EXHIBIT A
SCOPE OF SERVICES

SENSING FOR HOV/HOT LANE ENFORCEMENT

BACKGROUND

The goal of this project is to develop a system involving sophisticated hardware and powerful software algorithms to automatically estimate the occupancy of passenger vehicles in high occupancy vehicle (HOV) and high occupancy toll (HOT) lanes. Tasks 2-4 must occur concurrently, and are executed through most of the research project period. The objective of the project is to develop and test the performance of a system to automatically detect vehicle occupancy in HOV/HOT lanes. The end product of the research will quantify the performance of the system across different lighting and prevailing traffic conditions, as well as assess the integration of the system into a comprehensive HOT/HOV monitoring tool, and explore its deployment for law enforcement activities within such facilities. The tasks for accomplishing the objectives are summarized below.

OBJECTIVE

The benefits of this work can be summarized into:

1. Significant improvements in the enforcement of HOV/HOT lanes;
2. Safer working conditions for State Troopers;
3. An increase in revenue, since more violators can be caught; and
4. Creation of data (vehicle trajectories, velocities, number of vehicle occupants, etc.) that could support infrastructure decisions of significant magnitude (i.e., if the particular HOV implementation is the one that makes the most sense, given its usage, how the HOV traffic patters interact with the traffic flow in the other lanes, counts of near-misses when neighboring lanes have significantly slower traffic).

Potential users are State Police, traffic engineers, and planners from entities like MnDOT, the Federal Highway Administration (FHWA) and other Departments of Transportation (DOTs). Users could even benefit from knowing the traffic patterns at a particular HOV/HOT site. The benefits will be measured based on metrics that compare the collected data to the ground-truth.

SCOPE

The project outcomes will assist the State Patrol in detecting violators of the HOV/HOT lanes. By using infrared (IR) and visible range cameras, the system will alert the State Troopers who will be in a safe location about possible violators. The project involves system deployment and builds on the University's previous research in the area with Honeywell and MnDOT.

WORK PLAN

<u>**Task Descriptions**</u>

Task 1: Honeywell Tri-Band Camera System Evaluation

The main objective of the task is to understand baseline performance specifications and operational characteristics of the software and hardware of the Honeywell Tri-Band camera system. Once the system is fully operational, initial experiments will evaluate system performance with stopped vehicles. The University will assess how far the system can detect stopped vehicle occupants at different times during the day. Also, camera position parameters will be evaluated, i.e. height, with respect to vehicle, yaw angle, etc. A suitable roadway location will be selected, based on budgetary scope, and with the guidance of the Technical Advisory Panel (TAP) to conduct the experiments with the tri-band sensor.

Task 2: Deployment Design for Field Data Collection

The University will design a data collection site and plan, which will provide temporary roadside data collection for Dual-Band IR sensor data collection across different traffic conditions and lighting. For example, MnDOT currently has a facility located on the shoulder, complete with electrical connectivity, a crank-down camera pole, an enclosure cabinet to house internet communication and potential data collection hardware for different roadside sensors. The research team will coordinate with the TAP to seek advice and field deployment constraints. To test sensing capabilities, it is important to consider possible sensor positioning to allow "frontal" vs. "side" vide perspectives to test different plausible positions for optimal performance of the system. If such a site is used, the team will evaluate relevant deployment periods where the macroscopic traffic flow characteristics are similar to HOV prevailing traffic conditions, for example, during critical peak periods.

Task 3: Sensor Deployment and Data Collection
The University will collect temporary roadside deployment of the Honeywell Sensor and initial datasets before beginning Task 5. Several such temporary data collection deployments will be necessary throughout much of the project period, to steer Task 4, as well as Task 3. The University will document time of day, length of data collection periods, and prevailing traffic characteristics during this task, for all experiments. The University will also test other specific sensor settings. The University will analyze and construct a database of comparative ground truth pedestrian counts within each vehicle.

Task 4: System Architecture Design for Dual-IR Band Based Occupancy Detection
The objective of this task is two-fold: 1) design a system architecture that can integrate with state-of-practice, or available state-of-the-art, commercial technologies, and communication and processing hardware to achieve future wide-spread deployment on HOV/HOT lane facilities; and 3) review recent commercial hardware technologies that could be integrated into the system architecture for occupancy detection with the University's technique. One such requirement would be the ability to time-synchronize and co-register sensor outputs. The team will research cost vs. performance through sensor specifications, as well as test such sensors with relevant field experiments, as defined by Tasks 1 and 2. Achieving the objectives in this task requires a spiral approach, between plausible sensor positioning and sensor designs, and algorithm development for passenger discrimination and detection.

Task 5: Algorithm Development and Refinement
The University will design algorithms to: 1) co-register and align images from the different spectral bands; 2) discriminate passenger objects/features from non-passenger objects/features (e.g., "background"); and 3) detection and classification algorithms. The University will explore and evaluate several common feature spaces (descriptors) coupled with different pattern classification techniques to discriminate and register human body and head shapes. For example, high dimensional image features, such as vector descriptions of blob shapes of human heads, Histogram of Gradients (HOG), which measures the distribution of edge intensities and orientations, vs. lower dimensional statistical descriptors, such as mean intensities, and their associated variances and higher order moment expectation calculations. The University will estimate the skin color pixels based on YCbCrRGB color space data: (Y, Cb, Cr) and RGB. These are considered powerful descriptors for the problem of object detection and classification, especially for human detection and classification. The University will also develop automatic alignment and object segmentation from the moving vehicles from different perspectives.

Task 6: Compile Report, Technical Advisory Panel Review and Revisions
The University will prepare a draft report, following MnDOT's publication guidelines, to document project activities, findings and recommendations. This report will need to be reviewed by the TAP, updated by the University's Principal Investigator, and then approved by the Technical Liaison before this task is considered complete. Holding a TAP meeting to discuss the draft report and review comments is strongly encouraged. TAP members may be consulted for clarification or discussion of comments.

Task 7: Final Published Report Completion
During this task, the Approved Report will be processed by MnDOT's Contract Editors. The editors will review the document to ensure the document meets the publication standard. The University's Principal Investigator will then prepare the Final Report and submit it for publication through MnDOT's publishing process.

<u>Task Deliverables</u>

Task:	Deliverable(s):
1:	Demonstration of the System Capabilities, at a site selected with TAP guidance
2:	Quarterly Reports; Presentation to the TAP
3:	Quarterly Reports; Data Collection Sample "Movies" and Image Sets; Presentations to the TAP
4:	Quarterly Reports; Presentation to the TAP
5:	Quarterly Reports; Presentation to the TAP
6:	Draft of the Final Report
7:	Final Report

PROJECT SCHEDULE

	2014											2015						
Months:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Task Completion Dates**
Task 1	X	X	X	X	X													June 30, 2014
Task 2			X	X														May 31, 2014
Task 3			X	X	X	X	X	X	X	X	X	X						January 31, 2015
Task 4								X	X	X	X	X	X					February 28, 2015
Task 5														X	X	X		May 31, 2015
Task 6														X	X	X		May 31, 2015
Task 7																X	X	June 30, 2015

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