## QUARTERLY AV TESTING REPORT

4th QUARTER 2018

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## BACKGROUND

nuTonomy is an autonomous vehicle (AV) company. We are a part of Aptiv, a global mobility technology company. Our mission is to radically improve the safety, efficiency, and accessibility of transportation in cities worldwide. Since January 2017, we have been testing our AV's on the public roads in Boston. nuTonomy and the City of Boston have agreed to a Test Plan, which asks nuTonomy to report on our AV testing quarterly. This Report covers our progress during the Fourth Quarter of 2018.

In this Quarter, we continued to collect data in the Seaport and South Boston neighborhoods to expand and refine our high-definition maps. With our recent move into a new primary office space in the Fan Pier development of the Seaport, we have been focused on implementing map features to connect our new office into our existing map network. As of this Quarter, we have validated this new map area and can now autonomously drive to and from our office.

Being able to access this new area is valuable for our internal development, and it is also valuable for demonstrating the technology. In the Fourth Quarter, nuTonomy worked with the City of Boston to host an educational event for local community representatives. Together with the City, we invited members of pedestrian, bicyclist, and safety advocacy groups to learn more about our technology, ask questions, and take demonstration rides in our AVs. As always, we found the feedback from our passengers helpful for our thinking about how to design a safe, affordable, and accessible AV service.

Our Boston team also continues to work closely with our Aptiv colleagues in Las Vegas to demonstrate the potential for a commercial AV service in that city. In the Fourth Quarter, Aptiv announced that we had given over 25,000 paid autonomous rides to the public as part of our Lyft pilot in Las Vegas. Passengers continue to review the rides positively, with an average feedback rating of 4.95 out of 5 stars. Aptiv AV's currently service 37 pick-up and drop off locations in Las Vegas, which now include the Las Vegas Convention Center and Las Vegas City Hall.

## SUMMARY

### Miles Driven

As we stated in our Report in the Third Quarter of 2017, nuTonomy has exceeded the 600 autonomous miles required for Phases B1, B2, C1, and C2 of the Test Plan. As always, it is important to note that our autonomous driving in Boston represents a small fraction of accumulated autonomous mileage. While our footprint in Boston is small, our autonomous driving in Boston is high leverage: the complexity of road conditions and the density of vehicles, pedestrians, cyclists, and other road users accelerates our research.

### Locations Driven

During the Fourth Quarter, we operated our AV's in autonomous mode on streets in the Seaport and in the periphery of South Boston. Specific roadways include: A Street, Black Falcon Avenue, B Street, Bond Drive, Boston Wharf Road, Congress Street, Courthouse Way, Cypher Street, D Street, Dorchester Avenue, Drydock Avenue, E Street, Fan Pier Boulevard, Fargo Street, Harbor Shore Drive, Northern Avenue, Pier Four Boulevard, Richards Street, Seaport Boulevard, Sleeper Street, Summer Street, Tide Street, West 1st Street, West 2nd Street, and various small connector streets. Additionally, we operated our AVs in manual mode for data collection and mapping purposes throughout the remainder of the Seaport and South Boston neighborhoods. We also conducted testing in our closed course facility in the Boston area.

### Crash Reports

We have not produced any crash reports, because our AV's have not been involved in any collisions during our testing in Boston.

### Failures with Autonomous Mode

We did not experience any unanticipated failures or disruptions while driving in autonomous mode. As we explain below in greater detail, in certain traffic scenarios our safety drivers take over manual control because of known limitations of the current state of AV software.

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## SUMMARY

### Takeovers

nuTonomy's safety drivers take over manual control in any situation in which they feel uncomfortable or unsafe. During the Fourth Quarter, our safety drivers took over manual control of our AV's in the following situations:

1. when emergency vehicles were in active operation (e.g., sirens and lights activated) in the roadway;
2. when law enforcement officers were manually directing traffic in intersections through which our AV's were travelling;
3. in certain situations in which construction vehicles were obstructing our lane of travel;
4. in certain situations in which oncoming vehicles or bicycles violated lane boundaries; and,
5. when other vehicles were exhibiting erratic behavior near our AV's.

A safety driver's decision to take over manual control in a given situation does not necessarily indicate that continued autonomous operation in those situations would be unsafe. Because we instruct our safety drivers to err on the side of caution, we expect that takeovers will occur in many situations in which the AV would have handled the situation without incident. We are continuously improving our AV software, and we are confident that our AVs will be able to handle each of these situations without a takeover after further development.

## LEARNING

### What We Have Learned

nuTonomy is one of a small number of companies in the world testing AV's year-round in a cold weather city. In winter, our AV's face the challenging conditions that are familiar to all Boston drivers: low-light, high cloud-cover, frigid temperatures, salted roadways, snowbanks, and active snowfall. One winter weather condition that presents a special challenge to AV's is dynamic lighting.

On certain occasions in the Fourth Quarter, low evening sun and solar glare affected our system for detecting the color of traffic signals. In a sense, the challenge for an AV's sensors resembles the challenge for human drivers: it can be difficult to perceive the state of a traffic light while staring into the sun. Likewise, solar glare can interfere with our traffic light detection software. Our system is designed to infer that a traffic signal is displaying a red light until the sensors can confirm the presence of a green light. If the inability to confirm a green light could create a safety risk, safety drivers are instructed to take over manual control of the vehicle.

When nuTonomy encounters a real world technical challenge like solar glare interfering with our traffic light detection, we prioritize the development of permanent hardware and/or software solutions, and implement an interim operational solution. In this case, our developers have added low-light data collection in the training of our algorithms. We have also made hardware adjustments, such as changing the exposure of a camera or adding glare shields. In the meantime, we have trained our safety drivers to be aware of this issue and know when to take over manual control preemptively.

Public road testing in Boston is a driving environment rich with technical challenges. We believe that our testing here will enable us to develop AV technology that will ultimately overcome the barriers to deploying an AV service in a dense urban area in a cold-weather climate. For that reason and others, we thank Governor Baker, Mayor Walsh, Secretary Pollack, Commissioner Fiandaca and their teams for their continued support of our AV testing in Boston.

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# IMAGES