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# Bi-Annual Report for MassDOT & City of Boston

2nd Half 2022

## Background

Motional is 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 driverless 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

operations in Las Vegas, which has safely provided more than 125,000 autonomous 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 2,000,000 miles in complex city environments worldwide while maintaining a record of zero at-fault incidents.

Today, our global team—spanning the U.S. 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 our global headquarters, Boston is a vital part of our research, development, and testing ecosystem.

In September 2021, we revealed our next-gen all-electric IONIQ 5 robotaxi, developed in collaboration with Hyundai. The IONIQ 5

robotaxi is based on Hyundai's award-winning consumer IONIQ 5, and has the same passenger-centric features, such as the neo-retro design, parametric pixel lights, auto flush door handles, low-profile interior, vehicle-to-load charging system, fast-charging capabilities, and 18.8 cubic feet of storage space - plus Motional's driverless technology package baked right into the design.

Boston has been an important part of Motional's international R&D ecosystem for over ten years. It's home to Motional's corporate headquarters, an operations hub, and state of the art closed-course testing facility. In 2021, we expanded our Boston presence with a multimillion dollar investment to grow our Seaport operations facility at Black Falcon, and increase hiring and R&D testing.

## Testing activity

Our testing efforts continue to focus on the Hyundai IONIQ 5 platform, which includes more advanced hardware and technical capabilities compared to previous Motional vehicles. We are working on transitioning our testing to our IONIQ 5 test car to our IONIQ 5 prototype vehicle. The prototype vehicle incorporates passenger experience features for ride hailing. Including passenger display that displays ride information, remote control assist button to help passengers connect with a remote representative, and external displays and lights that help riders identify their vehicle.

## Operational Design Domain (ODD)

Our vehicles are designed to operate in low-speed, urban environments in various conditions. We validate vehicle performance using simulation and bench tests, then in a closed-course setting before operating on public roads. To date, we have experience testing on public streets with a variety of road actors, including heavy vehicle traffic, emergency vehicles, construction, 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 traditional business hours (Monday through Friday, 9AM-5PM). This includes specialized closed-course testing at our test track in Suffolk Downs and on-road data collection and autonomous driving in the Seaport.

## Takeover procedure

Motional's vehicle operators can take over and manually control the vehicle 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. We are also refreshing our fault injection training with all vehicle operators where intentional system errors are introduced to make sure our operators takeover in the proper fashion before returning to public roads.

A snapshot of typical takeover examples include the following:

- When emergency vehicles were in active operation (e.g., sirens and lights activated) on the roadway;
- When law enforcement officers were manually directing traffic in intersections through which our AVs were traveling;
- When construction vehicles were obstructing our lane of travel;
- When oncoming vehicles or bicycles violated lane boundaries;
- When weather conditions deteriorated rapidly; and,
- When other vehicles were exhibiting erratic behavior near our AVs.

A vehicle operator'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 vehicle operators to err on the side of caution, we expect that takeovers will occur in many cases in which the AV would have handled the situation without incident.

## 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 vehicle operators take over manual control because of known limitations of the current state of AV software.

## Goals for future testing

We continue to test our autonomous capabilities through closed-course track tests

before transitioning to public road driving. Our IONIQ 5 vehicles are currently operating autonomously on public roads.

We are supporting internal autonomous rides around the Seaport for employees to experience the product they created and provide feedback.

We are supporting the enhancement of our sensors by collecting data while driving manually in rainy conditions. Collection of this data will help improve our autonomous performance of our cameras, radar, and lidar in rainy weather.

We are also using our IONIQ 5 robotaxis and our new simulation and virtual reality space to gather user experience feedback from the public. Motional's Product team will continue to get feedback from a diverse set of research participants regarding the capabilities they would like to see while riding in an autonomous vehicle in different scenarios.

We plan to host demonstrations for stakeholders from the city of Boston and MassDOT to learn more about our company and our technology.

## Insights

In October of 2022, Motional and Uber announced a commercial agreement to launch driverless ride-hail and delivery services using Motional's IONIQ 5 robotaxis.

The 10-year, multimarket agreement creates the opportunity for effective scaling and broad adoption of AVs by pairing Motional's advanced driverless technology with Uber's

network of millions of customers. Motional and Uber have a shared vision for AVs to offer an affordable, convenient, and safe transportation option for everyday travel. Motional's robotaxis are currently available to Uber riders in Las Vegas, and are conducting autonomous deliveries for Uber Eats customers in Los Angeles.

With this new partnership, we wanted to identify some of the hurdles that must be overcome prior to launching a robotaxi service in a new market.

Motional has a lengthy checklist to complete before picking up passengers or delivering goods. Robotaxis, after all, are part high-tech computer, part all-electric vehicle, part commercial product. They need to be trained, tested, and permitted. They need a dependable power source and a way to receive regular software upgrades. And, they need a consumer base eager to make riding in driverless vehicles part of their everyday routine. These are some of the steps Motional takes to get ready to launch a robotaxi service in a new city:

#### RIDER SAFETY

Nothing is more important than the safety of our passengers, as well as the safety of any drivers, pedestrians, or cyclists moving near our AVs. Before Motional launches in a new market, several tasks are conducted to ensure our AVs are safe for riders and other road users. Here are a few:

- Test drives: Motional's robotaxis undergo continuous testing to ensure

the technology is ready to handle the challenges of the road. Every market is different and has its own unique features, ensuring diverse data for our vehicles to learn from. For example, in Boston the vehicles experience old, narrow, curvy streets; in Las Vegas, the vehicles experience exotic cars and pedestrians in unusual costumes.

- Mapping: Using lidar, AVs create a highly detailed 3D image of all the roadways, intersections, even buildings in a new market, so that the onboard computers know exactly where they are at all times.
- Permitting: There is currently no uniform set of federal standards that govern the operation of autonomous vehicles in the U.S. Instead, Motional works with states and municipalities to secure all needed permits.

Widespread adoption of robotaxis won't happen unless passengers trust that they are safe. Before starting passenger service in any new market, AV companies such as Motional will take multiple steps to ensure the robotaxis operate safely.

#### INFRASTRUCTURE

Properly supporting a fleet of robotaxis is not something that can be done on a makeshift basis, or set up overnight. The amount of charging stations, data connections, and other infrastructure needed to support the advanced technology means robotaxi companies won't operate like a traveling roadshow, capable of setting up overnight in a new town. Instead, it

will require large facilities with upgraded utility infrastructure.

Motional's robotaxis, which are built on the Hyundai IONIQ 5, an all-electric crossover, are going to be some of the most-advanced vehicles ever mass-produced. The robotaxis feature a specially designed suite of more than 30 sensors including cameras, radar, and lidar, sport a powerful onboard computer system that allows the vehicle to see, think, and drive, and a next-generation battery platform - all of that technology will require a facility substantial enough to provide the fleet with regular maintenance and servicing.

These are some of the challenges that come with launching in a new market and Motional is committed to working with business leaders and policy makers to find solutions.

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

In September, Motional hosted a session during the 2022 National Association of City Transportation Officials (NACTO) convention where more than two dozen transportation planners, engineers, and advocates visited our Boston operations facility and heard from, Motional's President and CEO Karl Iagnemma, Chief Technology Officer Laura Major, and other Motional experts about the company's

driverless technology and approach to safety and accessibility.

One topic discussed was how a vehicle without a driver can indicate to other road users what action it intends to take. Team members from Motional's research team, explained that pedestrians may be uncertain what to do when they see an approaching vehicle and no human driver behind the wheel. Using VR-based scenarios, Motional has explored using vehicle-mounted LED strips, enhanced vehicle motor noise, an exaggerated vehicle nose dip, and other movements to communicate vehicle intent to pedestrians.

Another topic discussed was with regards to users with disabilities. Team members from Motional's user experience and human factors research, played video clips of people with disabilities explaining how challenging it can be to travel. Motional works with research participants with a variety of physical, sensory, and cognitive disabilities in order to design features that increase accessibility early in the product development process.

Finally, the group discussed traffic infrastructure and how Motional vehicles can travel on roads without enhanced technology. Motional plots out all the roadways, intersections, and traffic infrastructure within the service area - known as an operational design domain - before the robotaxi ever makes a test run. This way the vehicle is equipped with an accurate, onboard map regardless of the road conditions.

The conference provided a great opportunity to share information about our technology with key stakeholders.