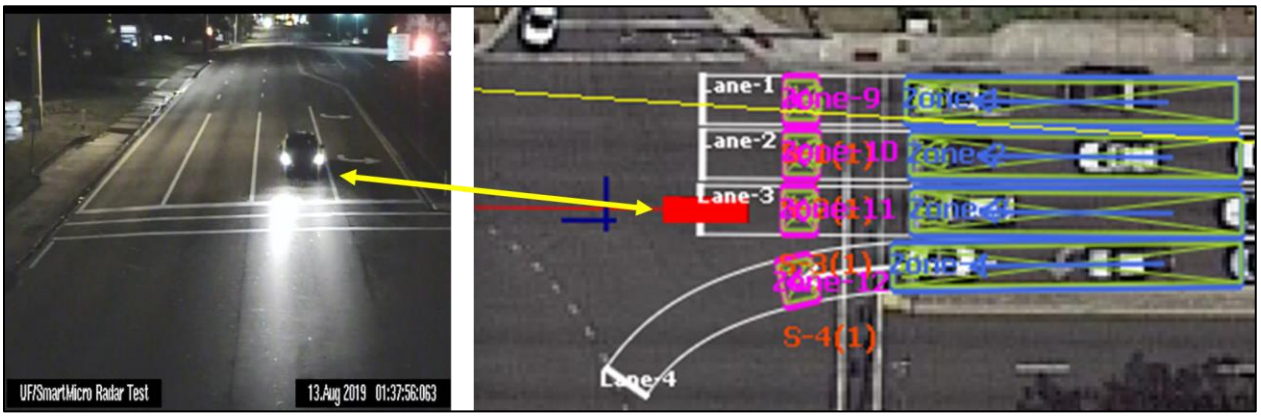

Figure 5 Time lag between smartmicro real-time and Iteris video

As mentioned 2 hours of side by side video was analyzed. The data from the videos were collected every 2 seconds for each lane. The final database includes 3600 rows for each lane ($2\ hours = 7{,}200\ seconds$, $\frac{7{,}200}{2} = 3{,}600$). All lanes combined has 14,400 data points ($4 \times 3{,}600 = 14{,}400$).

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To find the detection accuracy three measures were defined. In the following formulas O_1, O_2, O_3, O_4 are related to the possible detection conditions in **Table 1**.

A_1: Accuracy when a car exists in the detection zone:

$$A_1 = \frac{O_1}{O_1 + O_2} \times 100$$

A_2: Accuracy when there is no car in the detection zone:

$$A_2 = \frac{O_4}{O_3 + O_4} \times 100$$

A_3: Overall accuracy:

$$A_3 = \frac{O_1 + O_4}{O_1 + O_2 + O_3 + O_4} \times 100$$

Table 2 summarizes the detection aggregated results and their relevant accuracy for each lane and all lanes combined. The database for all lane combined includes 14,400 data points. In 61.6% of the data, there was at least one car in the detection zones. The detection accuracies were 97.8%, 99.4%, and 98.4% for A_1, A_2, A_3 respectively. The last two columns show the lower and upper bound of 95% confidence interval of the measured accuracies. The overall accuracy that is the focus of the study (A_3) was 98.42%.

The row percentages showed that the data was almost balanced between car presence and no car in detection zones for the right turn and through lanes. The most unbalanced lane was left turn, with 70.1% car presence and 29.9% no car in detection zones. The left turn lane A_1, A_2, A_3 were 94.6%, 99.7%, and 96.1%. On the left turn lane, it was observed that occasionally when the vehicles were stopped at the red phase, the detector drops the detection. That was the reason behind the lower accuracies on the left turn lane. Based on the numbers in **Table 2**, almost 69.0% of the false negative observations were related to the left turn lane (136/197). It could be due to the view angle of the left turn lane from radar. This could be informative in optimizing the location of radar. Modification of radar location may improve accuracy.

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Table 2. Detection accuracy results

All Lanes Combined							
Ground Truth	Detected	Not Detected	Row Total	Row Percentage	Accuracy	Accuracy 95% Confidence Interval	
Car exists in detection zone	8675	197	8872	61.6%	$A_1 = 97.87\%$	95.68%	99.88%
No car in detection zone	31	5497	5528	38.4%	$A_2 = 99.44\%$	96.76%	102.12%
Total			14400		$A_3 = 98.42\%$	95.75%	101.08%
Right Turn							
Ground Truth	Detected	Not Detected	Row Total	Row Percentage	Accuracy	Accuracy 95% Confidence Interval	
Car exists in detection zone	2352	13	2365	65.7%	$A_1 = 99.45\%$	95.35%	103.55%
No car in detection zone	1	1234	1235	34.3%	$A_2 = 99.92\%$	94.24%	105.59%
Total			3600		$A_3 = 99.61\%$	93.94%	105.28%
Through Lane 1							
Ground Truth	Detected	Not Detected	Row Total	Row Percentage	Accuracy	Accuracy 95% Confidence Interval	
Car exists in detection zone	1957	23	1980	55.0%	$A_1 = 98.84\%$	94.38%	103.30%
No car in detection zone	12	1608	1620	45.0%	$A_2 = 99.26\%$	94.32%	104.20%
Total			3600		$A_3 = 99.03\%$	94.09%	103.97%
Through Lane 2							
Ground Truth	Detected	Not Detected	Row Total	Row Percentage	Accuracy	Accuracy 95% Confidence Interval	
Car exists in detection zone	1977	25	2002	55.6%	$A_1 = 98.75\%$	94.32%	103.19%
No car in detection zone	15	1583	1598	44.4%	$A_2 = 99.06\%$	94.09%	104.03%
Total			3600		$A_3 = 98.89\%$	93.92%	103.86%
Left Turn Lane							
Ground Truth	Detected	Not Detected	Row Total	Row Percentage	Accuracy	Accuracy 95% Confidence Interval	
Car exists in detection zone	2389	136	2525	70.1%	$A_1 = 94.61\%$	90.75%	98.48%
No car in detection zone	3	1072	1075	29.9%	$A_2 = 99.72\%$	93.65%	105.80%
Total			3600		$A_3 = 96.14\%$	90.17%	102.11%