

# **ASSESSING SYSTEM IMPLEMENTATION READINESS OF THE DRIVER ALCOHOL DETECTION SYSTEM FOR SAFETY (DADSS) TO REDUCE ALCOHOL-IMPAIRED DRIVING IN A REAL-WORLD DRIVING PILOT DEPLOYMENT PROJECT**

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## **ABSTRACT**

The Driver Alcohol Detection System for Safety Program – a joint effort of the National Highway Traffic Safety Administration and the Automotive Coalition for Traffic Safety - has been developing unique, in-vehicle alcohol detection systems to more effectively address the problem of alcohol-impaired driving. These technologies, both breath-and touch-based, are intended to be seamless with the driving task, non-intrusive, accurate, fast, reliable, durable, and require little or no maintenance. Now in Phase III of development, the breath-based technology is ready for real-world road testing in a naturalistic setting in the State of Virginia, U.S.A. The Driven to Protect Powered by DADSS initiative, is a partnership with the Virginia Department of Motor Vehicles Highway Safety Office and the Automotive Coalition for Traffic Safety. As the technical and program management lead, KEA Technologies, Inc. has instrumented and deployed a small fleet of pilot test vehicles to examine the data from breath-based prototype sensors under various environmental, driver/user interaction, and user demographics conditions. The alcohol detection system is known to be accurate, precise, reliable, and maintainable based on laboratory and controlled test results. This pilot program seeks to obtain data from naturalistic, uncontrolled test conditions. The pilot program will determine if: a) the system is generally accepted by drivers, b) there are any technical modifications required to significantly improve the system, and c) the system is ready for wider implementation in fleet, privately-owned, commercial, or other vehicles. Four 2015 Ford Flex “For Hire” commercial livery service vehicles have been instrumented with in-vehicle breath-based alcohol detection sensors including supporting data collection and transmission systems. The Pilot Deployment Project is ongoing with a goal of collecting at least 15,000 data points from the sensors. Lessons learned will be used to refine the performance specifications, sensor technology, and data acquisition systems for future on-road vehicle testing.

## **INTRODUCTION**

Alcohol-impaired driving - defined as driving at or above the legal limit of 0.08 g/dl or 0.08 percent in all U.S. States except where the limit is 0.05 g/dl in Utah - is one of the primary causes of motor vehicle fatalities on U.S. roads every year. In the U.S. in 2017, 10,874 people were killed in alcohol-impaired driving crashes (NHTSA, 2018). And specifically as it relates to this Pilot Deployment project, in 2017, 248 people were killed and 4,430 injured on Virginia’s roadways due to alcohol-impaired crashes.

There are a variety of countermeasures that have been effective in reducing this excessive toll, many of which center around strong laws and visible enforcement (Ferguson, 2012). However, to drastically reduce these deaths it will be necessary to prevent alcohol-impaired drivers from driving in the first place. To that end, the National Highway Traffic Safety Administration (NHTSA) and the Automotive Coalition for Traffic Safety (ACTS) began research in February 2008 aimed at identifying potential in-vehicle approaches to identifying and preventing alcohol-impaired driving as it happens. ACTS members are comprised of motor vehicle

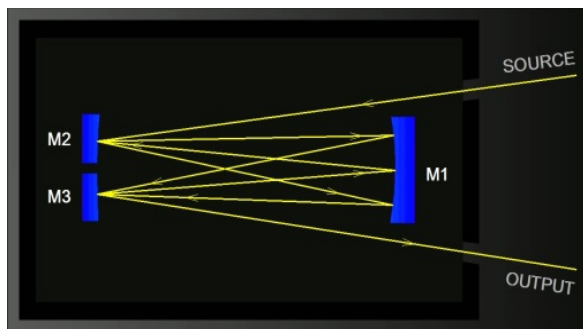
manufacturers representing approximately 99 percent of light vehicle sales in the U.S. This cooperative research partnership, known as the Driver Alcohol Detection System for Safety (DADSS) Program, has identified feasible non-invasive technologies aimed at preventing alcohol-impaired driving (Ferguson et al., 2009, 2010, Zaouk et al., 2015, 2017). These technologies are designed to be seamless with the driving task, they are non-intrusive, accurate, fast, reliable, durable, and require little or no maintenance. The vehicle cannot be driven when the device registers that the driver's blood alcohol concentration (BAC) meets or exceeds 0.08 g/dl.

The breath-based prototype sensors have been installed and integrated into vehicles for pilot testing in real-world driving conditions. Results from these tests will help to determine whether the system is generally accepted by drivers, if there are any technical modifications required to significantly improve the system, and whether or not the system is ready for wider implementation in fleet, privately-owned, commercial, or other vehicles.

## SENSOR TECHNOLOGY

### Breath-Based Sensor technology

The breath-based approach uses sensors to measure the concentrations of alcohol and carbon dioxide (CO<sub>2</sub>) in the breath simultaneously. The known quantity of CO<sub>2</sub> in the human breath is an indicator of the degree of dilution of the alcohol concentration in exhaled air. Diluted breath is drawn into the sensor by a fan, which directs infrared light beams on the breath sample and analyzes the wavelengths returned for both alcohol and CO<sub>2</sub>. Breath alcohol concentration is then quickly and accurately determined. (Hök et al., 2006, see Figure 1).

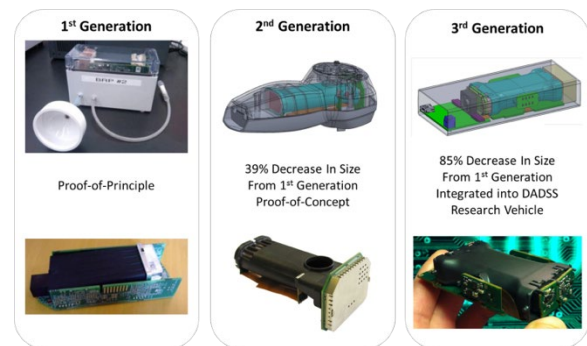


**Figure 1. Breath-based sensor block diagram**

The ultimate goal of the DADSS sensors is to passively measure breath alcohol within the vehicle cabin - without direct input from the driver. The challenge with the breath-based system is to meet the

stringent performance requirements while measuring highly diluted breath. Thus, a significant component of the research is focused on understanding expired breath aerodynamics within the vehicle cabin and identifying effective locations for the sensors.

The breath-based sensor has been updated in Phase III with the goal of improving this capability. The latest, 3<sup>rd</sup> Generation version (Gen. 3), underwent a complete re-design to increase resolution for passive sensing, reduce the overall size, and obtain improved performance over the full temperature range of -40°C to +85°C as defined in the DADSS Performance Specifications. A major improvement of the Gen. 3 sensor over previous versions was the optical module configuration in which ethanol detection takes place over the full length of the device where CO<sub>2</sub> is detected cross-wise. With this configuration there is no systematic timing difference between the two signals, enabling the possibility of passive in-vehicle sensing (Ljungblad et al., 2017). See Figure 2 for a graphic representation of the sensor evolution.



**Figure 2. Evolution of Breath-based DADSS Sensor**

## NATURALISTIC DRIVING TRIALS – JRT Pilot Deployment Project

### Overview

Driven to Protect, Powered by DADSS, has partnered with James River Transportation (JRT), a transportation company with offices in Richmond and Norfolk, VA, to conduct the first in-vehicle, on-road naturalistic test trials with prototype breath-based alcohol sensors in their vehicles. In August 2018, the first Ford Flex vehicles in the JRT commercial fleet started operating from Richmond International Airport (RIC) and Norfolk International Airport (ORF), conveying clients to local destinations. The breath-based prototypes were seamlessly integrated into these fleet vehicles and are collecting real-world operational data throughout the ride. The feedback and data collected from drivers

will be invaluable in modifying the technology as it is prepared for widespread commercialization. Through mid-January 2019, the JRT vehicles have travelled nearly 40,000 miles in 149 days, and the sensors have been in operation more than 4,000 hours and collected over 16,000 data points.

### Vehicle Layout and Systems

Four 2015 Ford Flex vehicles (similar to that shown in Figure 3), initially two at RIC and two at ORF, have been instrumented with two Gen 3.1 breath-based sensors and one “reference” breath-alcohol sensor. Prior to installation, groups of sensors were characterized at the KEA Technology Laboratory in Marlborough, MA U.S.A. Characterization typically includes the use of a climate chamber where sensors are tested at  $-40^{\circ}\text{C}$ ,  $+22^{\circ}\text{C}$  (representing ambient), and  $+85^{\circ}\text{C}$ , and at controlled ethanol concentrations of 0.000%, 0.020%, 0.040%, 0.060%, 0.080%, and 0.100% Breath Alcohol Content (BrAC).

Each vehicle is equipped with two prototype sensors, one “reference” breath alcohol sensor, one data acquisition system (DAS), two data transmission technology systems (i.e., WIFI and 4G), and one video system including two cameras and digital video recorder.



**Figure 3. James River Transportation Ford Flex Driven to Protect Vehicle (Platform car shown)**

The two breath-based prototype sensors are collecting samples both in directed mode, where drivers direct their breath toward each of the sensors, and in “sniffer” mode to capture breath alcohol present in the ambient air. After comprehensive research that investigated optimal sensor placement in numerous locations within the vehicle, the sensor was adapted for installation in the JRT Pilot Deployment vehicles in two different positions: above the steering column and in the driver’s door panel. These positions improved analysis of the impact of cabin air flow and the driver’s position on alcohol measurements as well as optimized

performance. One breath sensor is mounted into the top of the steering column clamshell, directly in front of the driver’s face. A second sensor is mounted on the driver’s side door in the upper trim panel just forward of the driver’s left shoulder (see Figure 4).



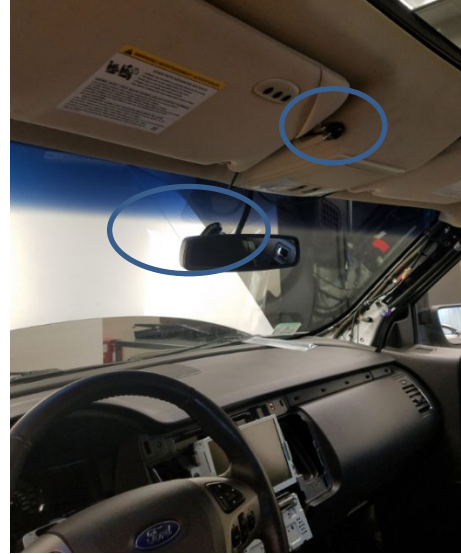
**Figure 4. DADSS Breath-based sensors; Steering column (top) and driver-side door (bottom)**

A “reference” handheld breath sensor is situated on the left side of the center stack and infotainment center. This sensor has been previously validated. As a part of the Test Plan, the drivers are required to blow into the reference sensor to provide “control” data for comparison against the prototype sensor data. Under 49CFR Part 40 alcohol conformance tests, this reference device has been recognized by NHTSA as an approved *evidential breath testing (EBT)* unit (see Figure 5).



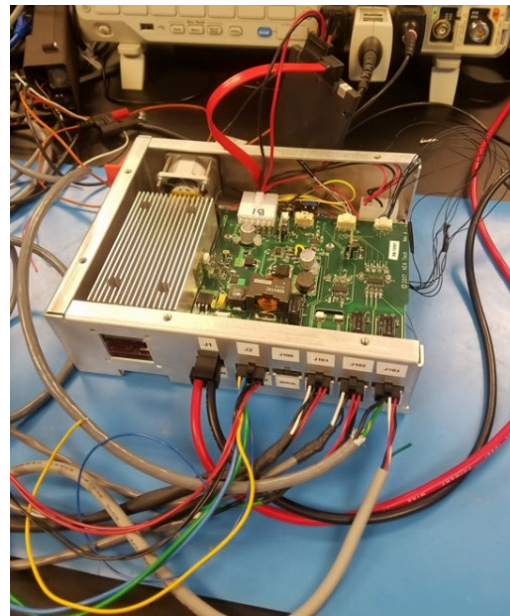
**Figure 5. Reference sensor**

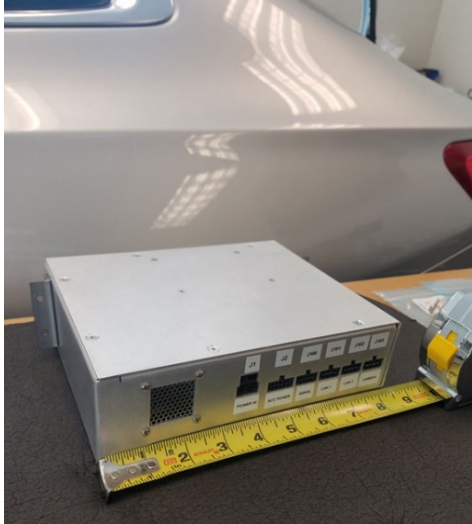
Two cameras record the drivers interaction with the sensors (see Figure 6) and video data are stored in an Axis DVR.



**Figure 6. Locations of video cameras**

The DAS is the central processing system – the “brain” of the DADSS system (see Figure 7). The DAS obtains power from the vehicle battery and distributes it to the other system components. Utilizing a wake signal from the 12V inverter in the car, the DAS activates once the vehicle power is activated through accessory or fully powered on. It powers the reference sensor and collects acquired serial data. The DAS relays power to the two prototype breath sensors and receives the Control Area Network (CAN) data coming from those sensors.





**Figure 7. Data Acquisition System (DAS), internal and external views**

In the JRT Pilot Deployment project, the DAS is mounted in the rear right quarter panel of each 2015 Ford Flex vehicles (see Figure 8).



**Figure 8. Location of Data Acquisition System (DAS) in Ford Flex vehicle**

One configurable vehicle-grade router with 3 antennas is the hub for Wi-Fi, 4G and GPS capabilities. Positive alcohol alerts and critical system information is sent from the DAS via 4G, while raw sensor and video camera data is sent via Wi-Fi when the vehicle is within range of the access point antenna and transmission equipment (see Figure 9). The router is mounted in the same rear quarter panel next to the DAS.



**Figure 9. Vehicle-grade Router location**

The GPS antenna is mounted inside the trim in the front right "A pillar" of the Flex. The Wi-Fi and 4G antennas are mounted in the front and rear of the cargo area window frame, respectively.

### **Driver Protocols**

Nineteen JRT-employed drivers have been using the sensor-equipped vehicles for their regular work shifts. Drivers were given training and orientation prior to the beginning of the pilot project with a focus on testing-related activities: when, where, and how to give "directed" breath samples. The protocol includes obtaining breath samples from drivers at the beginning and the end of each shift, and each time after a passenger is dropped off (i.e., when no passengers are present). No other changes were made to their regular work/drive routine.

At the beginning of the shift, using a phone app, drivers are asked to fill out a short survey including questions such as when they last consumed alcohol and how much, medical ailments, use of over-the-counter medications that might yield a false-positive (e.g. cold medications), and whether they have used mouth wash or hand sanitizer which may affect prototype sensor readings. When the driver starts the vehicle, the DADSS system (including DAS, sensors, and video system) turns on automatically, with no driver action required. At the beginning of the shift, the driver provides a "set" of samples: one directed breath sample into each of the prototype sensors (steering column and driver-side door). Next, the driver provides a deep-lung breath sample to the reference sensor by blowing into the disposable

plastic tube. This “set” of samples is repeated a second time to indicate the beginning of a shift. If there is a positive reference sensor reading ( $\geq 0.02\%$  BrAC), an alert will be sent wirelessly to JRT Management personnel for action, and to KEA for informational purposes. If the second sample using the reference sensor also reads  $\geq 0.02\%$ , then JRT will execute their standard operating procedure relating to suspicion of impairment and try to determine the cause of the reading. In the event of an invalid reference sensor reading, the driver will be prompted to give another sample. In addition to these active Driver test conditions, throughout the day the breath sensors are also operating in “sniffer” mode, passively testing the ambient air around the driver. All of the data from these “directed” and “sniffer” breath samples are captured and recorded in an on-line Data Viewer available only to specific authorized program personnel.

## DATA COLLECTION AND ANALYSIS

### Data Collection

The data analysis plan includes exploration of sensor measurements and troubleshooting sensor performance on a daily basis, as well as longer-term analysis of sensor performance. Data collection includes both qualitative feedback from drivers and quantitative breath alcohol measures during driving shifts. Because the drivers of the fleet vehicles are expected to be free of alcohol in their breath ( $< 0.02$  BrAC), the focus of the project is sensor performance with zero or low levels of breath alcohol. The goal to collect a total of 15,000 breath sensor measurements was reached after five months of deployment.

Quantitative data collection involves pre- and post-shift driver surveys that gather feedback on driver experience with the sensors but also inform any troubleshooting of anomalous readings or problems with the sensors and data acquisition system. Driver factors include last reported alcohol use and medication use (e.g. cold medicine) or use of other products that could trigger a positive sensor reading (e.g. mouth wash, hand sanitizer). Drivers also report on presence of intoxicated passengers in the vehicle and any challenges in providing breath samples. Continuous video surveillance adds information on driver interaction with the sensor and visual cues the sensor provides during use. In addition, two small focus groups were conducted to gain an understanding of driver receptiveness to the technology, preferences for sensor prompts, other

interactions with the sensors, and feedback on the program training and driver test plan.

Quantitative sensor data are collected continuously by the in-vehicle DAS. Data elements include the measured BrAC (g/210L) from both “directed” and “sniffer” breath prototype sensor samples in addition to the corresponding sensor firmware status, time from start up, breath dilution levels, and the breath-alcohol reference sensor measurement reading.

### Data Analyses

The objectives of the data analysis include assessment of driver receptiveness of the technology, case studies of false-positive prototype sensor readings (BrAC $\geq 0.02\%$ ), gathering data that inform technical modifications to improve sensor performance, surveilling the exposure of the sensors to in-vehicle use and troubleshooting issues that arise in this first field deployment. Lessons learned will be used to refine the sensor performance specifications, sensor technology and data acquisition systems for future on-road vehicle testing.

In the first approximately five months of the deployment, the prototype sensors have been present in vehicles driven nearly 40,000 miles during approximately 4,000 hours of driving time. During these shifts the prototype sensors measured BrAC from over 16,000 directed or “sniffed” breath samples. Pre- and post-drive surveys have been completed by a total of 19 drivers for over 200 shifts.

During this time, the reference sensor registered a positive BrAC ( $\geq 0.02\%$ ) in 4 events. Immediate follow-up to these events involved contacting the driver and asking about possible medication, mouthwash or other product use that would trigger a positive BrAC. Requested follow-on breath samples using the reference sensor showed a sharp decline to BrAC $< 0.02\%$  within twenty minutes. The conclusion in these 4 investigations is that mouthwash was likely the cause of the initial positive BrAC. Pre-drive surveys, in particular the questions regarding last alcohol use and use of medications and mouthwash, were critical in concluding that the positive breath samples were due to short-term, residual mouth alcohol from the over-the-counter products and not due to positive blood alcohol levels.

Driver feedback shows an initial learning and acclimation period in use of the prototype sensors. Around a quarter of post-drive feedback in the first two months indicated a problem with the sensors (21% and 25%, respectively). Reported problems during the shift then declined to 11% in the third months, 5% in the fourth months, and 0% in the fifth month. Feedback in the focus groups indicated that

there was a “small” learning curve in providing a breath sample to the sensors, but after “a short time” they “got the hang of it.” The focus groups provided feedback on driver-sensor interactions. Drivers expressed annoyance with the beeping from the reference sensor and the data acquisition fan. With respect to the prototype sensors, the drivers noted that the orange and green lights were informative/useful and not annoying. The drivers did not feel the prototype sensors were distracting.

The post-drive surveys were important for feedback on the functioning of the sensors and DAS. Several drivers reported problems with interference with in-vehicle GPS, radio, and keyless entry. This real-time reporting allowed quick technical modifications to be made to limit this interference.

As discussed above, the measured quantity of CO<sub>2</sub> in a breath is an indicator of the degree of dilution in the breath in ambient air. This degree of dilution is represented by a “dilution factor” (DF), computed based on the measured CO<sub>2</sub> compared to the expected exhaled CO<sub>2</sub> in human breath. For the purposes of this project, the data acquisition system reports all breath samples that resulted in a BrAC measure, regardless of DF.

Assuming all drivers were BAC negative, sensor readings above BrAC 0.02% were considered high erroneous readings. An interim analysis of the prototype data found that a quarter of the measures were above BrAC $\geq$ 0.02%. DFs ranged from 0 to 149. This analysis further found an association of erroneous high BrAC readings with a high DF (i.e. highly diluted breath samples). The lower the dilution factor, the lower the percent of erroneous readings.

To inform future filtering of the sensor readings by a given DF threshold in order to minimize erroneous readings, the project examined the trade-off between reducing erroneous readings without eliminating correct readings. The analysis suggests DF=30 as the cut-off because it hits a “sweet spot”: a reduction in the number of high/erroneous readings (1.8% of readings remain that are BrAC $\geq$ 0.02%) without deleting too many correct readings. In comparing readings at DF=30 to DF=25 and DF=20, we observed that lowering the dilution factor below 30 only eliminated correct measures (BrAC<0.02%).

In this ongoing project, sensors continue to be monitored to ensure they are performing as expected on a daily basis in order to identify immediate solutions and understand erroneous BrAC readings. Further analyses include examination of the agreement of breath sensors with the reference sensor and with each other; examining factors that affect this

agreement; and variations in sensor function over time and as a function of continued use.

## CONCLUSIONS

Significant progress has been made in the identification and development of DADSS sensor technologies that have the potential to be used on a more widespread basis in passenger vehicles. While the testing from this project and the data obtained are very important, analysis suggests that additional testing under other conditions is warranted. A near-term future project is planned to continue the on-road testing of the prototype sensors. This next stage in the development effort is the evaluation of the performance of the next generation (Gen 3.2) of prototype sensors in vehicles under real-world driving conditions including alcohol-positive samples obtained from dosed passengers under strict test conditions. The Driven to Protect, Powered by DASS initiative, is a partnership between the Virginia Department of Motor Vehicles, Highway Safety Office and the Automotive Coalition for Traffic Safety. This is the first state partnership with a private company to conduct in-vehicle, on-road test trials of the DADSS technology. KEA Technologies has installed the latest generation 3.1 prototype breath-based sensors into four vehicles in the James River Transportation commercial fleet. Results from this JRT pilot testing will be invaluable in finalizing the technology as it is prepared for widespread commercialization.

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