Quarterly Report for MassDOT & City of Boston

3rd Quarter 2020

Background

We are committed to designing for people: for families that need to get their children to school safely; for elderly passengers who need continued access to mobility; and for urbanites who, more than ever, have a choice in how they get around cities. We know that self-driving vehicles have the potential to bring vast benefits to humanity: increased mobility, fewer traffic-related deaths, and a greener planet. But the only way to fulfill these promises of tomorrow is to build trust in the technology today. We believe that when we demonstrate openness and collaboration, trust follows.

Our team's expertise in autonomous driving can be traced from our R&D roots at MIT and Carnegie Mellon University, where we showcased our autonomous technology in the DARPA Grand Challenge and DARPA Urban Challenge, to our present-day commercial operation in Las Vegas, which has provided more than 100,000 self-driving rides to members of the public. We are proud to report that our attention to safety has extended into our real-world operations. We have driven over 1,000,000 miles in complex city environments worldwide while maintaining a record of zero at-fault incidents.

Today, our global team—spanning North America and Asia—is dedicated to delivering safe and reliable production-ready SAE Level 4 robotaxis that will make roads safer and improve mobility worldwide. As we advance the technology, our people-first ethos will ensure that safety, security, and privacy are embedded in every step.

Since the formation of our autonomous driving joint venture between Hyundai Motor Group and Aptiv in March, we've made significant strides in establishing our corporate structure, building out our leadership team, and logging public road miles to advance our driverless product. In mid-August, we announced the launch of our new brand, Motional. While we've been in this

space for decades, our journey under the name Motional begins now—and we hope you'll come along for the ride.

Testing activity

Our focus lately is the vehicle's performance in suburban elements. The modifications we began last quarter to our test track to support this testing is now complete, with new speed bumps, driveways elements, and more. These elements will be validated on our test track before on-road testing across all sites (Boston, Singapore, Pittsburgh, and Las Vegas).

Operational Design Domain (ODD)

Our vehicles are designed to operate in low-speed (<35 MPH), urban environments in various conditions. We continuously validate all vehicle performance and behavior changes to our AVs in simulation, then in a closed-course setting before operating them on public roads. To date, we have experience testing on public streets with a variety of road actors, including heavy vehicle traffic, cyclists, and pedestrians. Additionally, we have operated our AVs safely in daytime and nighttime and windy, rainy, and snowy conditions in closed-course and public road environments.

Amount of testing

Our testing occurs primarily during regular business hours (Monday through Friday, 9 AM-5 PM). As mentioned above, this testing includes specialized testing in closed-course and data gathering in the Seaport / South Boston area.

Takeover procedure

Safety drivers take over manual control in any situation in which they feel uncomfortable or unsafe. Planned takeovers are also done when finishing a mission or approaching situations that are not within the outlined ODD.

During the Third Quarter, our safety drivers took over manual control of our AVs in the following situations:

- When emergency vehicles were in active operation (e.g., sirens and lights activated) in the roadway;
- When law enforcement officers were manually directing traffic in intersections through which our AV's were traveling;
- In certain situations in which construction vehicles were obstructing our lane of travel;
- In certain situations in which oncoming vehicles or bicycles violated lane boundaries;
- In certain situations in which weather conditions deteriorate rapidly; and,
- 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.

Description of ADS system failures

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

Goals for future testing

We continue to go through the design and testing process for user-friendly pick-up and drop-off. We have also conducted interviews from different accessibility groups to ensure we continue to broaden who is included in our testing. These components are crucial to making sure our platform is user friendly for a diverse and inclusive population. We plan to incorporate more learnings from this research into our testing.

As we move into the fall and winter, we'll be able to increase the amount of low-light testing, in addition to testing in adverse weather conditions, such as rain or fog. These are all tests we have undertaken in the past; however, we plan to increase their proportion within our overall testing mix.

Insights

Over the last quarter, we have been testing how AVs will be received within communities. Many of the first people to experience AVs will not be riders, but countless observers. We want to understand where their concerns are and how to make the experience more comfortable. By incorporating virtual reality into our testing regime, we can rapidly test these interactions in a way that would be difficult to emulate with in-person trials.

Imagine yourself as a pedestrian at a crosswalk. You see a vehicle approaching in the distance. You decide that it is safe to cross. That feeling of safety can be done by making eye contact or a hand wave from the driver. Examining the subtleties of these interactions and how to translate them onto autonomous vehicles has been a focus of the team's virtual reality testing. One way for AVs to signal to other road users is through "Expressive Robotics." Put another way, how can autonomous vehicles express their intent to other road users, absent a driver behind the wheel.

Using our Virtual Reality (VR) testing facility, we explored exaggerated vehicle movements as a method to convey the vehicle intent to other road users. For example, for an AV to communicate an intention to stop for a pedestrian, we need to anticipate natural cues that could be leveraged. These could include decelerating or stopping a vehicle earlier than a typical human driver. Audio signals also present interesting opportunities, like louder or braking sounds or exaggerated reductions in the powertrain sounds. Ideally, these cues are intuitive and do not require training on behalf of other road users.

At Motional, we are eager to test the potential of expressive robotics. We are reaching out to members of the community to evaluate. After testing 50+ people, the numbers look quite encouraging, but we continue to test to increase confidence and look forward to sharing our findings publicly. Although this is pertinent for AVs, there are plenty of situations where conventional

vehicles could make use of s uch expressions - particularly those where a driver is not visible because of glare or low-light.

Feedback for municipal and state transportation engineers, planners, and policymakers

A few weeks ago, we published our Consumer Mobility Report, detailing the results of a survey of over 1,000 Americans. Although there were many interesting takeaways, one relevant for policy-makers and AV companies alike is the considerable misunderstanding among the public about AVs. For example, 45% believe there is no difference between driving assist features, and 2/5ths of respondents believe that a car that parks itself is considered self-driving.

Such misunderstandings could lead to dangerous misuse of some platforms. Furthermore, lumping all SAE levels together as “self-driving,” including driver assistance features could slow trust in Level 4 and Level 5 vehicles. For example, if members of the public become jaded with the poor performance of systems incorrectly perceived as comparable (such as parking being equal to city driving), it could slow the adoption and the resulting safety benefits. It’s perhaps not surprising that later in our report, we show that the more knowledgeable individuals are with AVs, the more likely they are to trust them.

Allowing the public to interact with AVs in every city won’t be possible for some time, and with the pandemic ruling out in-person showcases, we’ll need to get creative with how we disseminate this information. Motional is ready to collaborate with policymakers to ensure the public understands, trusts, and can benefit from AVs on their streets.

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