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MAYOR

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Self-Driving Vehicle Testing in Pittsburgh
Summary of Findings

April 22, 2019

On March 1, 2019, Mayor William Peduto issued his Executive Order on Self-Driving Vehicle Testing and Operations in the City of Pittsburgh. That Order identified the Department of Mobility and Infrastructure (DOMI) as the lead department for such testing and directed the Department to propagate guidelines for submission of information on testing in the City.

DOMI released testing submission guidelines concurrent with the issuance of the Executive Order, also on March 1, 2019. The guidelines require new testers to submit materials no less than ten (10) days prior to the proposed initiation of testing and provided existing testers thirty (30) days to provide a retroactive submission.

This report provides a summary of findings.

Entities Conducting On-Road Testing in Pittsburgh

Five entities are currently testing on public streets in the City of Pittsburgh. They are:

- Aptiv
- Argo AI
- Aurora
- Carnegie Mellon University (CMU)
- UATC, LLC (“Uber”)

Impact on Local Employment

Across all entities engaged in on-road testing, over 1,300 people are employed locally in areas associated with the testing activities.

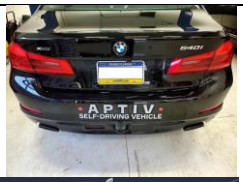
Testing Fleet

At the present time there are a total of 55 vehicles equipped with automated driving systems (ADS) and actively being used in on-road testing in the City of Pittsburgh.

Testers use a number of different vehicles from Original Equipment Manufacturers (OEMs). At the present time all use conventional passenger automobile vehicle types. The vehicles used include:

- Aptiv – BMW 540i and Chrysler Pacifica PHEV
- Argo AI – Ford Fusion Hybrid
- Aurora – Lincoln MKZ
- CMU – Cadillac SRX
- Uber – Volvo XC90

Vehicles will be uniquely identified by their trade dress:

Aptiv	All vehicles will be clearly identified by Aptiv branding.	  
Argo AI	Argo logo, roof-mounted self-driving sensor pod, front fender or rear roof sensors, Argo's or Ford Motor Company's logo, Argo's website URL www.argo.ai, or the phrases "Self-Driving Systems Development" or "Self-Driving Test Vehicle"	
Aurora	The Black Aurora logo will appear on both driver and passenger rear quarter panels. The words "Autonomous Test Vehicle" will be located along the bottom of both rear windows.	
CMU	The phrase "Carnegie Mellon University" will be located on the hood, on each side, and on the rear of each vehicle (a total of 4 locations).	
Uber	All vehicles will be clearly identified by Uber branding.	

Location of Testing

The greatest intensity of testing is occurring in the Strip District and Lower Lawrenceville, however testers report testing is currently occurring in 32 city neighborhoods including the following:

- Allegheny Center
- Allegheny West
- East Allegheny
- Bloomfield
- CBD/Downtown Pittsburgh
- East Liberty
- Friendship
- Garfield
- Greenfield including Four Mile Run
- Hazelwood
- Highland Park
- Hill District (Upper, Middle, Lower)
- Homewood
- Larimer
- Lawrenceville
- Morningside
- North Shore
- Oakland (North, Central, South)
- Point Breeze
- Polish Hill
- Shadyside
- South Side Flats
- Squirrel Hill (North and South)
- Stanton Heights
- Strip District
- Troy Hill
- Uptown

Additionally, testers conduct on-road testing in numerous surrounding communities including:

- Aspinwall
- Bellefield
- Blawnox
- Carnegie
- Churchill
- Edgewood
- Etna
- Fairview Heights
- Forest Hills
- Fox Chapel
- Gascola
- Greentree
- Harmarville
- McKeesport
- Millvale
- Monroeville
- O'Hara
- Plum
- Sharpsburg
- Schenley Heights
- Swissvale
- Unity

Level of Automation

All entities propose testing Level 4 self-driving systems – as defined by standards established by the Society of Automotive Engineers (SAE). SAE Level 4 automation means that a vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle outside of these conditions.

Testing Operations

For the most part, on-road testing will only occur on weekdays (Monday to Friday) with occasional testing on weekends. Testing is anticipated during both daytime and nighttime. Testing will generally occur only during favorable weather conditions. Testers do anticipate

operating controlled testing in rain, snow and other adverse conditions. Testers will pause operations in weather conditions that result in, or contribute to, loss of traction, low visibility, or conditions that do not support safe, controlled driving

Safety Provisions

Each entity testing vehicles in Pittsburgh has provided evidence their systems provide several layers of redundant safety protection.

All testers will operate with two operators in the vehicle – one driver and one associate in each vehicle while testing.

All vehicles have multiple disengagement mechanisms. If the presses or moves any one of these mechanisms the vehicle will disengage from self-driving mode These include:

1. Accelerator pedal
2. Brake pedal
3. Steering wheel
4. Disengagement button in console
5. Some vehicles have additional disengagement buttons in the steering wheel

Interior of an Uber vehicle. Other vehicle layouts may vary slightly.

Driver Screening

Each tester has a well-developed program for driver screening, ensuring that all have exemplary driving records and clear personnel background checks. Most testers require drivers to have technical experience in robotics, engineering, or other related fields.

Driver Training

Each tester has an established driver training program. This generally includes specific instruction on local traffic and driving laws and practices as well as intensive technical training in disengagement and how to diagnose and annotate driving systems. Vehicle operators learn safe driving techniques such as active scanning, reducing distractions, increasing attentiveness, taking breaks, and proper positioning of themselves and vehicle equipment.

Driver Operations

Each tester has a unique program to monitor and ensure driver attentiveness and readiness. This may include visual monitoring of the driver, requirements for active interaction with the vehicle, and frequent communications with the co-pilot. Driver protocols generally include periodic physical activity and stretching. Driver duration in the vehicle is limited to maintain alertness. Entities report a zero tolerance for drug and alcohol use.

Vehicle Detection and Sensors

All vehicles being tested in Pittsburgh share general commonalities in the equipment and systems used to support self-driving systems:

1. Light Detection and Ranging (LIDAR): LIDAR is a remote sensing method that uses light in the form of a pulsed laser to measure distances to actors and objects. Vehicles generally have one, top-mounted LIDAR unit with a range averaging 100 meters (m).

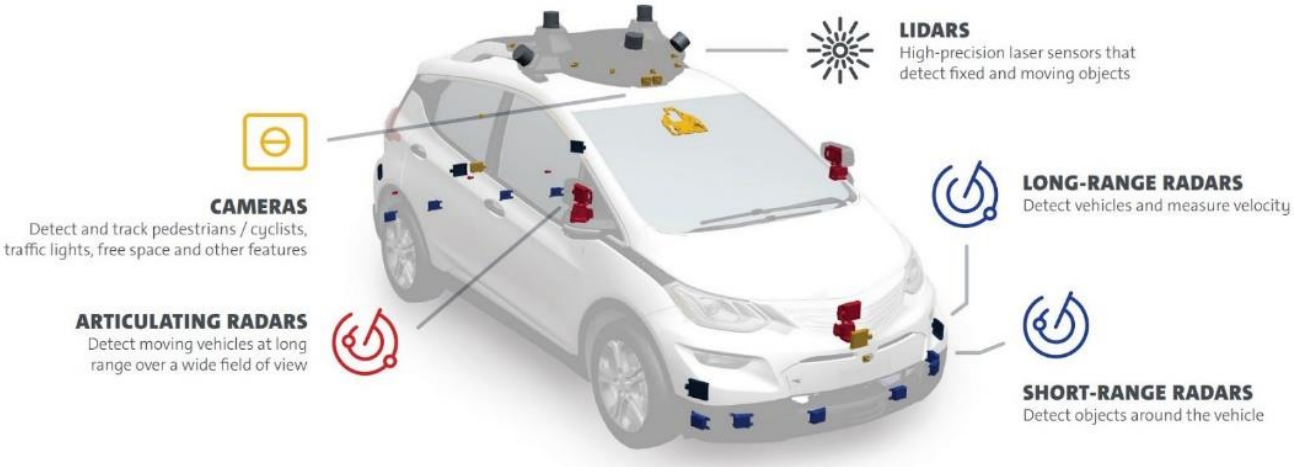
2. Cameras: High resolution cameras provide near-, medium-, and long-range imagery 360 degrees around the vehicle. Each vehicle has multiple cameras including on top of the vehicle and on all sides. Cameras and associated analytic systems are unique to each entity. Cameras provide imagery for sensing people and objects within 5 meters of the vehicle.

3. Radar: Radars provide object detection, ranging, and relative velocity of objects. Forward-facing radars are generally mounted below the headlamps, side-facing radars are in the front and rear corners of the vehicle, and rear-facing radars are near the ends of the bumper beam.

4. Global Positioning System (GPS): The GPS system provides rough position to support localization, vehicle command, map data, collects information and satellite measurements.

5. Self-Driving Computer: Each vehicle has an on-board computer running the many different software systems that analyze the inputs of the various sensors, imagery and data inputs, detect conflicts and predict and direct appropriate vehicle responses. The computer hardware and firmware are unique to each self-driving system.

6. Telematics: Custom telematics hardware and software provide cellular data communication to support carrier network redundancy, secure mobile data traffic, and



authenticated cloud communication.

Each automated self-driving system is unique, however they all have software that utilizes the various inputs provided by the vehicle sensors to perform a series of automated tasks:

Perception: The self-driving system gathers data from 360° around the vehicle. Perception software processes this data and combines it with maps into a full representation of the environment.

Localization: Inputs from the sensor suite and high-definition maps allow the self-driving system to determine where it is relative to the environment with a high degree of specificity.

Prediction: Prediction software takes a representation of the driving and uses this representation to predict what the actors or objects in the environment are likely to do next.

Routing and navigation: Routing software uses mapped information and real time operational conditions to determine what route the vehicle should use to reach its destination.

Motion planning: Motion planning software utilizes information gathered from actives sensors combined with pre-mapped information and the planned route to determine the appropriate actions for the vehicle to take.

Vehicle control: Vehicle control software executes the planned actions of the vehicle.

Self-driving systems are tested and validated at both a component level and system level.